EURO PM2023 CONGRESS & EXHIBITION

GLOBAL BOOK OF ABSTRACTS

Technical Programme Committee
15th February 2023

EPMA
european powder metallurgy association

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Technical Programme Committee
15th February 2023

SUMMARY

EURO PM2023 CONGRESS & EXHIBITION

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Technical Programme Committee
15th February 2023

MATERIALS

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15th February 2023

MATERIALS

HARD METALS, CERMETS AND DIAMOND TOOLS

EPMA european powder metallurgy association

EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235756856

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Hard metals, cermets and diamond tools

Author : Dr Ing Cinca Nuria (Hyperion Materials and Technologies, Spain)

Co-author(s) : Dr Lavigne Olivier (Hyperion Materials and Technologies, Spain)

Title : Effect Of WC Grain Size On The Corrosion Behavior Of WC-Co Cemented Carbide In Acidic, Neutral And Alkaline Media

Keyword(s) :
Cemented Carbides; Corrosion

Abstract :
The effect of the WC grain size on the corrosion resistance of cemented carbides is not well established in the literature. In this study, the electrochemical behaviour of WC-12wt.%Co hard materials with various starting grain sizes (ultrafine, fine and medium) were evaluated in aerated 3.5 wt.% NaCl media at pH 1, 6 and 11, by means of electrochemical methods (electrochemical impedance spectroscopy and polarization scans). Results showed that the corrosion resistance of the material is strongly dependant on the WC grain size. In acidic and neutral media, the corrosion resistance of the material increased with the increase of the WC grain size, while in alkaline media an inverse trend was observed. Results are discussed in terms of thermal residual stresses, thermodynamical stable phases in function of the pH, and varying sizes of anodic and cathodic areas resulting from different WC grain sizes.

Innovative Aspect(s) :
There seems to be some discrepancy in the literature with the WC grain size effect on corrosion. Involving different pH media in the study, we want to give a more application approach, intended to rationalize the microstructure design with the performance.

Reviewer's name : ……………………………………………………………………………………………….

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : ………………………………………………………………………………….

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235761011

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Hard metals, cermets and diamond tools

Author : Miss Fooladi Mahani Saghar (Universitat Politècnica de Catalunya - BarcelonaTech, Spain)

Co-author(s) : Dr Liu Chao, Dr Cai Xiaokang (Xiamen Tungsten Co., Ltd., China), Prof García-Marro Fernando, Prof Jiménez-Piqué Emilio, Prof Llanes Luis (Universitat Politècnica de Catalunya - BarcelonaTech, Spain)

Title : Damage Maps Of Cemented Carbides Under Contact Loading: Assessment By Means Of Hertzian, Conical, And Vickers Indentation

Keyword(s) :
Contact Loading; Contact Damage Map; Hardmetals; Indentation

Abstract :
Resistance to contact loading is a key issue to consider for microstructural design of cemented carbides to be used as tools and wear components. In this work, Hertzian, conical, and Vickers indentation has been implemented to assess contact damage response for three microstructurally different WC-Co cemented carbides; in doing so, distinct load ranges were applied: up to 294 N, 490 N, and 1470 N for Vickers, conical and spherical indentation respectively. Deformation and damage linked to indentations were inspected at both the surface and the subsurface, the latter through sequential tomography. Results are presented as damage maps as a function of applied load. It is found that critical load values for the emergence of cracks and their subsequent evolution are strongly dependent on indenter geometry (linked to specific stress fields) and fracture toughness of the material. Practical implications of these findings, in terms of damage tolerance, are finally discussed.

Innovative Aspect(s) :

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Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235762742

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Hard metals, cermets and diamond tools

Author : Prof Gordo Elena (University Carlos III Of Madrid, Spain)

Co-author(s) : Mr Sánchez-Escudero Gabriel, Mr Biedma Angel, Dr de Nicolás-Morillas María, Mr Villemur Juan (University Carlos III of Madrid, Spain), Dr Bertalan Claudio, Dr Useldinger Ralph (CERATIZIT Luxembourg S.àr.l., Luxembourg), Prof Llanes Luis (Univ Politècnica de Catalunya, Spain)

Title : Oxidation And Wear Behavior Of Co-free Hardmetals Using Ti(C,N) And WC Ceramic Phases

Keyword(s) :
Alternative Hardmetal; Co-Free; Oxidation; Wear; Mechanical Properties

Abstract :
This paper shows the results of mechanical properties (hardness, toughness, TRS) together with studies of wear and oxidation at high temperatures of a set of composite materials formed by a ceramic phase, Ti(C,N) or WC, and a Co-free metal binder. The materials have been processed by powder metallurgy, including milling, uniaxial pressing, and sinter-HIP. Standard cylindrical specimens have been used for TRS tests. The oxidation tests have been carried out in static air up to 1000°C. To study the wear behaviour, reciprocating sliding tests have been carried out, using WC-Co balls as countermaterial, loads of up to 50 N and test times up to 30 minutes. During the test, the coefficient of friction has been recorded, and after the tests, the mass variation has been measured, in addition to the width and depth of the wear tracks by means of an optical profilometer.

Innovative Aspect(s) :
Research in alternative compositions for hardmetals is usually focus on developing a correct microstructure and reaching appropriate mechanical properties of the novel ceramic-metal combinations. However, the interaction with environment is a key aspect that should be studied. In this work, it is studied the wear and high-temperature oxidation behaviour of a family of hard materials containing FeNiCr as binder phase, and the results compared with a commercial hardmetal. The microstructure and properties (hardness, toughness) of these materials were presented on previous conferences and published in journal articles, but the results shown here are new, and necessary to assess the potential of these compositions for some applications.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235762765

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Hard metals, cermets and diamond tools

Author : Dipl-Ing Zanon Matteo (Ecka Granules Germany GmbH | Kymera International, Germany)

Co-author(s) : Dr Förner Andreas, Mr Kossakowski Darek (Ecka Granules Germany GmbH | Kymera International, Germany)

Title : Hot Pressing Behaviour Of Newly Developed Premixed Materials For Diamond Cutting Tools

Keyword(s) :
Diamond Tools; Cobalt-Free

Abstract :
A new family of cobalt-free premixed materials for diamond cutting tools was developed as an alternative to both pure cobalt and "prealloyed" powders. This product family was designed to combine high mechanical properties with the compressibility and process simplicity intrinsic to the premixed approach. Hot pressing results are herein presented for several grades and compared to their free sintering performance. Influence of main processing parameters and their impact on physical and mechanical properties is discussed. The matrix interaction with synthetic diamonds and its degree of metallurgical bonding is studied as well, on both a qualitative and quantitative basis.

Innovative Aspect(s) :
There exists a still unmet need in the market for products which show a performance comparable to hydrometallurgical powders but produced via simpler, less energy-intensive, environmentally friendlier processes. Desirable is also a high compressibility, which automatically leads to relatively low shrinkage in free sintering processes, thus allowing for further efficiencies throughout the value chain.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235763624

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Hard metals, cermets and diamond tools

Author : Prof Dr Lengauer Walter (Vienna University of Technology, Austria)

Co-author(s) : Dipl-Ing Fürst Markus, Dipl-Ing Nahringbauer Peter (Vienna University of Technology, Austria), Dr Tarrago José Maria, Dr Moseley Steven (HILTI Corp., Liechtenstein)

Title : Tailoring Properties Of Ti(C,N)-based Cermets By Modification Of Starting Powders And Sintering Atmosphere

Keyword(s) :
Cermet; Sintering; Hardness; Fracture Toughness; Saw Blade; Metal Cutting

Abstract :
Various Ti(C,N) cermet grades were prepared by the conventional powder-metallurgical route. For each grade the starting powder formulation was varied with respect to the alloy status of the hard phases while keeping the overall starting composition identical. In addition, different sintering atmospheres were applied which influences the final C and N concentration. The sintered bodies were investigated for hardness, fracture toughness, porosity and eta phase formation. Analysis of C, N, O before and after sintering was done and thermal conductivity was measured on the dense-sintered materials. The influence of sintering atmosphere, powder type and carbon doping on N and C content, hardness, fracture toughness as well as on thermal conductivity is discussed. A broad range of different properties was achieved with the identical overall starting composition but different hard-phase powers and sintering conditions.

Innovative Aspect(s) :
Tuning properties without changing overall composition.
Use of sintering atmosphere for influencing properties.
Alternative powders- Materials with low supply risk.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235763635

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Hard metals, cermets and diamond tools

Author : Ms Navarrete Cuadrado Jazmina (CEIT-BRTA, Spain)

Co-author(s) : Dr Soria Biurrun Tomas, Dr Lozada Cabezas Lorena, Prof Dr Sanchez-Moreno Jose M. (CEIT-BRTA, Spain), , Mr Ibarreta Lopez Federico, Mr Martinez Pampliega Roberto (FMD CARBIDE, Fabricacion Metales Duros, S.A.L., Spain)

Title : Effect Of Vacuum Level On The Sintering Behaviour Of TiC-Fe-Mo-Cr Cermets

Keyword(s) :
TiC Cermets; Effect of Vacuum; Mo2C; Oxide Carbothermal Reduction; CCT Curves

Abstract :
The limited availability of materials like tungsten, cobalt or nickel is a risk for the hardmetal industry. TiC based cermets are candidates for replacement of hardmetals in certain hot wear applications. Air quenchable TiC-Fe-Cr-Mo cermets have been produced by vacuum sintering. Molybdenum was added either as Mo2C or as metallic powder. The vacuum level is critical for controlling compositional gradients and porosity removal. Introduction of argon overpressure once deoxidation phenomena are finished is key for avoiding binder evaporation. Mo2C powders induce higher densification that those based on metallic Mo. This is likely related to its finer particle size distribution and its contribution to the carbothermal reduction of oxides during the sintering cycle. CCT curves of selected compositions have been investigated for optimizing the thermal treatments required for achieving the required levels of hardness, strength and toughness.

Innovative Aspect(s) :
Compositional design of TiC-Fe-Cr-Mo cermets free of critical raw materials.
Study of the effect of vacuum during the heating ramp. No need of sinter-HIP equipment.
Analysis of carbothermal reduction of oxides and its relationship with the properties of selected powders.
Elimination of porosity and control of undesired surface gradients- Investigation of CCT curves for optimizing thermal treatments after sintering.

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Paper Number : EP235763660

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Hard metals, cermets and diamond tools

Author : Mr A Prabin (Kennametal India Limited, India)

Co-author(s) : Mr Auneau Florian (NGL Cleaning Technology SA, Switzerland), Dr Schmutz Patrik (EMPA, Switzerland), Mr Howard IV William (Kennametal Inc., USA), Mrs K S Anvitha (Kennametal India Limited, India)

Title : Corrosion Inhibition On Cemented Tungsten Carbides

Keyword(s) :
Cemented Carbide; Corrosion Inhibitors; Cobalt Corrosion Inhibitors; Cemented Carbide Processes

Abstract :
Cemented tungsten carbide (WC-Co) materials are made of tungsten-carbide grains embedded in cobalt matrix and been used for making metal cutting and mining tools through powder metallurgical processes. Cobalt is known to be sensitive to corrosion in aqueous environment and multiple surface preparation processes on the cemented carbide exposes cobalt to aqueous conditions where the knowledge on corrosion is less known. Thus, the study is aimed to understand the corrosion behavior of cemented carbides with different inhibitors in varying pH and temperature environments. This study also evaluates conditions where the corrosion inhibitor can be removed or reduced for varying cobalt binder, surface conditions for cemented carbide processes and for alternate corrosion inhibitors with lesser health and environmental impact. This will help in improving cemented carbide tool performance in high demanding service conditions and application in oil and gas extraction in tetra-phasic (sea water, sand, liquid and gaseous hydrocarbons) conditions.

Innovative Aspect(s) :
The information on the effect of different inhibitors used in the cemented carbide processes is not available currently. This study aimed to understand the corrosion behavior of cemented carbides with inhibitors and efficiency of the system in varying pH and temperature environments. Among the corrosion inhibitors, benzotriazole and its derivatives are known to be the most efficient, however these compounds are concerned by health issues (some of them are suspected of being carcinogenic) and environmental challenges (benzotriazole is considered as a micropollutant product). This analysis evaluates conditions where the corrosion inhibitor can be removed or used at lower concentrations without any impact on the WC-Co substrate along with inhibition efficiency comparison with alternate corrosion inhibitors.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235763766

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Hard metals, cermets and diamond tools

Author : Dr De Gaudenzi Gian Pietro (F.I.L.M.S. S.p.A., Italy)

Co-author(s) : Miss Tedeschi Sandra, Mrs Pirone Fransisca, Mr Ruggiero Domenico (F.I.L.M.S. S.p.A., Italy), Ing Tavola Francesco, Prof Dr Bozzini Benedetto (Politecnico di Milano, Italy)

Title : Electrochemical Recovery Of Metallic Values From Hardmetal Scraps: Can It Be Still Taken Into Consideration Or Should We Give It Up?

Keyword(s) :
Hardmetal Scrap; Critical Raw Material Recovery; Circular Economy; Carbon Foot-Print; Electrochemical Impedance Spectroscopy; Electrochemical Behaviour

Abstract :
Circular use of the main hardmetal constituents is mandatory for European industrial economy. Over the past 20 years some recovery processes have been integrated in the extractive metallurgy or directly in the hardmetal production processes. Among attempted recovery routes, electrochemical methods have been studied since the '50's, although they never climbed to the level of an industrial process. In this work, we present the crucial electrochemical knowledge-base that has enabled the definition of an electrochemical demolition process, claiming to overcome the productivity barrier that, so far, has hindered the industrial application of electrochemical scrap treatments. In particular, in this contribution, we concentrate on the systematic investigation, centered on Electrochemical Impedance Spectrometry, of the electrochemical response of HM in the pseudopassive and transpassive condition, an appropriate sequence of which is adopted in our electrochemical demolition process. As a worst-case benchmark, this study revolves around a representative series of corrosion-resistant grades.

Innovative Aspect(s) :
Development of a new, low carbon-footprint, electrochemical process for the recovery of Critical Raw Materials based on the mechano-electrochemical demolition of hardmetal scrap.Application of Electrochemical Impedance Spectroscopy (EIS) in order to examine in depth the transpassive behaviour of a corrosion resistant class of hardmetals. The relationship between pseudo-passive and transpassive behaviour of hardmetals.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235763795

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Hard metals, cermets and diamond tools

Author : Mr Anwer Zahid (KU Leuven, Belgium)

Co-author(s) : Prof Dr Vleugels Jef, Dr Huang Shuigen (KU Leuven, Belgium)

Title : High Entropy Carbide - Ni Based Cermets Prepared By In-situ Carbothermal Reduction Of Transition Metal Oxides

Keyword(s) :
High Entropy Carbide Cermets; Carbothermal Reduction; Pressureless Sintering; Microstructure

Abstract :
Fully dense high entropy carbide (HEC)0.8-Ni0.2 based cermets were prepared by in-situ carbothermal reduction of mixtures of transition metal oxides from Group IV, V and VIB by a one-step reactive sintering technique. The molar ratio of metal oxides and graphite in the starting powder mixtures was varied and the evolution of the microstructure, grain size and morphology of the HEC phase were studied in detail. The in-situ carbothermal reduction of oxides resulted in a high entropy carbide phase with a homogeneous atomic number contrast with an extremely faint core-rim structure. This study demonstrates a facile and cost-effective alternative synthesis approach to prepare chemically complex high entropy carbide based cermets in a one-step pressureless sintering cycle.

Innovative Aspect(s) :

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764239

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Hard metals, cermets and diamond tools

Author : Dipl-Ing Rodrigues Daniel (BRATS Sintered Filters and Metallic Powders, Brazil)

Co-author(s) : Dr Janasi Suzilene (BRATS Sintered Filters and Metallic Powders, Brazil), Mr Miranda Fábio (Univresity od São Paulo, Brazil), Dr Ing dos Santos Ortega Fernando (UNIVAP, Brazil)

Title : Gelcasting Of NbC20Ni Cemented Carbide

Keyword(s) :
NbC-Based Hardmetals; Gelcasting; Cemented Carbides; Near Net Shape Powder Processes

Abstract :
Gelcasting has been successfully used to produce high performance sintered ceramic components, and large shrinkage, during high temperature sintering, is usual to obtain high density parts, since very fine ceramic powders are used as raw material. The same approach can be considered for cemented carbides (hard metals), and near net shape parts can be produced with the use of adequate moulds and, if necessary, with the additional milling operations prior sintering. Fine niobium carbide and nickel powders were used to get aqueous slurries, that were adjusted to mould near net shape parts to get sintered cemented carbides with homogeneous microstructure, and with a good combination of hardness and toughness. The slurry stability was investigated considering mainly solids loading. Nature and amounts of monomers, dispersants and additives were also investigated. Samples and prototypes were sintered in high temperatures under vacuum, and characteristics as density, microstructure and hardness were evaluated.

Innovative Aspect(s) :
The innovative aspect of this paper is the use of a ceramic gelcasting rout to produce a new cemented carbide based on niobium carbide. The advantages of gelcasting, if compared with press and sintering processes, is the possibility to obtain complex shapes even for large pieces. Additionally, more homogeneous carbide and nickel mixtures can be obtained from suspensions, if compared with the conventional milling processes. Homogeneous powder mixtures can provide a better microstructure, with the binder (nickel) insulating the carbides, improving mechanical properties, particularly fracture toughness. The definition of good production parameters, during gelcasting and sintering, can be also considered as innovative.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764267

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Hard metals, cermets and diamond tools

Author : Dipl-Ing Serra Fanals Marc (Universitat Politècnica de Catalunya (UPC), Spain)

Co-author(s) : Dr García-Marro Fernando, Prof Dr Llanes Luis (Universitat Politècnica de Catalunya (UPC), Spain), Dr Ing Cinca Núria (Hyperion Materials&Technologies, Spain)

Title : Optimization Of Fatigue Strength Assessment In Hardmetals Using A Reduced Number Of Samples By Means Of Dixon And Mood Model

Keyword(s) :
Hardmetals; Fatigue; Fatigue Strength; Finite Fatigue Life; Dixon and Mood

Abstract :
Hardmetals are composite materials comprising carbides embedded in a ductile metallic binder. This combination, with different relative amounts and sizes of ceramic particles, allows obtaining a wide variety of microstructural qualities with excellent mechanical and tribological properties. However, many of the applications in which these materials are used involve cyclic stresses, which often lead to premature failure of components and tools. Therefore, studying the fatigue strength of hardmetals is a topic of great practical interest. A commonly used method to estimate the fatigue strength of structural materials is the "staircase method". Results obtained are usually analyzed by Dixon and Mood approach. Trying to optimize time and resources, this work analyzes the use of a modified staircase method, to optimize the methodology to both evaluate the fatigue resistance by using a reduced number of samples and improve the acquisition of statistical information on the reliability of the fatigue life.

Innovative Aspect(s) :
This work analyzes the use of a modified staircase method (versus the "traditional staircase methodology)", to optimize the methodology, evaluate the fatigue resistance by using a reduced number of samples and improve the acquisition of statistical information on the reliability of the fatigue life. In addition, this work is done within the framework of finite fatigue life, focusing on the first cycles (200,000) of the component's service life.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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Paper Number : EP235764634

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Hard metals, cermets and diamond tools

Author : Mr Andersson Tom (VTT, Finland)

Co-author(s) : Dr Lindroos Matti, Dr Ren Sicong, Mr Suhonen Tomi, Dr Laukkanen Anssi, Dr Lagerbom Juha, Mr Lindroos Tomi (VTT, Finland), Dr Rey Rodriguez Pilar (Aimen, Spain)

Title : Estimating Long Term Behaviour Of DED-printed AlCoNiFe Alloy

Keyword(s) :
Crystal Plasticity Modelling; Compositionally Complex Alloy

Abstract :
We present a prediction of longer term behaviour for an alloy designed for application, which require high strength materials even in elevated temperatures, with multiscale material modelling method. Material is designed to have suitable phase composition with CALPHAD-method and neural network tool that is taught with the empirical high entropy alloy design criteria. The material is estimated to be two phase (FCC-BCC) structure in as build condition and after heat treatment gamma-gamma' and BCC-B2 structure. Designed alloy is atomized and test specimens are produced with direct energy deposition method and heat treated to get the desired phase composition. Tensile tests and micromechanical characterization are combined with simulation tools to create a micromechanical model that is used for mechanical property and performance simulations. A workflow to combine the different length scales in order to assess the performance of the material and ultimately the final component is presented.

Innovative Aspect(s) :
New type of dual phase high strength material that has, according the ThermoCalc analysis, 4 phase structure when heat treated properly and that has the potential to have high strength also in higher temperatures. Also new micromechanical tools capable of simulating the behaviour of a material consisting of FCC (gamma-gamma' structure) and BCC (BCC + B2) phases have been developed and applied.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764988

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Hard metals, cermets and diamond tools

Author : Mr von Spalden Mathias (Fraunhofer IKTS, Germany)

Co-author(s) : Dr Ing Pötschke Johannes (Fraunhofer IKTS, Germany), Dr Rosiński Marcin (GeniCore Sp. z o.o., Poland)

Title : Reactive Sintering Of Hardmetal-diamond-composites With Adapted Binder Systems

Keyword(s) :
Hardmetal; WC; Diamond Enhanced Cemented Carbide; DECC; Diamond Tools; FAST; SPS; Coating; Reactive Sintering

Abstract :
In this work, a new approach for preparation of hardmetal-diamond-composites has been evaluated. The main challenge to overcome is the phase transformation of metastable diamond into graphite during sintering. Despite using field assisted sintering to reduce sintering time and temperature as well as an adapted Ni-Cu binder system instead of Co, graphitisation cannot be fully suppressed. To further reduce the amount of graphite formed, two measures were combined in this study. In the first step diamond grains with different coatings (Ti, TiC, W) were used. In the second step hardmetal powder with a slight carbon deficit was prepared to absorb excess carbon through in-situ formation of WC. Together with simultaneous optimisation of the sintering parameters, the introduction of coated diamonds and reactive sintering, graphitisation could be successfully minimized.

Innovative Aspect(s) :
To the authors' knowledge there has not been any approach to minimize the amount of graphite in diamond enhanced cemented carbides by simultaneously applying a FAST process, using an optimised composition of a Co-free binder system as well as coated diamonds and reactive sintering.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765016

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Hard metals, cermets and diamond tools

Author : Prof Dr de Oro Calderon Raquel (TU Wien, Austria)

Co-author(s) : Prof Dr Schubert Wolf-Dieter (TU Wien, Austria)

Title : Insights On The Microstructural Characteristics Of WC-Co-Ru Cemented Carbides

Keyword(s) :
WC Based Cemented Carbides; Ru Additions; Phase Formation; Mechanical and Magnetic Properties

Abstract :
WC-Co cemented carbides alloyed with Ru are relevant for the hardmetal industry in spite of their high cost. These alloys are used in applications requiring very demanding thermal properties and good performance in aggressive and abrasive media, and for some applications, it is difficult to find an alternative material that could offer a similar performance. This paper will provide important insights on phase formation, solubilities and microstructural characteristics of WC-Co-Ru alloys with different carbon contents that can shed some light on the mechanisms that affect the mechanical performance of these materials.

Innovative Aspect(s) :
Systematic study of the system WC-Co-Ru at different carbon contents.
Phase formation and phase characteristics, solubilities, hardness and magnetic properties.
Effect of cooling rates.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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Paper Number : EP235765024

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Hard metals, cermets and diamond tools

Author : Ing Mégret Alexandre (University of Mons, Belgium)

Co-author(s) : Ing Rodriguez Paco (Diarotech, Belgium), Prof Dr Vitry Véronique, Prof Dr Delaunois Fabienne (University of Mons, Belgium)

Title : Influence Of The Amount Of Recycled Cemented Carbide Powder On The Mechanical Properties Of WC-Co Parts Sintered By Unconventional Technologies

Keyword(s) :
Recycled Powder; Ball Milling; Unconventional Sintering; Hardness; Grain Size Distributions

Abstract :
The trend in the cemented carbide field is to reduce the use of raw cobalt powder in tungsten carbide parts and to develop new binders: indeed, the cobalt price fluctuates extremely due to different factors, mainly its massive use in batteries of electric vehicles, and its extraction as by-product of copper and nickel mining.The use of a recycled tungsten-cobalt carbide powder skirts the cobalt problem and allows the sintering of WC-Co parts without raw Co powder. In this study, the material is composed of two powders: a powder made from raw materials (WC and Co powders mixed together) and a recycled powder (crushed powder containing 7.5 wt% Co). HIP and SPS are used as sintering technologies before morphological and mechanical characterizations. Mechanical properties of these samples can be tuned with the addition of recycled powder and the parts resulting from the experiments are in total competition with conventional ones.

Innovative Aspect(s) :
The characterization of recycled tungsten carbide-containing powder is rare in the literature. We propose a study of the influence of the amount of recycled WC-Co powder for the carbide tool field. Moreover, different sintering technologies are studied to evaluate the most efficient.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765050

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Hard metals, cermets and diamond tools

Author : Mr Biedma Trillo Ángel (University Carlos III of Madrid, Spain)

Co-author(s) : Dr Chirico Rodríguez Caterina del Carmen, Mr Villemur Tamarit Juan, Dr Gordo Odériz Elena (University Carlos III of Madrid, Spain), Dr Herraiz Lalana Enrique, Dr Pérez Rodríguez Marcos, Dr Sanz Moral Luis Miguel (ArcelorMittal Global R&D SLab, Spain)

Title : Effect Of The Addition Of Nanoparticles In The Design Of Hard Metals And Cermets

Keyword(s) :
Alternative Hard Materials; Boron Nitride; Graphene; Microstructure; Mechanical Properties

Abstract :
In the replacement of the traditional WC-Co, the reduction of critical raw materials is sought. However, alternative compositions have not yet become substitutes in their entirety. Instead of adding secondary carbides, the addition of small amounts of nanoparticles may be of interest in improving the design of new alternative cemented carbides and cermets compositions. In this research boron nitride and graphene have been dispersed on the ceramic phase in order to study the effect on the microstructure and mechanical properties of two compositions formed by Ti(C,N)-FeNiCr and WC-FeNiCr and processed by powder metallurgy techniques. It has been found that the introduction of these nanoparticles has produced microstructural variations and has increased the hardness values of the initial compositions. This method and results demonstrate that it is possible to control the mechanical properties of hard metals and cermets with alternative compositions by means of small modifications.

Innovative Aspect(s) :
It has been studied alternative compositions for the traditional WC-Co cemented carbides. The metallic binder phase FeNiCr is a critical raw materials free composition, replacing Co. By the introduction of boron nitride and graphene, other methods are avoided as it is the introduction of heavy metal carbides. Our research provides another point of view when it comes to developing this type of materials through small modifications as it is the introduction of nanoparticles.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765296

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Hard metals, cermets and diamond tools

Author : Mr Oliveira Gonçalo (University of Coimbra, Portugal)

Co-author(s) : Mr Mineiro Ricardo, Prof Dr Rocha Senos Ana Maria (University of Aveiro, Portugal), Dr Fernandes Cristina, Mr Figueiredo Daniel (Palbit S.A, Portugal), Prof Dr Vieira Maria Teresa (University of Coimbra, Portugal)

Title : WC-Co Versus TiCN|WC--Co, Ni For Internal Cooling Cutting Tools

Keyword(s) :
Material Extrusion (MEX); WC-Co; Ti(CN)|WC-Co,Ni; Filament of Ceramic Composite

Abstract :
New tool are required for the cutting tool industry to make more efficient and tailored solutions. Material extrusion (MEX) as an additive manufacturing should be used to process cermets based on WC-Co or TiCN|WC and Co, Ni metallic binders. MEX is an interesting technology due to its versatility to make from different feedstocks cutting tools with inside complex geometries. MEX became possible to make hollow tools with more efficient and complex cooling solutions, based on constructal or conformal cooling. However, it is not yet easy to replicate the main MEX parameters developed for organic or metallic materials when the feedstock is based on ceramic powder. The main objective of this study is to contribute to a better understanding of the cermet behaviour as function of ceramic powder. Defects of 3Dobject made from two different powder selected were analysed, along with a debinding strategy that best outfits the elected design.

Innovative Aspect(s) :
WC-Co and Ti(CN)|WC-Co,Ni cutting tools with constructal and conformal internal cooling system.
Filaments based on WC-Co and Ti(CN)|WC-Co,Ni powder, optimized for MEX production requirements.
Near net-shape manufacturing with almost no waste.

Reviewer's name : ....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765328

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Hard metals, cermets and diamond tools

Author : Mr Biedma Trillo Ángel (University Carlos III of Madrid, Spain)

Co-author(s) : Miss Vera Vionnet Camila, Dr Tabares Lorenzo Eduardo, Dr Gordo Odériz Elena (University Carlos III of Madrid, Spain), Dr Schsuchnigg Stephan, Dr Kukla Christian, Dr Cano Cano Santiago (Montanuniversitaet Leoben, Austria)

Title : Multi-Material Cermet-Stainless Steel Parts By Pellets Extrusion Additive Manufacturing

Keyword(s) :
3D Printing; Composite Extrusion Modelling (CEM); Pellets Additive Manufacturing (PAM); Multi-Material Additive Manufacturing (MMAM); Cermets; Stainless Steel

Abstract :
Material extrusion is a versatile group of additive manufacturing techniques which can be used for the production of metal, ceramic or composites, using filaments or pellets of highly-filled polymers. This study explores the feasibility of printing multi-material parts by pellet extrusion. Two different feedstocks have been produced with the same binder system and two different powders: a cermet with composition Ti(C,N)-FeNiCr and 316L stainless steel. Two extrusion heads, each one with a different feedstock, have been used to print three types of samples: monomaterial, bimaterial and gradient material. The debinding and sintering processes are studied by measuring properties after each step: such as shrinkage, relative density, mass loss and hardness, as well as controlling the microstructure and structural integrity of the samples throughout the process.

Innovative Aspect(s) :
The possibility of producing mono and multi-material parts by pellets extrusion additive manufacturing has been studied. Thanks to the combination of two print heads, laminated geometries and even gradients can be obtained, thus creating a distribution of properties within the part.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765382

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Hard metals, cermets and diamond tools

Author : Ing Berger Christian (Fraunhofer IKTS, Germany)

Co-author(s) : Dr Ing Pötschke Johannes, Dr Ing Scheithauer Uwe (Fraunhofer IKTS, Germany)

Title : Correlation Of Different Cemented Carbide Starting Powders With The Resulting Properties Of Components Manufactured Via Binder Jetting

Keyword(s) :
Cemented Carbide; Powder, Additive Manufacturing; FESEM, Hardness, Hardmetal, Binder Jetting

Abstract :
For some years now, the production of cemented carbide via the powder-based additive manufacturing process binder jetting has been pursued. Binder jetting offers the possibility of high production compared to alternative AM processes. Due to the powder-based process, the green bodies usually have a low green density, which means that only higher Co contents with lower resulting hardnesses are possible. By choosing the right starting powder and a suitable post-processing, the previous limits can be extended and the appropriate powder can be chosen depending on the application. In the context of this study, the correlation between different cemented carbide starting powders with different morphologies is investigated and evaluated for their processability in the BJT process and the resulting properties of the sintered components.

Innovative Aspect(s) :
First time consideration of different starting powders (> 4) with strongly different morphology in the BJT process of cemented carbide and their effect on the properties of the sintered bodies. All powders can be processed to full density bodies. Here, hardnesses of over 1300 HV10.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765405

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Hard metals, cermets and diamond tools

Author : Prof Miranda Georgina (CICECO - Aveiro Institute of Materials, Portugal)

Co-author(s) : Miss Basílio Liudmila, Mr Guimarães Bruno, Prof Carvalho Óscar (CMEMS - University of Minho, Portugal), Dr Fernandes Cristina, Mr Figueiredo Daniel (Palbit S.A., Portugal), Prof Dr Silva Filipe (CMEMS - University of Minho, Portugal)

Title : Fabrication Of Micro-scale Laser Textured Surfaces On WC-Co Green Compacts

Keyword(s) :
WC-Co; Green Compacts; Laser Surface Texturing; Micropatterns

Abstract :
Laser surface texturing has a high potential for the development of innovative solutions for the cutting tool industry, by allowing the fabrication of high-precision micro-scale geometries. In this study, different cross-hatched micropatterns were explored, by using an Nd:YAG laser to texture WC-10wt% Co green compacts. After dewaxing and sintering, a complete characterization was performed to evaluate topography, roughness, and dimensions of the fabricated textures. This study allowed to conclude on the better scanning strategy and laser parameters for obtaining a given texture geometry with defined dimensions on a reproducible manner. Besides allowing to modify a selected surface area, targeting to higher wettability or increased contact area, this approach has shown not to compromise the integrity and mechanical strength of the compact, allowing to preserve the tool conventional functionality.

Innovative Aspect(s) :
Due to the high hardness of WC-Co, surface modification of this material is very difficult by conventional machining. The adoption of green compacts laser surface texturing allows to overcome the challenges of conventional machining, such as the appearance of micro cracks, due to locally induced thermal mismatches, as well as allowing a high material removal rate, good surface quality, precise dimensions and the production of complex shapes.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765427

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Hard metals, cermets and diamond tools

Author : Dr Srinivasan Suresh (University of Warwick, United Kingdom)

Co-author(s) : Prof Marshall Jessica, Mr Gillham Joe, Dr Singh Gurdev (University of Warwick, United Kingdom)

Title : Tungsten Carbide For Radiation Shielding: A Comprehensive Review

Keyword(s) :
Cemented Tungsten Carbides; Radiation Shielding Material; Nuclear Power; Nuclear Medicine

Abstract :
Cemented tungsten carbides (cWC)s are attractive radiation shielding material candidates, from their high density, ease of manufacture and excellent mechanical properties. Recent research indicate that cWCs can have better radiation shielding behaviour compared to conventional candidate materials. The application of tungsten carbide as a radiation shielding material has not been well understood due to the use of highly activating Co and Ni as the main binder alloys and still lacking in the literature. cWCs are of particular interest since the mixture of high and low Z-elements offers effective shielding against gamma and neutron radiation, photons and fast neutron capture|removal cross section. The presence of carbon in cWCs contributes to the moderation of fast neutrons flux, reducing their contribution to total dose rate. In this paper, tungsten carbide applications in nuclear power and nuclear medicine are reviewed. The key challenges and further research for the future direction are highlighted.

Innovative Aspect(s) :

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765436

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Hard metals, cermets and diamond tools

Author : Mr Guimarães Bruno (CMEMS - University of Minho, Portugal)

Co-author(s) : Dr Fernandes Cristina, Mr Figueiredo Daniel (Palbit S.A., Portugal), Prof Dr Silva Filipe (CMEMS - University of Minho, Portugal), Prof Miranda Georgina (CICECO - Aveiro Institute of Materials, Portugal)

Title : Chip Morphology Evaluation On Turning Of 316L Stainless Steel Using Laser Surface Textured WC-Co Cutting Tools

Keyword(s) :
WC-Co Cutting Tools; Laser Surface Texturing; Micropatterns; Turning; Chip Morphology

Abstract :
During machining processes, a large amount of heat is generated, especially in the cutting zone, due to deformation of the material and friction of the chip along the surface of the tool, resulting in a wear increase and consequently reducing the lifetime of cutting tools. Surface texturing can help improve their tribological performance by increasing load carrying capacity, providing a better availability of lubricant at the tool-chip interface and reducing the tool-chip contact area. In this sense, this work proposes the fabrication of cross-hatched micropatterns on WC-Co cutting tools by laser surface texturing of green compacts, for improving these tools performance and life. Turning of 316L stainless steel was performed with textured tools to assess and evaluate the chip morphology of the different cross-hatched micropatterns, being these findings benchmarked against conventional cutting tools and correlated with the tool wear.

Innovative Aspect(s) :
The addition of surface textures to WC-Co cutting tools can help improve their tribological performance by increasing load carrying capacity, providing a better availability of lubricant at the tool-chip interface and reducing the tool-chip contact area. In this sense, this work resort to a laser surface texturing of WC-Co green compacts approach, to create cross-hatched micropatterns in cutting tools for improving these tools performance and life.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765461

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Hard metals, cermets and diamond tools

Author : Ing Cabezas Laura (CIEFMA - Department of Materials Science and Engineering (UPC), Spain)

Co-author(s) : Dr Jiménez-Piqué Emilio, Prof Llanes Luis (CIEFMA – Department of Materials Science and Engineering (UPC), Spain), Dr Pötschke Johannes (Fraunhofer Institute for Ceramic Technologies and Systems, IKTS, Germany)

Title : Micromechanical Mapping Of High Entropy Carbide Based Hardmetals

Keyword(s) :
High Entropy Carbides Based Hardmetals; Massive Nanoindentaion; High-Speed Nanoindentation; Statistical Analysis; Small-Scale Mechanical Properties; Microstructural Assemblage

Abstract :
High Entropy Alloys (HEA), mixture of an equal or relatively large portion of five or more elements are presented as a good replacement providing good wettability, high toughness, wear resistance, and temperature stability. Inspired by the concept of HEA, high entropy carbides (HEC) have gained attention in recent years. Within this context, the microstructure and micromechanical properties of the same (HEC) composed of (Ti, Ta, Nb, V, W) with two different binder, Ni and Co, were characterized. Hardness (H), elastic modulus (E) and H|E cartography maps were obtained by using a high-speed nanoindentation mapping technique, which allows not only to assess the intrinsic mechanical properties of HEC, binder and interphase, but also the successful microstructural assemblage. A total of 40,000 imprints were performed in each grade. The obtained data sets are statistically treated following two deconvolution approaches: 1D and 2D Gaussian fitting, providing the micromechanical behaviour of these novel carbides.

Innovative Aspect(s) :
This study developes a small-scale assesment of the mechanical properties, Hardness and Elastic Modulus, in a hardmetal composed by High Entropy Carbides (HEC) with two different binders, a novel material. This approach is conduct using an advanced micromehcanical technique; high-speed nanoindentation. It allows to develope arrays with thousands of imprints which it means thousands of data. Thanks to that a statistical analysis can be developed, to validate not only the reliable of the intrinsic mechanical properties of HEC particles, binder and interphase region, but also by the successful mirroring of microstructural assemblage within the mechanical maps attained.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765471

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Hard metals, cermets and diamond tools

Author : Dr Ing Gestrich Tim (Fraunhofer IKTS Dresden, Germany)

Co-author(s) : Dipl-Ing Hering Benjamin, Dr Ing Pötschke Johannes, Dipl-Ing Vornberger Anne, Dr Kaiser Arno, Dipl-Ing Gruner Daniel (Fraunhofer IKTS Dresden, Germany)

Title : Thermophysical Properties Of Hardmetals In Dependence On Used Carbide And Binder Phase Composition

Keyword(s) :
Hardmetals; High Entropy Carbide Cobalt; Tungsten Carbide High Entropy Alloy; Thermal Diffusivity | Heat Conductivity, Electrical Conductivity; Grain Size; Carbon Balance

Abstract :
Alternative compositions of hardmetals with hard phases other than WC and binder phases other than Co are more and more interesting due to both CRM (critical raw materials) and CMR (carcinogenic mutagenic reprotoxic) issues. So far, a basic understanding how other hard phases or binder phases change the thermophysical properties is not known. To address this question hardmetals with similar grain size and amount of metallic binder but different chemical composition are prepared and their magnetic properties as well as the electrical and heat conductivity | thermal diffusivity are analysed. Next to a reference straight tungsten carbide-cobalt grade (WC-Co), other compositions are niobium carbide-cobalt (NbC-Co), a high entropy carbide-cobalt (HEC-Co) and to study alternatives binders WC-Fe-based and WC-HEA (high entropy alloy).

Innovative Aspect(s) :
Newly developed hardmetals (Co-free- | HEA-binders or grades with high entropy carbides) require new methods to evaluate the material properties after sintering with regard to grain size and carbon content. Electrical and heat conductivity | thermal diffusivity may be used for this purpose. In order to obtain more information on the correlation between these properties, different grades of hardmetals are characterised and discussed.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235763911

Requested presentation type : Poster Presentation

Topic : Materials **Subtopic :** Hard metals, cermets and diamond tools

Author : Prof Dr Carreno-Morelli Efrain (University of Applied Sciences and Arts Western Switzerland, Switzerland)

Co-author(s) : Ing Meylan Ludovic, Ing Rodriguez-Arbaizar Mikel, Prof Dr Constantin Raymond, Ing Stucki Michel, Prof Dr Waelder Georg (University of Applied Sciences and Arts Western Switzerland, Switzerland)

Title : Cermet Cutting Tool Inserts Improved By Laser Grinding And HIPIMS Coating

Keyword(s) :
Cutting Tool Inserts; (TiCN)-Mo-Ni; Cermets; Compaction; Sintering; Laser Grinding; HiPIMS Coating; Palmqvist Toughness; Hardness; Wear Resistance

Abstract :
Ti(C,N)-Mo-Ni cermets cutting tool inserts have been produced by cold compaction and sintering of commercial ready to press granules. The insert cutting edges were sharpened by laser grinding before coating with a TiAlN layer by High power impulse magnetron sputtering (HiPIMS). The inserts have been characterized by hardness, Palmqyist toughness, density measurements and SEM observation. Titanium Grade 5 bars were turned to evaluate the coated cermet performance and compared with commercial tungsten carbide inserts treated with the same surface finishing.

Innovative Aspect(s) :
Development of new cermet inserts by sharpening with ultrashort pulse laser, followed by HiPIMS coating.

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EURO PM2023 CONGRESS & EXHIBITION
01-04 October 2023

Paper Number : EP235764264

Requested presentation type : Poster Presentation

Topic : Materials **Subtopic :** Hard metals, cermets and diamond tools

Author : Dipl-Ing Rodrigues Daniel (BRATS S, Brazil)

Co-author(s) : Prof Dr Otávio dos Santos Marcelo (Mauá Institute of Technology, Brazil), Mr Miranda Fábio, Prof Dr Ferreira Batalha Gilmar (University of São Paulo, Brazil)

Title : WC Cemented Carbides: Microstructural Aspects Comparing PBF-L Additive Manufacture And Convencional LPS

Keyword(s) :
WC-Based Hard Metals; Alternative Binder Phases; L-PBF Additive Manufacturing Microstructural Characterization for Hard Metals

Abstract :
This work aims to compare the conventional powder metallurgy, via Liquid Phase Sintering (LPS, with additive manufacture (AM), via PBF-L (Laser Powder Bed Fusion), considering WC cemented carbides and binders like Co, Ni and mixtures of Co and Ni. The mixtures were produced from dried slurries and some powder agglomeration was obtained with the use of organic binder. The great challenge was to improve flowability to obtain bed as homogeneous as possible, so, additionally, a vibrating container was used to spread powder trying an uniform bed. Conventional samples were produced by press and high temperature vacuum sintering. For AM, laser power versus velocity were investigated. Microstructures were evaluated considering carbide distribution and the presence of cracks and porosities. The effects of different metallic binders were presented and discussed Ni and mixtures of Ni and Co presented better results for PBF-L.

Innovative Aspect(s) :
The innovative aspect of this paper is the discussion the microstructures for hard metals comparing conventional LPS processes with PBF-L additive manufacture. The evolution of the LPS processes during more than 100 years establishes fundamentals and technology considering different classes (mixtures of different carbides and metallic binders) and processes to achieve a proper microstructure considering a specific application. For PBF-L we do not have a liquid phase for a enough period of time to wet properly the carbides, and process adjustments or post processing should be necessary to customize microstructure considering different applications.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765435

Requested presentation type : Poster Presentation

Topic : Materials **Subtopic :** Hard metals, cermets and diamond tools

Author : Dr Gomes Uilame (Universidade Federal Do Rio Grande Do Norte, Brazil)

Co-author(s) : Mrs Oliveira Gerlânea, Dr Lima Maria José, Mr Santos Fernando (Universidade Federal Do Rio Grande Do Norte, Brazil)

Title : Study Of The Effect Of Sintering Temperature On Hard Metal(WC-15%pNi.)

Keyword(s) :
Hard Metal; Powder Metallurgy; High Energy Grinding; Microhardness; Sintering

Abstract :
The objective of this work was to investigate the effect of temperature on the sintering of the WC-15%pNi composite. The sintered product was obtained through powder metallurgy processing steps, in which tungsten carbide powders – WC with an addition of 15%w. Nickel – (Ni) were ground in a high-energy planetary mill for 8 hours. Samples sintered at temperatures of 1350°C and 1450°C with an isotherm of 30 and 90 minutes were characterized by SEM, EDS, optical microscopy, and microhardness measurements. According to the results, the sample sintered at a temperature of 1450°C and an isotherm of 90 minutes showed the highest microhardness value, equal to 1095.2 HV.

Innovative Aspect(s) :
Carbides are of great technological importance, as they have a high melting point, good wear resistance and extreme hardness. Due to these factors, they have great applicability as special matrices in the aerospace, war, metallurgical and chemical industries. Thus, nickel has been widely used in studies as a substitute for cobalt in hard metal due to its greater resistance to corrosion and oxidation, presenting a lower cost when compared to cobalt and does not present risks to the environment because it is not toxic. In addition to the reported aspects, the use of Ni as a substitute for Cobalt does not cause a reduction in the mechanical properties of the hard metal.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765066

Requested presentation type : Poster Presentation

Topic : Materials **Subtopic :** Hard metals, cermets and diamond tools

Author : Prof Dr Filgueira Marcello (Northern Fluminense State University, Brazil)

Co-author(s) : Dr Rosa Joice, Ing Guimarães Renan, Dr Ing Lugon Rafael (Northern Fluminense State University, Brazil)

Title : SPS Manufacture Of Self-Lubricated CNT Added Hardmetals Inserts

Keyword(s) :
Hardmetals; SPS; Carbon Nanotubes; Metalworking; Flank Wear; Mechanical Properties

Abstract :
This work developed a hardmetal insert based on ultrafine tungsten carbide and cobalt, in order to improve its properties with the addition of carbon nanotubes (CNTs). The Spark Plasma Sintering (SPS) was applied as a consolidation technique of the WC-10 wt% Co mixture with 0.00, 0.10 and 0.25 wt% CNTs. The performance of the sintered inserts was evaluated through dry turning operation of a SAE 4140 steel. Flank wear of the inserts was evaluated after each pass, with an improvement in insert performance with the addition of 0.10 wt% CNTs, with a reduction of 13% in the flank wear lenght, compared to the system without CNTs. The physical and mechanical properties were evaluated too, observing the increase of the apparent density (14,27 g|cm^3) , the stability of the Vickers hardness (14,96 GPa) and the increase of the fracture toughness (12,17 MPa.m1|2) for the hardmetal with 0.10 wt.% CNTs.

Innovative Aspect(s) :
The innovation merit is the incorporation of cnt to the hardmetal, thus improving mechanical properties, mainly the self-lubrication effect - enabling dry machining, saving costs and considering the environment conservation. Other important innovation is the use of the spark plasma sintering as manufacture route to process the inserts, taking into consideration the 4.0 industry requirements.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765022

Requested presentation type : Poster Presentation

Topic : Materials **Subtopic :** Hard metals, cermets and diamond tools

Author : Prof Dr Senos Ana (University of Aveiro, Portugal)

Co-author(s) : Mr Rodrigues Joaquim, Dipl-Ing Mineiro Ricardo (University of Aveiro, Portugal), Dr Ing Fernandes Cristina (Palbit S.A., Portugal), Dr Sanchez-Herencia António (Instituto de Cerámica y Vidrio, CSIV, Spain)

Title : Development Of Low PcBN Composites By SPS

Keyword(s) :
Spark Plasma Sintering; Thermo-Calc; PcBN; Cermet; Cutting Tool; Microstructural Design

Abstract :
Cubic boron nitride (cBN) is normally used as a composite with ceramic and|or metallic matrixes to form PcBN (Polycrystalline cubic Boron Nitride) materials which are commonly employed in machining applications. While high cBN (70 – 90% vol.) is only produced by HPHT (High Pressure High Temperature) techniques, low cBN (40 – 70% vol.) could also be consolidated by SPS (Spark Plasma Sintering), since a higher volume of metallic binder is present. In this work, a cBN micrometer powder was combined with TiCN and Ni to produce composites with a matrix of hard phases that were predicted by the phase diagrams calculated with a thermodynamic tool. The SPS technique was used for the thermal consolidation of the PcBN compositions, at temperatures below 1600°C, in order to achieve a dense specimen and maintain the BN cubic form which are the requisites for machining applications.

Innovative Aspect(s) :
Thermodynamic calculations and experimental validation in PcBN compositionscBN-TiCN-Ni composites produced by colloidal processing routecBN-TiCN-Ni composites consolidated by SPS.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235763985

Requested presentation type : Poster Presentation

Topic : Materials **Subtopic :** Hard metals, cermets and diamond tools

Author : Prof Dr Filgueira Marcello (Northern Fluminense State University, Brazil)

Co-author(s) : Dr Soffner Layzza, Mr Guimarães Renan (Northern Fluminense State University, Brazil)

Title : A Novel Hardmetal Based On Niobium Carbide

Keyword(s) :
Hardmetals; NbC; FeNiNb Alloy; Alternative Binders; SPS

Abstract :
Successful use of Fe-Ni-Nb alloys as a binder for WC-based hardmetals have been reported. In this work, a novel NbC-based hardmetal NbC-10% wt Fe-Ni-Nb were prepared by spark plasma sintering (SPS), for 5 min, 40 MPa at temperatures 1280°C, 1300°C and 1350°C. The samples produced were investigated focusing on their structure, mechanical and thermal properties. All samples showed an increase in NbC crystallite size and n-phase formation. The processed NbC-FeNiNb hardmetal presented good densification and hardness of approximately 1726 HV30, fracture toughness 12.5 ± 0.1 MPa.m1|2, Young's modulus 385 ± 4 GPa, which is shown as a viable alternative in applications such as cutting tools. TG and DSC analysis confirmed the formation of a liquid phase and more carbides contributing to the mechanical properties of the composite. The thermal properties showed that the thermal diffusivity and thermal conductivity for NbC-FeNiNb was lower than for WC-Co carbide.

Innovative Aspect(s) :
NbC hardmetal composites with Fe-Ni-Nb binder were successfully produced by spark plasma sintering method. As a whole, results point to the successful replacement of Co by FeNiNb developed binder, and to the replacement of WC by NbC in hardmetals.During sintering of the NbC-Fe-Ni-Nb cemented carbide, ɳ phase was formed for all temperatures. At optimal sintering temperature, the highest hardness, KIC, and elasticity modulus were achieved.Thermal expansion coefficient measured between 200 and 750°C reported are 6.14 × 10−6°C−1.Thermal analysis DSC and TG of the studied composites showed the formation of some niobium carbides.Thermal diffusivity and thermal conductivity of NbC-FeNiNb was lower than WC-Co hard metals.

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EURO PM2023 CONGRESS & EXHIBITION

Technical Programme Committee
15th February 2023

MATERIALS

FERROUS MATERIALS

EPMA european powder metallurgy association

EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235746422

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Ferrous Materials

Author : Mr Vikner Peter (Aubert&Duval, France)

Co-author(s) : Mr Egea Philippe, Mr Michel Loic, Mrs Legay Florence (Aubert&Duval, France), Dr Joffre Thomas (IPC, France), Mr Garabedian Stephane (IPC, France), Dr Langer Lukas (Fraunhofer IGCV, Germany)

Title : Influence Of Different Heat Treatments On Mechanical Properties, Corrosion Resistance And Polishability For LPBF Manufactured Stellar® X15TN Stainless Tool Steel

Keyword(s) :
Additive Manufacturing; Parameters Optimization; Martensitic Stainless Steel; Plastic Injection Mold; Tooling; Heat Treatment Development; Mechanical Properties; Corrosion Resistance

Abstract :
Stellar® X15TN (Euro number 1.4123) is a cobalt free 0,4% C martensitic stainless steel which is easy to print by LPBF despite its relatively high carbon content. The steel combines a capability to be heat treated to over 58 HRC with a good corrosion resistance and an excellent polishability. Therefore, Stellar® X15TN is suitable for plastic injection molds with conformal cooling, surgical tools, cutting tools for food processing but also other parts and tools where a combination of high hardness and corrosion resistance is requested. Different heat treatments are presented to achieve a final hardness in the range 36-58 HRC, whilst also providing a lower intermediate hardness needed for machining operations. The effects on the impact toughness, the corrosion resistance and the polishability are also presented.

Innovative Aspect(s) :
Stellar®X15TN is the first easy to print high carbon martensitic stainless steel with a hardness of +58 HRC that is commercially available. The high cleanliness in combination with the good printability ensures an optimal polishability. Being magnetic and relatively soft in its as-built and stress relieved state makes it easy to machine, which is necessary for example for drilling and threading of fixation holes. The fact that it is cobalt free is another important feature. Previous studies have exposed the printing parameters. This work proposes some optimized heat treatments and their impact on the main usage properties

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235749781

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Ferrous Materials

Author : Dr Giroud Tiphaine (Aubert & Duval, France)

Co-author(s) : Mr Egea Philippe, Mr Vikner Peter, Dr Mayer Charlotte (Aubert & Duval, France), Dr Vivès Solange (Aubert & Duval, Spain)

Title : Development Of An Invar Strengthened By Ni3Nb-Gamma" Phase Precipitation Suitable For Additive Manufacturing

Keyword(s) :
Additive Manufacturing; Nickel-Iron Alloy; Stellar® InvHard; Alloy Design; Low CTE

Abstract :
Stellar® InvHard is a Nb-enriched Invar designed for additive manufacturing (LPBF). It will be launched on the market in 2023. Compared to Invar 36, Stellar® InvHard exhibits increased mechanical strength while maintaining a low coefficient of thermal expansion. The hardening of this alloy is inspired by superalloys 706 and 718 strengthened by Ni3Nb-γ" phase that precipitates in the austenitic matrix; also containing carbides and Nb-rich δ phase. The precipitation of the γ" phase can be controlled through annealing and aging treatment's optimization, leading to a hardness in a range: 300-420 HV. Insights on microstructure and processability will also be presented along to coefficient of thermal expansion and tensile strength results.

Innovative Aspect(s) :
Stellar® InvHard is the first high strength alloy with low coefficient of thermal expansion designed for the additive manufacturing process that is commercially available. This work presents the development of this low CTE grade where the chemical composition has been optimized to offer printability and increased mechanical strength. The combination of dimensional stability and high strength with the design freedom of additive manufacturing enables the production of complex and lightweight parts for aerospace, cryogenic and precision instruments.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235756038

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Ferrous Materials

Author : Dr Andersson Michael (Höganäs AB, Sweden)

Co-author(s) :

Title : Modelling Of Fatigue Strength Of Astaloy CrS

Keyword(s) :
Fatigue Strength; Fracture Mechanics

Abstract :
Astaloy(R) CrS is a water atomized iron powder, alloyed with 0.85%Cr and 0.15%Mo, recently developed to meet increasing demands for sustainability. For many applications, fatigue strength is a limiting factor, why reliable fatigue models and data are keys to using materials to their best potential. Not least for sustainability reasons. This paper focuses on the fatigue strength of Astaloy CrS, where the performance of this new material is compared to more traditional alloying systems, such as FeCuC. In parallel, a fracture mechanics fatigue model is developed to predict the strength of the material. With this model, it is possible to simulate both the effect of density as well as stress concentrations to estimate component strength under different conditions.

Innovative Aspect(s) :
The paper presents material data for a new material as well as an innovative way to model fatigue strength of sintered steels.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235756235

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Ferrous Materials

Author : Dr Lindsley Bruce (Hoeganaes Corporation, USA)

Co-author(s) : Mr Kraus Neal (Hoeganaes Corporation, USA)

Title : Comparison Of Soft Magnetic Composites And Lamination Assemblies

Keyword(s) :
Soft Magnetic Composites; Lamination Steels

Abstract :
Lamination sheet steel used for magnetic stator cores have excellent magnetic properties within individual sheets. The comparison of these individual sheet properties, such as maximum saturation and permeability, with powder-based soft magnetic composites appears unfavorable for SMC use. The properties of lamination assemblies, however, is lower than individual sheets due to stacking factor and the presence of insulation layers. Further, it is commonly understood that these stacks tend to work best at lower frequency, whereas SMC is more suited to higher frequency. The number of direct comparisons of SMC and lamination steel stacks is limited in the literature, resulting in broad generalizations. In this study, test rings made with assemblies of 3 lamination steel grades and 2 grades of SMC will be evaluated under different test conditions. The direct comparison will enable users of the technology to understand the benefits and limitations of each approach.

Innovative Aspect(s) :
Understanding behavior of SMC and laminate assemblies in a direct evaluation, and identifying operating conditions where each best performs.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235760998

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Ferrous Materials

Author : Mrs Junghetu Corina (Hoeganaes Corporation Europe S.A., Romania)

Co-author(s) : Mrs Junghetu Corina (Hoeganaes Corporation Europe S.A., Romania), Dr Ing Schade Chris, Mrs Horvay Kerri, Mr Murphy Tom (Hoeganaes Corporation, USA)

Title : Influence Of Heat Treatment On Mechanical Properties Of Parts Produced By Laser Powder Bed Fusion From Wear Resistant Alloys

Keyword(s) :
Wear Resistant Steels; Additive Manufacturing

Abstract :
Applications that require wear resistance use hard materials which are difficult to machine. The most common forming method is by grinding but that limits the part geometry that can be achieved. Using additive manufacturing to form parts will open the range of possible geometries and functionalities that have never been explored. In this study, the microstructures and mechanical properties were evaluated for as-built and heat treated samples for a series of wear-resistant alloys developed to provide a range of properties for different tooling applications. The samples were prepared by printing with the laser powder bed fusion technique and then heat treated in different conditions. Standardized wear testing and the toughness of the material were evaluated as well.

Innovative Aspect(s) :
Evaluates the properties of the wear resistance steels developed for Additive Manufacturing function of the heat treatment performed. It presents the correlation between heat treated microstructure and mechanical properties as well as abrasion resistance properties.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235762746

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Ferrous Materials

Author : Prof Dr Gierl-Mayer Christian (Technische Universität Wien, Austria)

Co-author(s) : Dipl-Ing Geroldinger Stefan, Dr De Oro Calderon Raquel, Prof Dr Danninger Herbert (Technische Universität Wien, Austria)

Title : Comparison Of Low Alloyed Cr-Mo PM Steels By Thermoanalytical Techniques

Keyword(s) :
PM Steel; Themoanalysis; Dilatometry, DTA

Abstract :
Low alloyed steel powder Fe-0.85Cr-0.15Mo-C is dedicated to substitute Fe-Cu-C for PM steel precision parts. It is known from previous research that the introduction of oxygen sensitive elements like chromium leads to a change in deoxidation behaviour during the sintering process of PM steels compared to classical alloying elements like copper, nickel or molybdenum. This behaviour strongly depends on the chromium content of the powder. DTA|MS and DIL|MS experiments of this powder in different atmospheres are compared to classical Fe-Cu-C and higher chromium alloyed powders to reveal significant changes during the heating stage of the sintering process and to show if special measured are needed to sinter these steels compared to Fe-Cu-C. Thermal treatment to simulate dewaxing is performed to investigate the change in surface chemistry of the pressed compacts. The thermoanalytical experiments are accompanied by analysis of carbon and oxygen content and by microstructural characterization.

Innovative Aspect(s) :
Thermoalytical experiments on new powder grade Astaloy CrS are poerformed and compared to other PM steels. Variations of atmosphere and processing conditions will give insight in the sintering behavior of the new material.

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EURO PM2023 CONGRESS & EXHIBITION
01-04 October 2023

Paper Number : EP235762969

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Ferrous Materials

Author : Ms Yöyler Sibel (Tallinn University of Technology, Estonia)

Co-author(s) : Dr Surzhenkov Andrei, Dr Antonov Maksim, Mr Viljus Mart, Mr Traksmaa Rainer, Dr Juhani Kristjan (Tallinn University of Technology, Estonia)

Title : Analysis Of Microstructure And Abrasive Wear Of Fe-based Hardfacings With TiC, In-situ Synthesized From TiO2

Keyword(s) :
Hardfacing; PTA Welding; Stainless Steel; Abrasion Test

Abstract :
Fe-based hardfacing with TiC reinforcement receives considerable attention due to the increasing demand for protective hardfacings. The present research focuses on the investigation of microstructure and abrasive wear behavior of Fe-based hardfacing with TiC, in-situ synthesized from TiO2. The plasma transferred arc (PTA) welding method was used for in-situ synthesis of TiC on the S235 substrate using 72 h ball-milled AISI 316L stainless steel (ss), TiO2, and graphite powders. Scanning electron microscopy (SEM) was used to analyze the microstructure, and energy dispersive spectroscopy (EDS) analysis was used to determine the distribution of TiC. XRD analysis was used to define the phases. Vickers hardness was measured, and ASTM G65 abrasion test was applied to evaluate the wear resistance of the hardfacings. Wear mechanisms were studied under SEM.

Innovative Aspect(s) :
The main innovation of this research is the wear testing of Fe-based hardfacings with TIC reinforcement. There were several attempts to synthesize TiC from TiO2, however, the wear resistance of specifically these hardfacings was almost never tested.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764026

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Ferrous Materials

Author : Dr Olsson Fredrik (Höganäs AB, Sweden)

Co-author(s) : Dr Vattur Sundaram Maheswaran, Ing Johansson Pernilla (Höganäs AB, Sweden)

Title : Evaluation Of Prior Austenite Grain Size On Heat Treated Low Pressure Carburized Chromium P|M Steels Using EBSD

Keyword(s) :
PAGS; EBSD; PM Steel; LPC

Abstract :
The martensite phase is of vital importance in PM steels thanks to its ability in enhancing mechanical properties and increasing component performances. The component behavior can be further improved by the addition of Ni and heat treatment after sintering in form of casehardening by low-pressure carburizing (LPC). Time and temperature of the sintering process determines the austenite grain sizes, which in turn have large impact on the martensitic transformation. Knowing the prior austenite grains sizes (PAGS) is crucial for better understanding the influence from the sintering process conditions on the martensite formation during LPC. However, the PAGS are difficult to reveal for evaluation by conventional light optical methods, which favors analytical approaches based on Electron Backscatter Diffraction (EBSD) measurements. This paper investigates the effect from different sintering temperatures on PAGS and related martensitic microstructure in a chromium pre-alloyed PM steel with and without Ni additions after LPC utilizing EBSD.

Innovative Aspect(s) :
The impact of PAGS on martensite formation in low pressure carburisation of Cr-containing steel by means of EBSD is important in understanding optimal sintering process and heat treatments. An EBSD approach can simplify the procedure of evaluating PAGS.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764029

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Ferrous Materials

Author : Mr Lindroos Tomi (VTT, Finland)

Co-author(s) : Mr Lagerbom Juha, Dr Tervo Jyrki, Dr Jokiaho Tuomas, Mr Antikainen Atte (VTT, Finland)

Title : Nitrogen Alloyed Austenitic Ni-free Stainless Steel For Additive Manufacturing

Keyword(s) :
Ni-Free; Additive Manufacturing; Nitrogen Alloying

Abstract :
Nitrogen alloyed Austenitic Nickel-free Stainless Steel (ANFSS) is one of the most promising group of materials for consumer and health care products. They can be used to substitute not only conventional AISI 316L, but also Titanium and Co-Cr alloys. Previously the utilization of Nitrogen alloyed materials has been limited due to high work hardening rate. Recent developments in powder metallurgy, e.g. Additive Manufacturing (AM), are offering economically feasible net shape manufacturing routes to go around machining related problems. In the present study a viable processing route for ANFSS powder is introduced. It includes gas atomization and AM of test specimens by laser- and sinter-based methods. Special attention is paid on controlling the nitrogen content in different processing steps including solution annealing. The results show that by proper selection of processing parameters, the nitrogen content can be kept in desired level, thereby controlling the mechanical and corrosion properties of ANFSS alloys.

Innovative Aspect(s) :
Use of abundant alloying elements to realize high performance alloy.
Benefit from additive manufacturing to realized materials hard to machine.
Utilization of nitrogen alloying to control final properties of alloy.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764056

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Ferrous Materials

Author : Mrs Olsson Elin (Erasteel, Sweden)

Co-author(s) : Dr Lardon Jean-Marc (Aubert&Duval, France), Mr Stern Nicolas (Erasteel, France), Dr Sundin Stefan (Erasteel, Sweden)

Title : Effect Of Cleanliness On Corrosion And Toughness Of Powder Metallurgical Martensitic Stainless Steels

Keyword(s) :

Abstract :
Martensitic stainless steels are highly alloyed in C, Cr and Mo for hardness and corrosion resistance and often in V for increased wear resistance. Due to the high alloying content, powder metallurgy (PM) including gas atomization and hot isostatic pressing (HIP) can be used to increase properties such as strength, fatigue resistance etc., thanks to almost elimination of segregations. However, further improvement of properties is made possible thanks to the recent developments of gas atomization process, which give very low levels of non-metallic inclusions. High cleanliness of PM material is well known to be critical for good polishing ability, fatigue resistance, strength etc. This paper describes results regarding the effect of cleanliness, composition and heat treatment on the impact toughness and salt spray corrosion resistance of different PM martensitic stainless grades containing 14 to 20% Cr, more than 1% C and Mo + V.

Innovative Aspect(s) :
The influence from amount of non-metallic inclusions on corrosion properties of PM martensitic stainless steel has to the best of our knowledge not been presented before. The effect is clearly there, which is probably not self-evident for the general audience. The paper and presentation will also show detailed SEM study on how the type of corrosion differs for the different materials and heat treatments. In addition, some results on toughness will be shown and how it is influenced as well from cleanliness.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764243

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Ferrous Materials

Author : Mr Radtke Felix (Institute of Applied Powder Metallurgy and Ceramics (IAPK), Germany)

Co-author(s) : Mr Becker Louis, Dr Ing Lentz Jonathan, Prof Dr Weber Sebastian (Chair of Materials Technology (LWT), Germany), Dr Ing Herzog Simone, Prof Dr Broeckmann Christoph (Institute of Applied Powder Metallurgy and Ceramics (IAPK), Germany)

Title : High Nitrogen Steels Produced By PBF-LB|M - Process Strategy And Properties For Ceramic Additivated Metal Powders

Keyword(s) :
Ceramic Additivated Metal Powder; High Nitrogen Steels; PBF-LB|M; Powder Properties; Recycling; Humidity; Si3N3

Abstract :
Additivated powders for the powder bed fusion – laser beam (PBF-LB|M) process allow to innovative materials, which can not be produced by conventional manufacturing techniques. In this study, Si3N4 powder is added to austenitic steel powder for the manufacturing of high nitrogen steels (HNS). Therefore, two different types of additivation are investigated using tumbling mixers with and without grinding balls. Variations in the oxygen content and particle size distribution of the ceramic powder are analyzed to gain knowledge regarding influences on the rheological and reflective properties of the additivated powder. The flowability and packing density are determined as a function of humidity and drying parameters of the powder. First samples of the investigated powders were processed by PBF-LB|M. Microscopic investigation reveals new insights inton the melting mechanisms of metal|ceramic mixtures. An analysis of the residual powder gives first indications regarding recyclability.

Innovative Aspect(s) :
The formation of HNS via additive manufacturing is limited by the nitrogen solubility of the steel melt. In contrast, the austenite phase shows a significantly increased solubility for nitrogen, which increases mechanical properties and corrosion resistance. For this reason, an accumulation of nitrogen in the steel matrix within the solid phase is aimed. Shaping is provided by the PBF-LB|M process assuming that only the steel melts while the Si3N4 particles only partly dissolve into the melt. The undissolved Si3N4 particles are dissolved by a subsequent HIP treatment, allowing nitrogen to diffuse into the component. In addition HIP brings the advantages of densification and homogenization.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765115

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Ferrous Materials

Author : Prof Dr de Oro Calderon Raquel (TU Wien, Austria)

Co-author(s) : Dr Hojati Milad, Mr Geroldinger Stefan, Prof Dr Gierl-Mayer Christian, Prof Dr Danninger Herbert (TU Wien, Austria), Dr Hellein Robert (Miba Sinter Austria GmbH, Austria)

Title : Sustainable Hybrid Alloyed PM Steels

Keyword(s) :
Sintered Steels; Hybrid Alloying; Masteralloys; Sinter-Hardening

Abstract :
The use of recyclable, non-toxic and non-critic alloying elements is becoming increasingly important in the last years. In particular, the unstable prices of Ni and Cu, and the increasing demand for these elements from the electromobility sector can eventually increase the prices, eliminating the price-competitiveness advantage of PM-steels. This work shows the newest advances in the investigation of PM-steels produced from more sustainable base powder alternatives (as AstCrS), combined with FeMnSi-based masteralloys (i.e. hybrid-alloy approach). Chemical analysis, CCT diagrams and mechanical properties will be presented for steels with different hybrid compositions, sintered and heat-treated under different conditions. The results show how, by properly adapting the sintering conditions and by combination with sinter hardening treatments, the use of more sustainable alloy compositions could be extended to additional PM application areas.

Innovative Aspect(s) :
Ni, Cu free PM-steels - Use of newly developed enviromentally friendly base powders (as Ast CrS).
Use of newly developed Ultra High Pressure water atomized masteralloys (FeMnSi-based).
CCT-diagrams of newly developed Hybrid-alloyed PM steels- Mechanical properties of as sintered and sinter hardened materials.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION
01-04 October 2023

Paper Number : EP235765422

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Ferrous Materials

Author : Ms Sweeney Fort Natasha (University of Sheffield, United Kingdom)

Co-author(s) :

Title : Producing Functionally Graded Precious Metal Doped Stainless Steels By Field Assisted Sintering Technique

Keyword(s) :
Cathodic Modification; Platinum Group Metals; Field Assisted Sintering Technique (FAST); Corrosion Prevention

Abstract :
Stainless steels' ability to resist corrosion is improved via cathodic modification. This is achieved through coating or bulk alloying with precious metals. However, this approach to the enhancement of stainless steels has yet to find commercial success due to its high costs and the propensity for precious metal coatings to debond. This project aims to make cathodic modification more economical by incorporating precious metals into stainless steels by functional grading. In this study, Ru- and Pd-doped 316L and 17-4PH stainless steel powders were sintered using FAST and corrosion tested. Near full density was attained and elemental segregation was not observed in the sintered samples. This new approach shows potential for reducing the volume of precious metals used in cathodic modification while improving long-term corrosion performance.

Innovative Aspect(s) :
Research has shown that cathodic modification of stainless steels can be achieved by bulk alloying and coating. However, the powder metallurgy approach to cathodic modification remains unexplored, as does using functional grading as a means of incorporating precious metals using metal powders. To the best of the author's knowledge, FAST has not before been used to produce precious metal-doped stainless steels nor undoped 17-4PH stainless steels.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765450

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Ferrous Materials

Author : Ing Reis Cruz Francisco (Univ. Coimbra, Portugal)

Co-author(s) : Dr Santos Rúben F. (University of Porto, Portugal), Ing C. Silva Pedro (Ramada Aços S.A., Portugal), Dr Ramos Ana Sofia, Prof Dr Vieira Teresa (Uniersity of Coimbra, Portugal)

Title : Powder Bed Fusion For Chemical Composition Optimization Of Tool Steel

Keyword(s) :
Hardening Mechanism; Powder Bed Fusion (PBF); Nanoprecipitates; Tool Steel; Properties Gradient; Steel Nanocomposite

Abstract :
Powder Bed Fusion (PBF) of tool steels as AISI H13 could contribute to a significant improvement of hardness by the presence of nanometric carbides. Moreover, new chemical compositions could be in gradient from top to inside 3Dobject. During additive manufacturing suitable powder mixtures of steel and vanadium&carbon allow the formation of nanocarbides. These elements are selected regarding the exceptional behavior of nanosized vanadium carbides in hardening. The cooling rate in the top surface of melt pool in PBF reaches 106 K|s, inducing low size carbides, from nanometric to micrometric, as the deepness of the analysis increases. In the present study, vanadium and graphene were added to AISI H13 powder. The possible carbon in excess, dissolved in the matrix, must be similar to the previous carbon percentage of H13 (0.35 %wt.). Microstructural analyses were carried out mainly by HRTEM of FIB samples acquired in top surfaces and middle of 3Dobjects.

Innovative Aspect(s) :

Reviewer's name : ....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : ....

Notes to author : ....

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Paper Number : EP235762245

Requested presentation type : Poster Presentation

Topic : Materials **Subtopic :** Ferrous Materials

Author : Prof Dorofeyev Vladimir (Platov South-Russian State Polytechnic University (NPI)), Russia)

Co-author(s) : Dr Sviridova Anna, Dr Berezhnoi Yury, Dr Bessarabov Eugene (Platov South-Russian State Polytechnic University (NPI)), Russia), Miss Sviridova Svetlana (Derzhavin Tambov State University, Russia), Dr Vodolazhenko Roman (MIREA - Russian Technological University, Russia)

Title : High-Temperature Heating Effect On The Transformation Of Non-Metallic Inclusions, The Structure And Properties Of Hot-Deformed Powder Steel

Keyword(s) :
Hot Forging; Porous Preforms; Mechanical Properties; Brittle and Ductile Fracture; Interparticle Jointing; Cohesion; Contact Interaction; Particle Surface; Alloying; Microalloying; Vanadium; Oxidation; Iron Powder; Dispersion Hardening; Dissolution - Prec

Abstract :
In order to decrease the negative impact of non-metallic inclusions on the properties of powder steels, the possibility of their diffusion dissolution during long-term high-temperature vacuum sintering or post-deformation annealing was studied. In the production of steels, iron powders with various contents of impurities were used. To decrease the tendency of austenite grains to grow, vanadium was added to the mixture composition. The content of carbon and vanadium was varied, as well as the modes of sintering and annealing. Heat treatment was performed after hot forging or annealing. The performance of high-temperature sintering or annealing causes a decrease in the size of non-metallic inclusions. Near the former particles of inclusions finely dispersed particles of secondary precipitates ("satellites") precipitate during the cooling process, which do not have a softening effect on the material. The modes of sintering are determined, which provide the minimum sizes of inclusions and vanadium-bearing carbides.

Innovative Aspect(s) :
A decrease in size of non-metallic inclusions during high-temperature sintering reduces the risk of formation of micropores and microcracks at the sites of localization of these inclusions during hot repressing porous preforms. On the contrary, in the case of post-deformation annealing, micropores and microcracks that have arisen during hot repressing near large inclusions are practically not healed.

Reviewer's name : ……………………………………………………………………………………………….

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : ……………………………………………………………………………………….

Notes to author : ……………………………………………………………………………………………….

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Paper Number : EP235765561

Requested presentation type : Poster Presentation

Topic : Materials **Subtopic :** Ferrous Materials

Author : Dr Ing W. Sequeiros Elsa (LAETA|INEGI, Portugal)

Co-author(s) : Dipl-Ing M. Costa José, Dr Ing F. Santos Rúben, Prof Dr F. Vieira Manuel (LAETA|INEGI, Portugal)

Title : A Benchmarking Case Study And Comparison Of Die Specimens' Production Thru L-PBF Systems For Industry: Dimensional, Surface, Microstructural, And Mechanical Characterization

Keyword(s) :
Metal-Based Additive Manufacturing; Laser Powder Bed Fusion; Maraging Steel

Abstract :
Additive Manufacturing (AM) has become an emerging technology for the mass-production industry , with cost reduction and process improvement potential. This study aims to evaluate the production of dies through Laser Powder Bed Fusion (LPBF) technology, manufactured with different LPBF systems, well-established in the global market. The selected material was maraging steel powder EN 1.2709, and each supplier chose the process parameters according to their experience and systems parameterization. Different tests were performed on the dies to compare them: microstructure characterization, SEM|EDS and EBSD analysis, microhardness tests, surface analysis, and 3D dimensional measurements. Although the material and technology were the same, distinct characteristics were found in the evaluated parts. Based on the main results, one part was selected and tested successfully in an industrial production environment. This work has shown that different LPBF equipment, although using identical powder alloy , technology principles, and part requirements, originate distinct alloy characteristics.

Innovative Aspect(s) :
This study aims for an industrial application through producing maraging steel parts with LPBF. Different equipment manufacturers were used, and an extensive characterization was performed, mainly in the final parts. Although maraging steel parts produced by LPBF are well reported in the bibliography, there isn't any study that compares the output of different LPBF equipment from the standpoint of the powder and final part properties. LPBF systems are complex and require several operational conditions: system configuration, parameters, and powders assume a relevant character, making process optimization difficult. As well, the main LPBF systems are closed, which means different parameters for the same purpose. This was a study focused on the selection of the best final part, with industrial application, produced by LPBF considering the main well-established systems on the market.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

Technical Programme Committee
15th February 2023

MATERIALS

NON FERROUS MATERIALS

EPMA
european powder metallurgy association

EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235768755

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Non ferrous Materials

Author : Ing Fayanás Aintzane (Ceit-BRTA and Tecnun (Universidad de Navarra), Spain)

Co-author(s) : Dr Ordás Nerea, Dr Urionabarrenetxea Ernesto, Dr Iturriza Íñigo, Dr Veiga Ángela (Ceit-BRTA and Tecnun (Universidad de Navarra), Spain), Ing Valls Isaac (Rovalma, S.A., Spain)

Title : Development Of Nickel Aluminium Bronzes By Powder Metallurgy For Marine Applications

Keyword(s) :
Nickel Aluminium Bronze (NAB); Erosion-Corrosion; Prealloyed Powder; Mechanical Strength

Abstract :
Nickel aluminium bronze alloys (NAB) are commonly used to manufacture components for marine industry, like valves, bearings or hubs, due to their high mechanical strength and excellent corrosion resistance in seawater. Powder Metallurgy (PM), in contrast to conventional production processes, offers a more efficient use of raw materials and near-net-shape (NNS) components with fine and isotropic microstructures with improved performance.In this work, conventional PM (compaction and sintering) and PM-HIP (Hot Isostatic Pressing of encapsulated powder) have been explored to obtain fully dense NAB from gas atomised powder with Cu-9Al-4.5Ni-0.9Mn (wt.%) composition. The results show that an adequate selection of process parameters leads to fully dense materials with a microstructure suitable for exposure to marine environments. Final heat treatments are responsible for further microstructural refinement and dissolution of detrimental brittle phases, like martensitic ß or coarse rosette ?I, resulting in enhanced mechanical strength, ductility and resistance to erosion-corrosion in seawater.

Innovative Aspect(s) :
The conventional manufacturing processes to obtain NAB components for the marine industry include casting, rolling, extrusion or wrought, followed by machining. In contrast, Near-Net-Shape (NNS) processes, including PM and PM-HIP, minimise the need for machining operations, which results in energy savings and minimisation of waste material. In addition, R&D activities in PM of NAB alloys are limited and usually report final relative densities below 92%, leading to poor behaviour against erosion-corrosion. The results presented in this work demonstrate the feasibility to achieve 100% dense NABs by PM. Finally, the use of pre-alloyed powder has a positive impact on the sustainability and circularity of the components developed through the route here proposed. Component, can be recycled and used as raw material for the production of new powder once they reached the end of their useful life, provided the chemical composition and uptake of contaminants like C or O is controlled.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235754770

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Non ferrous Materials

Author : Miss Charteau Mélanie (Université de Poitiers - Institut Pprime, France)

Co-author(s) : Prof Joulain Anne, Prof Brunet-Gauthier Véronique, Prof Audurier Valérie (Université de Poitiers - Institut Pprime, France)

Title : Study Of The Mechanical Properties Of A Cu|C Composite With ZrC Interphase

Keyword(s) :
Metal matrix composite (MMC); Interphase; Microstructure; Mechanical properties, Carbon fiber; Copper matrix

Abstract :
Electronic devices present a large coefficient of thermal expansion (CTE) mismatch between the copper thermal drain and the ceramic and silicon parts. This causes thermomechanical stresses at the interfaces resulting in component failure. Copper composites reinforced with carbon fibers are materials of choice to overcome this drawback due to their expected adaptive CTE. To ensure good transfer of properties, chemical bonding between the matrix and reinforcement is necessary.The challenge of this work is to synthesize these composites, by hot isostatic pressing or hot uniaxial pressing, with a 2D or 3D orientation of carbon fibers respectively, and to produce in-situ a Zr-based interphase during the densification step. The microstructure and chemistry of the matrix, and those of the interphase, will be finely characterized by transmission and scanning electronic microscopy. The mechanical properties will be studied at room temperature at different scales.

Innovative Aspect(s) :
The synthesis of a composite with a copper matrix and randomly oriented carbon fiber reinforcement by powder metallurgy.
The multi-scale study of the mechanical properties of Cu(CuZr)|Cf composite and the relationship with the microstructure.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235762996

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Non ferrous Materials

Author : Dr Lorenzon Ivan (Pometon SpA, Italy)

Co-author(s) :

Title : Development Of Pure Copper Premixes For The Production Of Sintered Components With High Density And Electrical Conductivity

Keyword(s) :
Pure Copper Powder; Sintered Copper Components; Sintering of Pure Copper

Abstract :
In the heart of the EV but also of electronic components, copper is used throughout because of its high electrical conductivity, durability and malleability.EV use more than double the copper of an internal combustion engine automobile and it is also used heavily in EV-infrastructure like charging stations and in electrical grid infrastructures.Sintered Copper components could be cornerstone not only for the Powder Metallurgy future in automotive applications but also for the EV revolution.Pometon, by the experience on production of ECP and WA copper, is developing some ready to press products to meet the needs of the classical sintering production process for the fabrication of copper components. This study shows the developing a high purity and highly densifying copper powder given fundamental guidelines to facilitate the classical sintering to obtain the chemical, physical and mechanical characteristics needed for E-automotive and electronic applications.

Innovative Aspect(s) :
Production of sintered parts, via classic sintering, with high density and high conductivity for the EV and electronics market.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235763056

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Non ferrous Materials

Author : Dr Romero Carlos (Universidad Carlos III de Madrid, Spain)

Co-author(s) : Mr Villemur Juan, Prof Gordo Elena (Universidad Carlos III de Madrid, Spain)

Title : Effect Of C Additions On The Sintering And Properties Of Titanium Hydride And Ti-6Al-4V

Keyword(s) :
Titanium; Sintering; Properties

Abstract :
Still considered a very damaging impurity whose content needed to be minimized, C could become an alloying element for Ti for non-critical applications if the standards are relaxed, especially given the importance of MIM and binder-based AM technologies. In the literature, the C content is dependent on the binder used, the debinding method and the sintering, but these parameters can also affect others, like the density of the part. Therefore, the aim of this work is to isolate the effect of the C content on titanium alloys and study its effect on the sintering behaviour and its properties. This is done adding carbon black to titanium hydride and to Ti-6Al-4V powder blends processed by pressing and sintering, and assessing changes in the thermal behaviour prior to sintering, the density of the material, the microstructure, composition and mechanical properties.

Innovative Aspect(s) :

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : ....

Notes to author : ....

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764660

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Non ferrous Materials

Author : Ms Goettgens Valerie (Univeristy of Innsbruck, Austria)

Co-author(s) : Dr Braun Jakob, Dr Kaserer Lukas, Prof Dr Leichtfried Gerhard (University of Innsbruck, Austria)

Title : Eutectoid ? -Ti Stabilizers In Ti-6Al-4V Leading To High Strength: A Comparison Of Copper And Chromium Addition In Laser Powder Bed Fusion

Keyword(s) :
Ti-6Al-4V; Laser Powder Bed Fusion; Additive Manufacturing; Alloy Development; Titanium Alloys; Intermetallic Compounds

Abstract :
Laser Powder Bed Fusion (LPBF) is the most frequently used additive manufacturing (AM) method for metals and alloys. It enables the production of near-net shape parts with high geometric complexity, which is impossible with conventional manufacturing methods. The most commonly used Ti alloy in LPBF is Ti-6A-4V, which shows unfavorable martensite formation due to the extremely high cooling rate in this process. This work presents the further development of Ti-6Al-4V to avoid martensite formation by stabilizing primary ß-Ti. This was achieved by adding 2.88 wt% Cr and 3.5 wt% Cu, both eutectoid alloying elements forming intermetallic strengthening compounds with Ti. The tensile strength was 1450±26 MPa by Cr and 1362±14 by Cu addition. Martensite was effectively avoided. This work compares the theoretical, microstructural, and mechanical differences between adding Cu and Cr.

Innovative Aspect(s) :
Ti-6Al-4V is the most frequently used Ti alloy in LPBF but exhibits martensite formation due to an extremely high cooling rate of up to 10/8 K|s in this process. Martensite leads to severe embrittlement, and costly post-process heat treatments, in which martensite decomposes, are essential for industrial applications. Post-process heat treatments could become redundant with the presented alloying concept, where the eutectoid alloying elements Cr and Cu stabilize primary β-Ti. At the same time, in situ precipitated intermetallic compounds of Ti-Cr or Ti-Cu lead to ultra-high-strength properties compared to pure Ti-6Al-4V. This work presents two approaches for an easy-to-process LPBF-specific alloy that exhibits excellent mechanical properties.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764683

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Non ferrous Materials

Author : Dr Ing Deirmina Faraz (Siemens Energy, Sweden)

Co-author(s) : Dr Ing Adegoke Olutayo (Siemens Energy, Sweden), Ing Del Col Matteo, Prof Dr Pellizzari Massimo (Trento University, Italy)

Title : Effect Of Layer Thickness And Laser Energy Density On The Recrystallization And Grain Growth In A Single-phase Ni Superalloy Fabricated By Laser Powder Bed Fusion

Keyword(s) :
Additive Manufacturing; Productivity; Ni Superalloy; Recrystallization; Grain Growth

Abstract :
Recent advances in design and manufacture of laser powder bed fusion (L.PBF) equipment capable of providing larger laser powers, has led to the utilization of larger powder bed layer thicknesses aimed at improving the productivity. The change in the effective heat input to the powder bed, as a result of increasing the layer thickness affects the thermal history, and constitutional supercooling and, leading to the development of different grain morphologies at different layer thicknesses. In this communication, we report on the influence of the initial as built microstructure, with a particular focus on the layer thickness and laser energy density, on the recrystallization and grain growth behavior of the L-PBF processed Hastelloy X. It was shown that the as-built (AB) microstructure and grain morphology were systematically dependent on the laser energy density, and the kinetics of the recrystallization was significantly increased by increasing laser energy density.

Innovative Aspect(s) :
The work contains systematic investigation of the dependency of heat treatment response of Laser Powder Bed Fusion (L-PBF) processed single phase austenitic Ni superalloy on the layer thickness and laser energy density. for this purpose, parts having layer thicknesses up to 120 micormeters were studied. From an industrial perspective, even if larger layer thicknesses significnatly improve the productivity in AM processes, given the thermal stabity of the microstructure, difficulties in achieving a full recrytallization and efficient grain growth, hence reducing the anisotropy in mechanical properties, might become a challanging and interesting topic to be investigated.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235748755

Requested presentation type : Poster Presentation

Topic : Materials **Subtopic :** Non ferrous Materials

Author : Prof Dr Nagode Ales (University of Ljubljana, Faculty of Natural Sciences and Engineering, Slovenia)

Co-author(s) : Mr Velikajne Nejc, Dr Paulin Irena (Institute of Metals and Technology, Slovenia), Mr Zorc Matija, Mrs Veber Anemarie, Prof Dr Bizjak Milan (University of Ljubljana, Faculty of Natural Sciences and Engineering, Slovenia)

Title : Process Optimisation And Microstructural Development Of SLM Fabricated AlSi10Mg Alloy

Keyword(s) :
AlSi10Mg; Selective Laser Melting; Laser Power; Scanning Speed; Thermoelectrometry; Microstructure and Mechanical Properties

Abstract :
AlSiMg10 is a heat-treatable hypoeutectic alloy with good castability and weldability, which makes it interesting for additive manufacturing (AM).In the present work, selective laser melting (SLM) technology was used to fabricate samples of AlSi10Mg alloy. However, one of the main challenges is to produce an alloy with good microstructural homogeneity and as little porosity, residual stresses or even cracks as possible.The main objective of the experimental research was to find the optimal process parameters for the fabrication of AlSiMg10 samples by SLM, which have a suitable microstructure and mechanical properties. Since defects in the microstructure are usually due to inadequate process parameters, the effect of laser power and scanning speed were investigated. Microstructural analysis was performed using SM and SEM|EDS|EBSD. The changes in microstructure during post-processing heat treatment were followed in-situ by thermoelectrometric measurements based on electrical resistivity.

Innovative Aspect(s) :
As part of our research, we investigated the influence of laser power and scanning speed on the microstructural and mechanical properties of AlSi10Mg alloy produced by SLM. For highly reflective materials, it can be challenging to achieve suitable properties with as few defects as possible. Microstructure was characterized by SM and SEM with EDS and EBSD; however, the changes in microstructure were tracked by thermoelectrometric measurements based on electrical resistivity, allowing in situ monitoring of microstructure evolution.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION
01-04 October 2023

Paper Number : EP235763901

Requested presentation type : Poster Presentation

Topic : Materials **Subtopic :** Non ferrous Materials

Author : Dr Ing Kołacz Dariusz (Łukasiewicz Research Network - Institute of Non-Ferrous Metals, Poland)

Co-author(s) : Dr Ing Kulasa Joanna, Dipl-Ing Lis Marcin, Dipl-Ing Brudny Anna, Dipl-Ing Krukowski Karol, Dipl-Ing Hury Anna, Dipl-Ing Muzia Grzegorz (Łukasiewicz Research Network - Institute of Non-Ferrous Metals, Poland)

Title : Tribological Tests Of CuSn10 Composites With The Addition Of Rhenium

Keyword(s) :
Tin Bronze; Rhenium; Composite; Pressing; Sintering; Hot Isostatic Pressing; Microstructure; Electrical Conductivity; Hardness; Tribological Tests

Abstract :
The article presents the results of tribological tests of composite materials based on CuSn10 with the addition of rhenium. The tested sinters were made by powder metallurgy. In the first stage, powder mixtures were prepared according to the scheme (mass chemical composition): 99% CuSn10 + 1% Re, 90% CuSn10 + 10% Re. Tin bronze (CuSn10) was used as a reference material. Samples for testing were obtained in two ways. In the first, powder mixtures were sintered directly under pressure using the SPS technology, in the second, compacts were initially produced in the process of double-sided axial pressing in steel dies, and then sintered and densified using the HIP method. Microstructure, electrical conductivity, hardness and tribological tests were performed on the obtained sinters. Tribological tests were conducted at elevated temperatures for selected sinters. A positive effect of the addition of rhenium on the sliding properties of the tested composites was observed.

Innovative Aspect(s) :
Tribological tests of CuSn10 composites with the addition of Re indicate a positive effect of rhenium on the sliding properties of these materials. Moreover, the addition of rhenium increases the hardness of the composite. Tin bronze with CuSn10 is used for example for machine parts such as bearings, bushings and drives which must sustain heavy loads. Increasing the sliding properties of materials with an increase in their hardness at the same time can positively affect the possibilities and scope of the use of tin bronzes, for example in bearings or sliding sleeves, by reducing operating costs and increasing the service life of sliding bearings.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

Technical Programme Committee
15th February 2023

MATERIALS

LIGHT MATERIALS

EPMA
european powder metallurgy association

EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235725900

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Light Materials

Author : Dr Ing Martucci Alessandra (Politecnico di Torino, Italy)

Co-author(s) : Ing Marchese Giulio, Ing Aversa Alberta, Prof Manfredi Diego, Prof Biamino Sara, Prof Ugues Daniele, Prof Bondioli Federica, Prof Messori Massimo, Prof Lombardi Mariangela, Prof Fino Paolo (Politecnico di Torino, Italy)

Title : A Time-saving Empirical Strategy For The Geometric Optimisation Of Support Structures Validated On AlSi10Mg And IN625 Alloys

Keyword(s) :
PBF-LB|M; Support Structures; Residual Stress; Empirical Strategy; Decision Support Matrix; Geometrical Indexes; AlSi10Mg; IN625

Abstract :
PBF-LB\M is a promising additive-manufacturing process that allows the production of complex-shaped functional components for a wide variety of applications. However, the layer-by-layer scanning and high cooling rates result in a high thermal gradient (?T) and, thus, in thermally induced stresses that could lead to undesirable cracking and delamination phenomena. A strategy to reduce the ?T and facilitate a correct heat flow is using support structures. However, the support geometry needs to be properly optimised, considering that the thermal resistance increases as the support-height increases and the contact cross-section decreases. For the design phase, it is also essential to consider the anchoring function of the support structures. Based on these considerations, two indices and a decision support matrix were developed in the present work for a quick and efficient setting of geometric parameters. The robustness of the developed strategy was verified on two very different alloys: AlSi10Mg and IN625.

Innovative Aspect(s) :
Support structures are broadly used in the literature to prevent problems related to the extremely high PBF-LB\M cooling rate and ensure proper sample-platform adhesion. However, the simulated methods for the geometric optimisation of support structures currently available are affected by errors in the powder bed and PBF-LB|M solidification phenomena modelling. Furthermore, available software for designing support structures tends to focus on the sample-platform adhesion function and not on ensuring a correct heat flow. The novelty of this work is the development of an easy-to-implement empirical method that allows the most appropriate geometric parameters for residual stress reduction and a correct sample-platform adhesion to be quickly defined. This strategy is based on the use of two geometrical indices and a decision-support matrix. Moreover, the method robustness was established by testing this innovative approach on two materials with very different thermophysical properties but likewise residual stress-sensitive, AlSI10Mg and IN625.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235734146

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Light Materials

Author : Ms Nkosi Nompumelelo (Stellenbosch University, South Africa)

Co-author(s) : Prof Sacks Natasha (Stellenbosch University, South Africa)

Title : Effect Of Build Direction On The Tensile Properties Of A Ti6Al4V Alloy Manufactured Using Selective Laser Melting

Keyword(s) :
Ti6Al4V; Tensile Test; Microstructure; Scanning Pattern; Selective Laser Melting

Abstract :
In this study the effect of build direction on the tensile properties of a Ti6Al4V alloy produced by selective laser melting was investigated. Initial cubes were printed using three different scanning patterns, namely island, meander and bi-directional alternating and rotated at 67°, to determine the optimum pattern producing the highest density and hardness. From the initial results all three patterns produced similar densities of > 99%, while the island pattern had the highest average hardness. Tensile test samples were printed in the vertical and horizontal directions in terms of the gauge length respectively, using the island pattern. The ultimate tensile strength, % elongation and Young's modulus were determined. The microstructure of the samples was studied using scanning electron microscopy, energy dispersive spectroscopy, x-ray diffraction and computerized tomography. The tensile samples printed in the vertical direction had better strength properties.

Innovative Aspect(s) :
Understanding of how the build direction influences the tensile properties of a Ti6Al4V alloy manufactured using selective laser melting. Investigating the role of the resultant microsctructure, deposition parameters and feedstock powder on the tested properties.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235763571

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Light Materials

Author : Dipl-Ing Yamashita Taiki (Kansai University, Japan)

Co-author(s) : Dr Sato Tomohiro, Prof Dr Saitoh Ken-ichi, Prof Dr Takuma Masanori, Prof Dr Takahashi Yoshimasa (Kansai University, Japan)

Title : Development Of Composite Materials For Additive Manufacturing Using Environmentally Friendly Materials

Keyword(s) :
PLA; Composite Materials; FDM; Sliding Members

Abstract :
In the machine parts as sliding members, complex shapes and small-lot production are required. Therefore, manufacturing with Fused Deposition Modeling (FDM) technology using resin materials has attracted attention. However, in this method mechanical properties are inferior to those of metallic materials. In addition, many of the resin materials are petroleum-based resins, and environmental problems are a concern. In this study, we tried to improve it by mixing polylactic acid (PLA) with MoS2 as solid lubricants. PLA is a material with carbon-neutral properties. In the experiment, we used specimens made by a 3D printer after mixing raw materials and passing through intermediate materials. The stability of the composite is worse than that of PLA alone in friction tests. However, the coefficient of friction was partially low. This is thought to be the result of the function of the properties of MoS2 as a solid lubricant.

Innovative Aspect(s) :
Innovative aspects of our study is that it contributes to the improvement of environmental pollution from two directions, materials and manufacturing processes. The main material, PLA, is derived from plants and has biodegradability, which means that it can be decomposed in the natural environment.FDM used for modeling does not require a mold and can use materials without waste. Intermediate materials like pellets and wire-like filaments are required for modeling with FDM. In recent years, there have been an increasing number of prior publications using 3D printers as additive manufacturing technique, but there are few examples of experimenting by making specimens from intermediate materials. In addition, the range of research will be expanded by changing materials to be combined with PLA according to the assumed machine parts without limiting it to MoS2. Therefore, the results of this research have many points that can be used for general purposes.

Reviewer's name : ……………………………………………………………………………………………….

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764195

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Light Materials

Author : Ing Recalcati Sébastien (EPoS Technologies SA, Switzerland)

Co-author(s) : Dr Ing Fais Alessandro (EPoS Technologies SA, Switzerland)

Title : Diffusion Of Carbon In Titanium During Electro-Sinter-Forging

Keyword(s) :
Titanium Alloys; Titanium Composites; Reinforced Titanium; Interstitial Diffusion; Electro-Sinter-Forging; Field Assisted Sintering; FAST

Abstract :
This work investigates the diffusion mechanism of carbon in titanium during Electro-Sinter-Forging (ESF) at different levels of Standard Energy Input [J|g]. Carbon diffusion along interstitial sites occurs extremely rapidly (full dissolution and reprecipitation happen in less than one second) and seems to be favored by the high electrical current densities (up to 1 kA·mm2) that pass through the material during ESF. When sintering a mixture of CP-Ti and 0.5% wt. graphite, carbon atoms diffuse and react with titanium to precipitate acicular TiC whiskers in a near-fully to fully dense material. The shape of these precipitates evolves with increasing levels of energy from being finely dispersed sharp whiskers to a dendritic-like network. Understanding this behavior opens new possibilities to design novel reinforced Electro-Sinter-Forged titanium alloys or composites by precisely tweaking the precipitate's shape and arrangement to optimize structural or functional properties of the material.

Innovative Aspect(s) :
In high speed single pulse methods, densification occurs in completely out-of-equilibrium conditions. This allows the fabrication of novel metastable alloys and composites as can be seen in the microstructures produced in this work. Here, an observation of the diffusion behavior of carbon in titanium enhances the understanding of the underlying mechanisms that go on during Electro-Sinter-Forging. Specifically, details of a new Ti-C alloy are given, with improved mechanical properties with respect to standard Electro-Sinter-Forged CP-Ti. Comparison with an Ti-50Al Electro-Sinter-Forged metal-metal composite, with no diffusion from Al (a substitutional atom in Ti) helps create the framework to a novel design path for titanium alloys and composites by combining substitutional and interstitial alloying elements.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764676

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Light Materials

Author : Dr Yilmazer Hakan (Yildiz Technical Univertsity, Turkey)

Co-author(s) : Mr Sadikoglu Yusuf Atilla (Turkish Aerospace Industries, Turkey), Ms Kuçuk Şeyma (Ford Otosan, Turkey), Dr Gokcekaya Ozkan, Dr Nakano Takayoshi (Osaka University, Japan), Dr Turu İrem Cemre, Dr Bulutsuz Aslı Günay (Yildiz Technical University, Turkey)

Title : Effect Of Dual Heat Treatment On Additively Manufactured Ti-6Al-4V Alloys Through Selective Laser Melting And Electron Beam Melting

Keyword(s) :
Ti-6Al-4V; Additive Manufacturing; Heat Treatment; Corrosion Behavior; Mechnical Properties

Abstract :
Coorrosion resistance and mechanical properties has influences on large scale usage of the addively manufactured Ti-6Al-4V alloys. Therefore, a double annealing heat treatment has been studied to optimize the corrosion resistance and the mechanical properties of the Ti-6Al-4V alloy produced by EBM and SLM in this work. With first heat treatment at 1050°C for different holding times for 30 min, 1 h and 2 h. Afterwards, the second heat treatment was applied for half an hour annealed samples in the first heat treatment. With second heat treatment, it was aimed to increase the reduced mechanical properties by preventing formation of martensite phase. While the holding constant time of 1 hour, different holding temperatures were tried which were 650°C, 750°C and 850°C. All heat treatments were carried out under the argon atmosphere. The microstructure, mechanical properties and corrosion behaviour of the alloy

Innovative Aspect(s) :

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764719

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Light Materials

Author : Dipl-Ing Simola Jukka (EOS Finland Oy, Finland)

Co-author(s) : Dipl-Ing Virtanen Eero, Dipl-Ing Välikangas Jarno (EOS Finland Oy, Finland)

Title : Development Of Novel Aluminium Alloy For Additive Manufacturing For Applications Requiring High Conductivity

Keyword(s) :
Aluminium; Novel; Material Development; Alloy Development; Conductivity; Electrical Mobility; Satellite Communications; Telecommunications; Thermal Management; Additive Manufacturing; L-PBF; EOS

Abstract :
A novel low alloyed aluminium grade was developed for additive manufacturing to meet targets of high electrical and thermal conductivity combined with moderate strength. Typical application fields for it would be telecommunications, waveguides for satellites, electric mobility applications and thermal management. For example, coupling of radiofrequency transmissions by the material is dependent on its surface conditions, including surface roughness and surface electrical conductivity. To tackle this, particular attention in the development was steered towards thin wall and fine feature buildability. Due to high conductivity of the material, the resulting melt pool size was limiting its suitability for filigree designs. This work is completed with parameter study using smaller spot size and|or pulse modulation for laser beams within EOS machines. Being a novel material, characterization of mechanical properties and corrosion properties was done as well. Material passed stress corrosion cracking test ECSS-Q-ST-70-37C classifying as Class 1- high resistance to stress corrosion.

Innovative Aspect(s) :
Novel aluminium material for additive manufacturing, high conductivity combined with moderate strength. Filigrene part processability improvements using novel laser scanning features and process monitoring using EOS DMLS systems.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765372

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Light Materials

Author : Miss Lagalante Ilaria (Politecnico di Torino, Italy)

Co-author(s) : Miss Martucci Alessandra, Dr Aversa Alberta, Prof Lombardi Mariangela, Prof Manfredi Diego Giovanni (Politecnico di Torino, Italy)

Title : Characterization At Room And High Temperature Of Scalmalloy® Lattice Structures By LPBF

Keyword(s) :
Lattice Structure; Scalmalloy®; LPBF; Cell Topology; Compressive Test; High Temperature

Abstract :
Great interest has been expressed towards lattice structures in the past decade thanks to their excellent specific strength, surface area, and ensured light-weighting. Mechanical behaviour is affected not only by chosen material, but also by cell topology and relative density, allowing performance customization. In this field, additive manufacturing (AM) has enhanced the lattice design space, thus expanding their range of applications. Also, new materials developed to the benefit of AM generated new opportunities. Scalmalloy® is one of them. Used in aerospace, automotive and others, it owes its success to its excellent corrosion resistance, ductility, and strength-to-weight ratio.The present work aims to characterize Scalmalloy® lattice structures produced by Laser Powder Bed Fusion process. It focuses on the optimization of the main process parameters to obtain full dense struts. The role of the lattice topology on mechanical performance was investigated. Furthermore, compressive tests were conducted at room and at high temperature.

Innovative Aspect(s) :
Lattice structures have sparked interest in many fields in the past years. At the same time, Scalmalloy® has become one of the most required Al alloy, thanks to its excellent mechanical properties and low density, becoming increasingly popular in elite areas such as automotive racing, like Formula 1. Combining both advanced design and high-performance material makes possible to obtain previously unachievable results. Nonetheless, only few studies have explored this application, doing so with partial results.This study provides a complete analysis of the optimization and characterization process, including different cell topology and relative density in order to define the limitations and the opportunities of this high-performance alloy in a lattice design by LPBF. Moreover, mechanical behaviour is examined not only at 20 °C, as usually performed, but also at 200 °C, taking into account possible applications at high temperature, such as for new compact heat exchangers.

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Paper Number : EP235765700

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Light Materials

Author : Dr Neubauer Erich (RHP Technology GmbH, Austria)

Co-author(s) : Dipl-Ing Ariza-Galván Enrique, Dr Horky Jelena (RHP Technology GmbH, Austria)

Title : Assessment Of Plasma Metal Deposition (PMD) For The Manufacturing Of Titanium Based Metal Matrix Composites

Keyword(s) :
Metal Matrix Composites; Plasma Metal Deposition; Additive Manufacturing; Specific Stiffness

Abstract :
Plasma Metal Deposition is an additive manufacturing technology which is suitable for the fabrication of large structures. Especially for space relevant components with sizes of > 0.5 meter this method offers a potential to fabricate parts made from light weight metals with enhanced stiffness. The PMD process uses a plasma welding torch where powder or wire is used as a feedstock. The layer by layer processing allows to realize near net shape structures. Especially by using powder as a feedstock there is a large flexibility in creating various alloys as well as metal matrix composites with modified properties. Within this study, the goal was to improve the specific modulus (ratio of Young´s modulus|density) by introducing ceramic particles into a titanium alloy matrix. Beside addressing the main challenges in the manufacturing of composites by blown powder methods, an overview will be provided on various ceramic particles which have been investigated.

Innovative Aspect(s) :
The innovative aspect is the manufacturing of a titanium composite using additive manufacturing methods. Blown powder methods are used for the fabrication of ceramic particle reinforced composites with the main aim to increase the specific modulus.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

Technical Programme Committee
15th February 2023

MATERIALS

FUNCTIONAL MATERIALS

EPMA
european powder metallurgy association

EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235753675

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Functional Materials

Author : Dr Vollert Florian (MIMplus Technologies GmbH & Co. KG, Germany)

Co-author(s) : Dr Maurath Johannes (MIMplus Technologies GmbH & Co. KG, Germany)

Title : Production Of NdFeB Magnets By Metal Injection Molding (MIM) - Challenges And Chances

Keyword(s) :
NdFeB; Permanent Magnets; Metal Injection Molding; MIM; Production Technologies; Functional Materials; Magnets

Abstract :
NdFeB magnets show the highest energy products of all known magnetic materials. It is predicted that the demand for this kind of magnets will increase in the following years. However, the required rare earth elements are almost exclusively produced in China. To reduce the dependency on China the recycling of NdFeB magnets is becoming more and more interesting. In the last few years, MIMplus has developed a process to produce NdFeB magnets from either virgin or recycling material by means of MIM. In contrast to the conventional production route via press sintering, MIM allows a high level of design freedom (complex shapes) with comparable magnetic properties.The focus on this work is a review of the different challenges that exist for this new production method in order to achieve the state of the art magnetic properties from press sintering.

Innovative Aspect(s) :
The possibility of producing NdFeB permanent magnets from recycling and virgin material with Metal Injection Molding (MIM) revolutionizes the magnets using applications. MIM allows for production of permanent magnets in a design freedom that hasn't been available so far. However, this production process together with highly reactive NdFeB powder, brings several challenges with it. The paper focusses onto the different challenges of the production of NdFeB permanent magnets via Metal Injection Molding to achieve state of the art properties of sintered permanent magnets.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235754756

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Functional Materials

Author : Ing Checa Fernández Blanca Luna (CEIT-Basque Research and Technology Alliance (BRTA) | University of Navarra, Spain)

Co-author(s) : Dr Martín García Jose Manuel, Dr Burgos García Nerea, Dr Sarriegui Estupiñán Gabriela (CEIT-Basque Research and Technology Alliance (BRTA) | University of Navarra, Spain)

Title : Study Of The Grain Growth Of Nd-Fe-B Atomized Powders With Different Nd Contents And The Addition Of Nb And Ga As Doping Metals

Keyword(s) :
Permanent Magnet; Gas Atomization; Nd-Fe-B- Alloy; EBSD; Grain Growth; Doping Metals

Abstract :
This work presents a detailed study of grain growth annealing of gas atomized Nd-Fe-B powders with different Nd content, ranging from 27.5 to 31.5 wt.%, and additions of Nb or Nb-Ga have been investigated. First of all, the microstructure and magnetic properties of the initial as-atomized powders for all the compositions were measured. Grain growth has been carried out at 1150°C for 5 hours. Nb addition resulted in the decrease of the final grain size due to the pinning effect of Nb-Fe rich compounds and the reduced amount of free Nd to form a liquid phase. Moreover, it has been determined by Thermo-Calc simulations that Nb content in the liquid increases when the Nd content decreases, enhancing the pinning effect. In contrast, Ga addition increased the liquid formed and enhanced the grain growth kinetics, particularly in the samples with the lower Nd content.

Innovative Aspect(s) :
The innovation of this research consists in the study of the effect of Nb and Ga on the grain growth process of atomized powders with different Nd contents. Currently, there is practically no information on the effect of these elements on the properties of atomized powders with different Nd content and the influence of these elements when a high temperature treatment is applied. As the demand for HRE element is on the rise worldwide due to its use in many fields of technology, the development of a Nd-Fe-B powder manufacturing process with enhanced magnetic properties in which the use of these elements is minimized is necessary.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235762510

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Functional Materials

Author : Prof Dr Carreno-Morelli Efrain (University of Applied Sciences and Arts Western Switzerland, Switzerland)

Co-author(s) : Ing Meylan Ludovic, Ing Rodriguez-Arbaizar Mikel, Ing Carthoblaz-Delèze Xavier, Prof Dr Chevailler Samuel, Ing Sahli Benoît, Dr Rajasundar Chandran, Dr Balestra Gioele (University of Applied Sciences and Arts Western Switzerland, Switzerland)

Title : Solvent-on-granules 3D-Printing And Material Extrusion Of Soft Magnetic Fe-6.5Si Alloy

Keyword(s) :
Soft Magnetic Alloys; Solvent on Granule 3D Printing; Material Extrusion; Sinter-Based Additive Manufacturing; Electrical Motors

Abstract :
Soft ferromagnetic parts have been produced by two sinter-based additive manufacturing techniques: Solvent on Granules 3D Printing (SG-3DP) and Material Extrusion (MEX). Fe2.7Si and Fe6.5Si powders were mixed with multicomponent binders, then shaped to granules. Different formulations suitable for SG-3DP and MEX respectively were processed. Square section toroids for magnetic measurements, test cubes and a rotor|stator prototype were printed.The green parts were debound under nitrogen and sintered under hydrogen atmosphere, in a single thermal cycle, using a retort furnace. The sintered parts were characterized by measurements of B-H hysteresis cycles, optical metallography and SEM observations.The impurity contents of carbon and oxygen were measured by melt extraction. The performance of parts processed by both SG-3DP and MEX methods, was compared with literature values obtained from conventional powder metallurgy processes.

Innovative Aspect(s) :
Processing of high silicon content soft magnetic Fe-Si by Solvent on Granule 3D Printing, and comparison with material extrusion 3D Printing.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235762561

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Functional Materials

Author : Prof Dr Bram Martin (Forschungszentrum Juelich, Germany)

Co-author(s) : Dr Maccari Fernando (Technical University Darmstadt, Germany), Dipl-Ing Keszler Monica, Dr Prasad Mishra Tarini (Forschungszentrum Juelich, Germany)

Title : Flash Spark Plasma Sintering Of Nd-Fe-B Magnets With Tailored Anisotropic Magnetic Properties

Keyword(s) :
Nd-Fe-B Magnets; Anisotropic Magnetic Properties; Flash Spark Plasma Sintering (Flash SPS); FAST|SPS

Abstract :
Flash spark plasma sintering (Flash SPS) is an attractive alternative method for the processing of Nd-Fe-B magnets with anisotropic magnetic properties. Therefore, a load is applied on a pre-compacted sample. Then, a well-defined power pulse is applied followed by deformation and densification of the sample in seconds. Compared to established processing of anisotropic magnets via hot pressing with subsequent die-upsetting, Flash SPS introduces the possibility of electroplasticity as an additional deformation mechanism. This mechanism has the potential to improve the magnetic properties through the fine-tuning of the microstructure. Our results reveal that suitable pre-heating of the sample before applying the power pulse plays a crucial role for tailoring grain size and grain aspect ratio, both being the key for well-pronounced anisotropic magnetic properties. For better understanding of the relationship between Flash SPS parameters, microstructure and resulting magnetic properties, in the present work a systematic parameter study has been done.

Innovative Aspect(s) :
Processing of Nd-Fe-B magnets via Flash SPS
Demonstration of well-pronounced anisotropic magnetic properties
Relationship between Flash SPS parameters, microstructure and magnetic properties Benchmark with other shaping technologies

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235763601

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Functional Materials

Author : Dr Ing Lindemann-Geipel Inge (Fraunhofer IFAM, Germany)

Co-author(s) : Dr Mix Torsten, Dipl-Ing Thamm Merlin, Dr Ing Reuter Kay, Dr Ing Kirchner Alexander (Fraunhofer IFAM, Germany), Prof Dr Weißgärber Thomas (Fraunhofer IFAM & Technische Universität Dresden, Germany)

Title : New Prospects For Fabrication Of Fe-6.5Si Soft Magnetic Components Using Powder Metallurgy

Keyword(s) :
Soft Magnets; Magnetic Measurement; Structural Characterization

Abstract :
Excellent soft magnetic properties of the Fe-6.5Si alloy are well known since a very long time. But its usage was hindered by the difficulty of processing by conventional methods. Until now, most innovative fabrication methods are limited to the lab scale. In this study, different powder metallurgical methods are demonstrated for the fabrication of soft magnetic Fe-6.5Si parts with industrialization potential. The magnetic properties as well as geometric limitations of the specific manufacturing processes will be compared for a sinter-based method (screen printing) with a powder bed based (E-PBF) and a more conventional pressing process (FAST|SPS) for manufacturing soft magnetic components from Fe-6.5Si. The magnetic properties of the components will be correlated with their structural properties. Most important aspects like different powder properties as well as fabrication constraints and conditions will be discussed.

Innovative Aspect(s) :
Study on the powder metallurgical fabrication of low loss Fe-6.5Si soft magnetic components.
Comparison of different manufacturing techniques (additive and conventional).
Correlation of magnetic properties with structural properties- Effect of powder characteristics size and process conditions on the magnetic properties.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235763857

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Functional Materials

Author : Dr Pejchal Vaclav (CSEM SA, Switzerland)

Co-author(s) : Mr Manzoor Ayman, Dr Sohrabi Navid, Dr Sereda Olha (CSEM SA, Switzerland), Mr Puyol Yoël (Almatech, Switzerland)

Title : Two-way Shape Memory Actuators By Laser Powder Bed Fusion

Keyword(s) :
Shape Memory Alloys; 4d Printing; Lpbf; Niti; Actuators

Abstract :
Compliant mechanisms can achieve macroscopic linear and rotary motion without friction, wear, and backlash. In recent years, the advent of Additive Manufacturing enabled new topologies for compliant mechanisms that were too complex to manufacture using traditional subtractive manufacturing methods. Today, at CSEM we tackle the challenge of the development of AM process for the next generation of compliant mechanisms with shape memory behavior. The advantages of using shape memory alloys such as NiTi are numerous: (i) actuation without micro-vibration, (ii) simplified assembly, (iii) simplified control of electronics. In this paper, we show the development of full-chain laser powder-bed fusion (LPBF) process covering feedstock specifications and selection, definition of the process window and post-process optimization for NiTi actuators aiming the actuation strain up to 4% with austenite start temperature above 50°C. Combined with shape memory training techniques two-way shape memory effect triggered by on-demand localized heating was achieved.

Innovative Aspect(s) :
The paper shows development of full-chain LPBF process for NiTi-based shape memory alloy including post-processing to achieve fully reversible two-way shape memory effect. The process enables to explore the untapped potential in design freedom for smart shape memory actuators. Potential applications will be discussed and presented.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764224

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Functional Materials

Author : Dr Ing Fais Alessandro (EPoS Technologies SA, Switzerland)

Co-author(s) : Ing Recalcati Sébastien (EPoS Technologies SA, Switzerland)

Title : Novel Metal Based Hard Magnetic Composites

Keyword(s) :
Magnets; Nd-Fe-B; MMC; Composites; Gold; Silver; Bronze; 18kt Magnetic Gold

Abstract :
We present here for the first time a series of novel hard magnetic metal based composites with increased mechanical and corrosion properties with an extended range of use, from sensors to jewelry. The novel Nd-Fe-B based materials, produced through a single step pulse discharge sintering, combine an increased toughness and mechanical stability with various degrees of polarization and coercivity that change with the volume fraction of the hard magnetic phase and the chemical composition of the metal base and of the Nd-Fe-B based powder. Unique combinations, such as Nd-Fe-B with gold to form 18kt magnetic gold, extend the use of magnets in domains where there are currently marginal, such as jewelry and watchmaking.

Innovative Aspect(s) :
We have combined a wide range of metals with Nd-Fe-B to create novel composites that have never been produced. Unique combinations such as the ones with gold, silver, bronze and even high melting point metals such as molybdenum are possible. Data and materials that have never been produced before are here presented.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764739

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Functional Materials

Author : Ms Köhler Marie Luise (Institute for Materials Applications in Mechanical Engineering, RWTH Aachen University, Germany)

Co-author(s) : Mr Norda Michael, Prof Dr Petzoldt Frank (Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM, Germany), Dr Ing Herzog Simone, Dr Ing Kaletsch Anke, Prof Dr Broeckmann Christoph (Institute for Materials Applications in Mechanical Engineering, RWTH Aachen University, Germany)

Title : Particle-reinforced Tool Steels Through Powder Additivation In Laser-based Powder Bed Fusion

Keyword(s) :
Laser-Based Powder Bed Fusion; Powder Blend; Carbides; Tool Steel; Isotropic Microstructure

Abstract :
Laser-based powder bed fusion (LPBF) is still rarely applied due to the limited range of available alloys. Powders of carbide containing tool steels have a low weldability and a high cracking tendency during processing. Additivation of an easily processable steel with high-melting carbides in the powder feedstock enables a higher carbide content in the alloys without affecting the processability. In this study, AISI H13 base steel was additivated with 5 wt.-% edged TiC. TiC remain as partially unmolten particles within the steel matrix and enhance macro hardness and wear resistance of the alloy while enabling a stable processing of crack-free alloys. Supplementary in-depth microstructure analysis by EBSD and texture analysis were performed and a shift toward isotropic microstructures was observed. The TiC act as nucleation sites for equiaxed grain growth during solidification, which eliminates the typical epitaxial grains in building direction and potentially reduces the anisotropy of mechanical properties.

Innovative Aspect(s) :
Powder blends have gained significant interest in research over the last few years. However, the focus has always been laid upon complete homogenization of the melt and less on particle reinforcement possibilities. Carbides in AM materials are usually very fine, limiting the application for abrasive wear environments. The novel approach offers the potential of good processability combined with enhanced carbide contents and resistance against abrasive wear.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765269

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Functional Materials

Author : Prof Dr Weißgärber Thomas (Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM & Technische Universität Dresden, Germany)

Co-author(s) : Dr Ing Studnitzky Thomas, Dipl-Ing Scheibler Jakob (Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM, Germany)

Title : Lithography Based Manufacturing Of Near Net Shape Dispersion Strengthened Copper Parts By Cuprous Oxide Reduction

Keyword(s) :
Metal AM; Dispersion Strengthening; Copper; Non Ferrous Materials; Highly Conductive Materials; Functional Materials

Abstract :
Dispersion strengthening of copper enables the combination of high strength and high conductivity. However, production of dispersion strengthened materials is complex and only yields semi-finished products. The following work presents a new approach based on cuprous oxide as matrix with dispersed Alumina. Powder mixtures are printed into a near net shape part via Lithography-based Metal Manufacturing. After debinding, cuprous oxide is reduced to copper in a hydrogen sintering atmosphere. Furthermore, the influence of milling the powder mixtures is investigated with samples produced by film drawing. Characterization includes scanning electron microscopy, Vickers hardness, and electrical conductivity measurements.Electrical conductivity reaches values of up to 78 % IACS. Vickers hardness surpasses pure copper, however, falls short of comparative values from the literature for dispersion strengthened materials. Reasons for that are insufficient densification and suboptimal dispersoid distribution. Optimization of densification and dispersoid distribution should be investigated in further studies.

Innovative Aspect(s) :
Additive Manufacturing of dispersion strengthened copper Complex near net shape dispersion strengthened parts Manufacturing of metal parts by reducing a metal oxide green part.

Reviewer's name : ……………………………………………………………………………………………….

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : ……………………………………………………………………………….

Notes to author : ……………………………………………………………………………………………….

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Paper Number : EP235765316

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Functional Materials

Author : Mr Sota Angel (CEIT-BRTA, Spain)

Co-author(s) : Dr Burgos Nerea, Dr Martin Jose Manuel (CEIT-BRTA, Spain), Dr Zhukova Valentina, Dr Ipatov Mihail, Dr Gonzalez Julian (UPV|EHU, Spain), Mr Osinalde Mikel (ELESA, Spain)

Title : Improvement Of The Magnetic Properties Of Powder Cores By Optimizing The Volume Fraction Of Amorphous Material

Keyword(s) :
Amorphous; Soft Magnetic Material; Electrical Insulator Coating; Core Loss; Density

Abstract :
Nowadays, new electromagnetic devices are developed in a wide frequency range application to cover technologies needs in high value sectors as automation, medical, electrical machines, aeronautic and more. Between these devices stand out those which work at high frequency operations, where high resistivity soft magnetic materials are employed to reduce Eddy current losses induced in AC electrical process.In this work, gas atomization is employed to obtain spherical amorphous powders with different compositions. As amorphous materials are very hard and brittle, conventional cold press consolidation of the magnetic powder after mixing with a polymeric binder resulted in a low density compact, thus limiting the maximum values of some magnetic properties, such as the saturation magnetization. To minimize this problem, powders with two different particle sizes were selected and mixed in a specific volume percent that maximizes spherical particles packing and the compact density.

Innovative Aspect(s) :
Nowadays, the use of electrical devices such as inductors, rotors and transformers is rising. Iron-silicon electrical sheet is the most common material for these applications due to its high magnetic saturation, high permeability, and good mechanical properties. However, its low electrical resistivity produces high power loss due to eddy currents at medium-high frequencies. Amorphous composites are a promising candidate to substitute the electrical steel at high frequency range.Amorphous composites have some drawbacks such as low permeability and low density. In this work, new amorphous composite with polymer bonding has been developed. Different particles sizes were mixed in a specific volume percent to increase compact density and then magnetic saturation. Also, stress relieved of amorphous powder has been carried out by heat treatment, reducing coercivity and power loss.

Reviewer's name : ……………………………………………………………………………………………….

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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Paper Number : EP235765357

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Functional Materials

Author : Dr Sarriegui Gabriela (CEIT-BRTA, Spain)

Co-author(s) : Dr Sarriegui Gabriela, Dr Martin José Manuel, Dr Burgos Nerea, Dr Urionabarrenetxea Ernesto (CEIT-BRTA, Spain), Dr Ugalde Gaizka, Dr Eguren Imanol (Mondragon Unibertsitatea, Spain)

Title : Short-loop Recycling Of NdFeB Scrap By Gas Atomization

Keyword(s) :
NdFeB Alloys; Gas Atomization; Recycling; Bonded Magnets; Magnetic Properties; Hard Magnetic Materials

Abstract :
In this work, it is presented a direct metallurgical route for the recycling of end-of-life (EoL) sintered NdFeB magnets to produce competitive bonded magnets. Three different grades of scrap, classified according to the total content of heavy rare earth elements, were converted into fresh recycled NdFeB powder by gas atomization. Several atomizations with He and Ar were conducted to produce isotropic spherical powders. The use of He as atomizing gas resulted in higher cooling rates and, thus, finer and almost fully amorphous particles. After proper annealing, the powder exhibited a greater improvement in magnetic properties. Laboratory specimens were produced by compression molding using an epoxy resin as bonding phase. The magnetic, mechanical and physical characterization of the bonded NdFeB recycled magnets confirm that gas atomization is a suitable process for recycling NdFeB scrap.

Innovative Aspect(s) :
Nowadays, there is a need for a stable supply of raw materials and lower cost magnets to meet the increasing demand. The main need of manufacturer end users is a European alternative source of bonded NdFeB magnets with competitive prices and fulfilling their performance specifications. Gas atomization is a highly productive industrial process that could be used as the starting process for the production of recycled powder. The manufacturing process of the recycled powder does not include any milling step, which typically produces material losses. Consequently, the use of gas atomization will contribute to the production of cheaper recycled powder and make it feasible to develop in a short term.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765549

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Functional Materials

Author : Dr Ing Poskovic Emir (Politecnico di Torino, Italy)

Co-author(s) : Ing Ceroni Marta, Ing Franchini Fausto, Prof Ferraris Luca, Prof Dr Actis Grande Marco (Politecnico di Torino, Italy), Dr Sangregorio Claudio (Institute for the Chemistry of OrganoMetallic Compounds, Italy), Prof Caneschi Andrea (Università di Firenze, Italy)

Title : The Implementation Of A Novel Approach To The Rare Earth Magnets Recycling

Keyword(s) :
Rare Earth Magnets Recycling; NdFeB Magnets; Bonded Magnets; Innovative Process

Abstract :
Rare Earth magnets have been used in different industrial sectors: household utilities, automotive applications, informatics sensors, etc. Rare Earth magnets show the best magnetic performance, predominantly in the case of Neodymium magnets. However, the economic aspect concerning the raw magnetic materials affects many of the magnet devices, mainly considering the instability of the raw material market. For these reasons, recycling NdFeB magnets is considered a promising solution. Different techniques are available, but they are generally expensive or very dangerous. This work proposes a new approach to recycling the NdFeB sintered magnets using a particular mechanical technique without using Hydrogen, resulting in a safer, less complicated and cheaper process than chemical methods. Based on an impact mill, the process has been performed to grind the magnets recovered from the hard disks. The operation was conducted in vacuum. Finally, some bonded magnets with recycled powder have been prepared and characterized.

Innovative Aspect(s) :
Many methods to recover the NdFeB powder from different devices have already been proposed, usually based on Hydrogen, such as Hydrogen decrepitation (HD) or hydrometallurgical methods, and alternatively chemical processes. All these processes show drawbacks, and their industrial scale-up is challenging and expensive. This work proposes a new approach to recycle the NdFeB sintered magnets using a particular mechanical technique without using Hydrogen, resulting in a safer, less complicated and cheaper process than chemical methods. Based on an impact mill, the mechanical process has been performed to grind the magnets recovered from the hard disks. The operation was conducted in a vacuum. Finally, some bonded magnets with recycled powder have been prepared and characterized.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764617

Requested presentation type : Poster Presentation

Topic : Materials **Subtopic :** Functional Materials

Author : Dr Heo Sung Gue (Korea Institute of Industrial Technology, Korea, Republic of)

Co-author(s) : Mr Lee YongKwan, Mr Sim Jae-Jin, Prof Oh Soong Ju, Dr Park Kyoung-Tae, Dr Seo Seok-Jun (Korea Institute of Industrial Technology, Republic of Korea)

Title : Effect Of Vacuum Annealing On Mesoporous Copper Cobalt Oxide($CuCo_2O_4$) For Supercapacitors

Keyword(s) :
Mesoporous; Copper Cobalt Oxide; Inverse Micelle; Supercapacitor; Vacuum Heat-Treatment

Abstract :
Mesoporous $CuCo_2O_4$ is interesting material for electrodes of high-performance supercapacitors because of their high surface area, controlled porosity and excellent electrochemical properties. In this work, mesoporous $CuCo_2O_4$ powders were synthesized using inverse micelle method and analyzed by X-ray diffraction(XRD), Brunauer-Emmett- Teller analysis(BET), transmission electron microscopy(TEM), and X-ray photoelectron spectroscopy(XPS). The mesoporous $CuCo_2O_4$ powders after additional heat-treatment at 250°C in vacuum atmosphere exhibited high specific surface area of 114cm2|g with pore size of 8nm. The mesoporous $CuCo_2O_4$ electrodes achieved maximum specific capacitance of 140 Fg-1 in 6M of KOH electrolyte. The capacitance retention was 91.4% after 3000 cycles at 1Ag-1. This superior electrochemical supercapacitor property is mainly due to increased surface area.

Innovative Aspect(s) :

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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Paper Number : EP235766656

Requested presentation type : Poster Presentation

Topic : Materials **Subtopic :** Functional Materials

Author : Dr Ing Tomiczek Blazej (Silesian University of Technology, Poland)

Co-author(s) :

Title : Development Of Maraging Steel-copper Composite Produced By Selective Laser Melting And Pressure Infiltration

Keyword(s) :
Selective Lase Melting; Gas-Pressure Infiltration; Maraging Steel; Copper; Composite

Abstract :
The main aim of the research was to develop a steel-copper composite with increased thermal conductivity for tools for plastics processing. In the first stage, samples of maraging 18Ni300 steel with microchannels of a specific geometry were produced by the selective laser melting method. The SLM process parameters were selected mainly regarding the maximum degree of densification. The research work carried out proved that with such selected parameters, it is possible to produce channels with a diameter exceeding 300 μm. A pre-vacuum gas-pressure infiltration was chosen among the known types of infiltration methods. Regardless of the infiltration pressure, all porous shapes were filled with liquid copper in the entire volume, and the composite materials produced in this way achieved full densification. The wettability and reactivity of the connection were determined based on microstructural tests carried out by optical and scanning electron microscopy.

Innovative Aspect(s) :
An innovative aspect of the research is developing a hybrid technology for producing steel and copper composite materials using selective laser powder sintering and pressure infiltration. Using the SLM technique, skeletons of maraging steel were made with appropriately designed channels filled with liquid copper thanks to pressure infiltration. The developed materials are characterized by a favourable system of mechanical properties and increased thermal conductivity, allowing them to be used as a tool material for injection moulds used in plastics processing.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

Technical Programme Committee
15th February 2023

MATERIALS

HIGH TEMPERATURE MATERIALS

EPMA
european powder metallurgy association

EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235763879

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** High temperature Materials

Author : Dr Gauthier-Brunet Véronique (Institut Pprime, France)

Co-author(s) : Dr Zuber Axel, Prof Dubois Sylvain (Institut Pprime, France), Dr Roger Jérôme (Laboratoire des Composites ThermoStructuraux, France), Prof Dr Gonzalez-Julian Jesus (Institute of Mineral Engineering, RWTH Aachen University, Germany), Prof Dr Ouisse Thierry (Laboratoire des Matériaux et du Génie Physique, France)

Title : High-temperature Oxidation Of Cr2AlC MAX Phase Produced By Different Powder Metallurgy Routes: Study Of The Relationship Between Microstructure And Oxidation Resistance

Keyword(s) :
MAX Phase; Hot Isostatic Pressing; Spark Plasma Sintering; Microstructure Effect; High-Temperature Oxidation Resistance; Grain Size; Grain Orientation; Roughness

Abstract :
MAX phases are a family of nanolayered carbides and nitrides widely studied for their unique properties cumulating those of ceramics and metals. Cr2AlC is considered as one of the most promising MAX phase for its corrosion resistance properties. In this study, fine and coarse-grained Cr2AlC samples were respectively synthesized using spark plasma sintering and hot isostatic pressing techniques. The operating parameters were varied to optimize the purity and the density of the end-product.Oxidation tests were carried out on polycrystalline and single crystal samples in the temperature range 800-1500 ?C. Thermodynamic calculations were also performed to give further analysis of the experiments and to better understand the oxidation mechanisms. The effect of both the oxidation conditions and the MAX phases microstructural characteristics (grain size and orientation, roughness…) were studied via the observation of the oxide layers morphology, the analysis of the oxidation products and the study of the oxidation kinetics.

Innovative Aspect(s) :
Optimization of the Hot Isostatic Pressing (HIP) operating parameters and optimization of the starting powders characteristics to produce dense and highly-pure Cr2AlC coarse-grained samples.
Comparison of the oxidation resistance of Cr2AlC polycristalline samples (made by powder metallurgy techniques) and single crystals.
Long-term oxidation tests (up to 1000h) under dry air, for temperatures as high as 1500°C.
Clarify the influence of grain size, grain orientation and surface roughness on the oxidation of Cr2AlC- Compare experimental data with thermodynamic calculations to propose an oxidation mechanism.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764049

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** High temperature Materials

Author : Prof Dr Dubois Sylvain (Université de Poitiers, France)

Co-author(s) : Dr Zuber Axel, Dr Brunet Véronique, Prof Dr Coupeau Christophe, Prof Dr Renaut Pierre Olivier (Université de Poitiers, France), Prof Dr Gonzalez Julian Jesus (Aachen University, Germany), Prof Dr Ouisse Thierry, Prof Dr Parry Guillaume (Université Grenoble-Alpes, France)

Title : Evidence For Plastic Deformation Of The Alumina Scale During High Temperature Oxidation Of Cr2AlC

Keyword(s) :
Cr2AlC; Buckling; Plastic Deformation; XRD Strain Measurements; Oxydation

Abstract :
Single-crystal and fine-grained samples of Cr2AlC were oxidized during isothermal oxidation treatment performed under dry air flow at temperature in the 1000-1400°C range during 100 h. A continuous alumina layer forms on top of the Cr2AlC surface whereas a Cr7C3 sublayer also appears. in-lab characterization of oxidized Cr2AlC samples shows that alumina buckles are formed. In-situ XRD measurements under synchrotron radiations were performed to measure the lattice strain during the oxidation process and deduce the stress value in the Al2O3 and Cr7C3 layers. Both layers undergo tensile stress during the isothermal oxidation, showing that the alumina doesn't buckle due to growth stress. During cooling, the tensile stress decreases and compressive stress appears due to the differences in thermal expansion coefficient; buckling of the alumina layer thus occurs. Finally, by coupling those results with finite element calculations allows demonstrating that alumina is plastically deformed.

Innovative Aspect(s) :
Evidence for tensile stress during oxide growth.
Evidence for compressive stress due to mismatch between thermal expansion coefficient.
Characterization of alumina bucklesFinite element calculations.
Evidence for plastic deformation of the alumina scale.

Reviewer's name : ……………………………………………………………………………………………….

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764254

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** High temperature Materials

Author : Dr Dopler Martin (Metalpine GmbH, Austria)

Co-author(s) : Mrs Koell Anna (Metalpine GmbH, Austria)

Title : From Raw Material To 3D-Printed Parts: Ways To Reduce Energy Consumption In LPBF-Processes

Keyword(s) :
Gas Atomization; Linear Stability Analysis; Inconel 718; Layer Thickness; Yield Strength

Abstract :
Additive Manufacturing via Laser Powder Bed Fusion has become an important production route for many materials such as Titanium or Nickel-based alloys. However, energy consumption of the process chain is high. On the one hand, the product yield of the powders is low in relation to the material put into the atomization process, while the necessary inert gas consumption is high. On the other hand, the laser melting process is limited by a combination of powder quality and printing parameters, which also results in a high energy need.In this study, examples are discussed, how energy efficiency throughout the 3D printing process chain can be increased. Amongst others, 3 main examples were identified:- nozzle geometry optimization to increase powder product yield- production parameter optimization to decrease gas consumption- printing parameter optimization to increase printing speed, accompagnied by using perfect powders.For all aspects, theoretical analysis are followed by practical test results.

Innovative Aspect(s) :
The innovation of the paper lies in the identification of the main energy consumers in the whole 3D-printing production. Optimisation steps are examined on the one hand by a theoretical analysis (e.g. linear stability approach for gas atomization), on the other hand we can also show practical achievements (higher product yield by nozzle optimization, high strength of the printed part despite doubling layer thickness, etc.)Hence, new ways can be suggested to optimise the energy efficiency of the whole process chain.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764657

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** High temperature Materials

Author : Mr Ariza Galván Enrique (RHP-Technology GmbH, Austria)

Co-author(s) : Mr Curti Pier Paolo, Dr Neubauer Erich (RHP-Technology GmbH, Austria), Dr Bača Ľuboš, Dr Ing Scheerer Michael, Dr Stelzer Nils (Advanced Aerospace and Composites GmbH, Austria)

Title : Improvement Of Thermal Mechanical Properties Of Inconel 718 Reinforced With Ceramic Particles Manufactured By Plasma Metal Deposition (PMD)

Keyword(s) :
Additive Manufacturing; Plasma Metal Deposition; Nickel Alloy; Mechanical Properties

Abstract :
Nickel superalloys due to their good thermal mechanical properties and corrosion resistance are widely used for high performance on high demanding applications and industries as space, aviation or (petro-) chemistry. Moreover, the processing of this material class is costly due to the raw material and problems related to traditional processing techniques as casting, forging or milling (hot cracking, porosity, work hardening or wear on milling tools).Within this study the alloy Inconel 718 is processed with Plasma Metal Deposition (PMD®), an additive manufacturing process with high deposition rates for large part production. Additionally, the alloy is reinforced with ceramic Al_2O_3 particles that improves the mechanical properties at high temperatures. The weldability is studied. To assess the performance test coupons are investigated and analysed with respect to the mechanical properties.

Innovative Aspect(s) :
This work aims to demonstrate the use of the Plasma Metal Deposition as an additive manufacturing Direct Metal Deposition technology using nickel-chromium super alloys powder feedstock reinforced with ceramic particles and compare the thermal mechanical properties with the standard alloy.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764980

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** High temperature Materials

Author : Mrs Carbajales Hernández Rita (University Carlos III of Madrid, Spain)

Co-author(s) : Dr Sobrino Fernández Celia, Dr Alvaredo Olmos Paula (University Carlos III of Madrid, Spain), Dr Lagos Miguel Angel (Tecnalia, Spain)

Title : Influence Of The Fabrication Process On The Corrosion Behavior Of Two High Entropy Alloys In Molten Solar Salt

Keyword(s) :
High-Entropy Alloys; Molten Salts; Corrosion; Arc Melting; Spark Plasma Sintering (SPS); Electrical Resistance Sintering (ERS); Concentration Solar Power (CSP) Plants

Abstract :
Heat storage in molten mineral salts is one promising option in energy conversion technologies, with concentration solar power (CSP) plants being the main exponent. However, the compatibility between molten salts and structural alloys has been of real concern due to corrosion problems. In the present work, the corrosion resistance in molten solar salt (40 wt.% KNO3|60 wt.% NaNO3) of two HEAs, one of original composition, FeCrMoAlTiNi, and one of eutectic composition, AlFeCrCoNi, is studied and compared with the SS316, an alloy used in CSP plants. In order to understand the variation of corrosion resistance with microstructure, the HEAs were processed by advanced fast and ultrafast techniques, Spark Plasma Sintering (SPS) and Electrical Resistance Sintering (ERS) and compared with samples processed by arc melting. The results obtained by Electrochemical Impedance Spectroscopy (EIS) confirm the promising use of HEA in applications in extreme environments.

Innovative Aspect(s) :
Hot corrosion is a problem that can implicate the reduction of the service life of engineering components. Accumulating heat in molten mineral salts is one of the options in energy conversion technologies that is proving to be operative. However, the compatibility between molten salts and the structural materials has been of real concern due to the corrosion problems. Although high entropy alloys are widely studied, there are little works on their behaviour under extreme conditions. In this work, the behaviour of an alloy of an original composition and a eutectic alloy processed by different techniques is studied. As already seen in other works, the manufacturing technique used in these alloys is key to achieve a homogeneous microstructure and for this reason the resistance to hot corrosion in samples processed by arc melting, and two fast and ultra-fast sintering techniques, SPS and ERS, are compared.

Reviewer's name : ……………………………………………………………………………………………….

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764983

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** High temperature Materials

Author : Dr Ing Mohammadzadeh Ahad (IMDEA materials, Spain)

Co-author(s) : Dipl-Ing De Nardi Alessandro (IMDEA materials, Spain), Dr Ing Omidbakhsh Faraz (Islamic Azad University, Tabriz Branch, Tabriz, Iran, Iran), Dr Ing Mostafaei Amir (Illinois Institute of Technology, 10 W 32nd Street, Chicago, IL, 60616, USA, USA), Prof Dr Torralba Jose Manuel (IMDEA materials, Spain)

Title : Additively Manufactured Novel CoNi-based High Entropy Superalloy

Keyword(s) :
High Entropy Superalloys; Laser Powder Bed Fusion; Process Optimization; Thermodynamic Modeling; Microstructure

Abstract :
A novel CoNi-based high entropy superalloy has been developed for fusion-based additive manufacturing processes based on high entropy alloy concepts. A multi-component compound (Co-35Ni-8Al-4Ti-4V-2W-2Ta-9Cr) was prepared via gas atomization. A comprehensive study was conducted to establish a process-structure relationship in laser powder bed fusion processed CoNi superalloy powder. The effect of processing parameters, including laser power and scan speed on part characteristics, was studied using the Design of Experiment approach based on the Response Surface Methodology. Numerical models validated by experimentation were used to develop a process window to attain parts with a relative density of >99.9%. Advanced electron microscopy incorporated with phase analysis and hardness measurement were used to observe grain structure and texture, defects, phase evolution, and mechanical behavior. It was concluded that thermodynamic predictions were in good agreement with microstructure analysis to attain a single-phase fcc solid solution in the powder and as-built coupons.

Innovative Aspect(s) :
Developing eight component CoNi based high entropy superalloy with a single-phase fcc microstructure. Production of the designed HESA powder via gas atomization. Consolidation of the developed powder by means of laser powder bed fusion approach. Validation of the thermodynamic predictions by advanced microscope analyses.

Reviewer's name : ....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : ....

Notes to author : ....

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765329

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** High temperature Materials

Author : Dr Sporer Dieter (Oerlikon Surface Solutions AG, Switzerland)

Co-author(s) : Mr Bautmans Ludo (Oerlikon Eldim B.V., Netherlands), Mr Beretta Davide (Georg Fischer Additive, Switzerland)

Title : Optimization Path For LB-PBF Manufactured Structures Of Inconel 738 LC

Keyword(s) :
Additive Manufacturing; Spherical Powder Material; Laser Beam Powder Bed Fusion; LB-PBF; Inconel 738LC Type; Crack Density; High Temperature Tensile and Stress-Rupture; Grain Structure for Use at High Temperature

Abstract :
Inconel 738LC is a superalloy with a high content of gamma prime precipitates to improve high temperature creep strength. This type of material is difficult to process in Additive Manufacturing by Laser Based Powder Based Fusion (LB-PBF) due to its inherent tendency to form microcracks during the laser processing. This paper reviews a systematic approach to mitigate the crack formation in 738 type compositions for LB-PBF by varying the alloy chemistry and the processing conditions. Further the creation of a commercial supply chain for components will be presented by transferring an optimized chemical composition into a commercial production environment including the necessary heat treatments that are required not only to perform a solutioning and precipitation treatment for the alloy but also to coarsen the grain structure which is inherently fine compared to castings

Innovative Aspect(s) :
Optimized chemistry for 738LC for Additive ManufacturingReduction of crack densities during LB-PBF processingOptimized HT procedureHigh temperature properties up to 927 °CTransfer of optimization into a commercial component manufacturing environment.

Reviewer's name : ....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : ....

Notes to author : ....

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765478

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** High temperature Materials

Author : Mr Mejía Reinoso Alexander (Universidad Carlos III de Madrid, Spain)

Co-author(s) : Dr Tan Qing, Dr Saksena Aparna, Dr Gault Baptiste (Max-Planck-Institut für eisenforschung GMBH, Germany), Dr Campos Gomez Mónica (Universidad Carlos III de Madrid, Spain), Dr Torralba José Manuel (IMDEA Materials, Spain)

Title : Powder Metallurgy Processing And Characterization Of Low Density Co-based Superalloys

Keyword(s) :
Co-Based Superalloys; Powder Metallurgy

Abstract :
Ni-based superalloys are widely used for high-temperature applications but their ?’-solvus temperature is close to their melting points. The Co - Al - W superalloys come up as an alternative but drawbacks such as low ?’-solvus temperature, and high density opened the field to low-density Co-based superalloys. This work has achieved a stable ?|?’ microstructure in three viable alternatives Co – 5Ti – 15V, Co – 10Al – 5Mo – 2Ta and Co – 10Ni – 5Al – 3Ta – 2Ti – 3V where the ?’-solvus temperature and volume fraction were enhanced. The alloys were processed by Spark Plasma Sintering (SPS) improving their microstructure by solution and aging treatments. Partitioning of alloying elements on ?|?’ phases was studied by Atom Probe Tomography (APT) and their mechanical properties at high temperatures were determined by performing heat compression and small punch creep tests.

Innovative Aspect(s) :
Due to the lack of strengthening mechanisms that are as effective as the L12-ordered γ' precipitates in Ni-based superalloys, traditional Co-based alloys has a limited used. In 2006, Sato et al. discovered Co-based superalloys, based on the ternary Co-Al-W system, with γ'-Co3(Al,W) precipitates with a coherent L12-ordered structure. Since Co has a higher melting point than Ni (1495 vs. 1455°C), these new superalloys have great potential to beat the high-temperature performance of existing Ni-based superalloys. This has generated extensive research and development interest in the design of Co-based alloys containing high volume fractions of γ' (~80%) and high solidus and liquidus temperatures (~150°C higher than those of Ni-based alloys). This research focuses on the replacement of part of the W by various γ' -forming elements and study their microstructre evolution by cutting edge techniques.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765533

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** High temperature Materials

Author : Mr Masari Facundo (Universidad Carlos III de Madrid, Spain)

Co-author(s) : Dr Hernandez Pascual Rebeca (Centre for Energy, Environmental and Technological Research (CIEMAT), Spain), Prof Dr Torralba Castello Jose Manuel (IMDEA Materials Institute, Spain), Prof Dr Campos Gomez Monica (Universidad Carlos III de Madrid, Spain)

Title : Design Of Alumina Forming Martensitic Steels For Power Generation Systems By Powder Metallurgy

Keyword(s) :
FeCrAl Alloys; Oxidation; Alloy Design; Additive Manufacturing; Alumina Forming Steels

Abstract :
Increasing the operating pressure and temperature of power plants is one method to increase their efficiency and hence lower CO2 emissions. The materials employed define the maximum operating parameters of a plant, ergo, it is crucial to develop new materials to raise its working conditions. Currently, alumina-forming austenitic steels), alloys vulnerable to stress corrosion cracking and irradiation swelling, are one of the materials used for temperatures about 750°C. A novel type of material is proposed, alumina-forming ferritic-martensitic steels, which have superior corrosion and swelling resistance. Advanced fabrication techniques like field-assisted sintering and selective laser melting are explored to achieve different microstructures, starting from pre-alloyed atomized powders. These microstructures were studied with SEM and TEM among other techniques, and the mechanical behaviour was observed at temperatures up to 700°C with small punch tests. Finally, corrosion tests were conducted at temperatures of 800°C and 1200°C for 500 and 8 hours, respectively.

Innovative Aspect(s) :
This is a new type of stainless steel, entirely developed by PM and especially targeted toward high-temperature applications. The formation of an alumina layer, different from the chromium oxide layer formed in standard stainless steel, is an alternate method of preventing oxidation. To maximize the ability to create alumina and obtain the desired microstructure, three distinct alloys with various Cr|Ni contents are proposed. Two advanced fabrication techniques are compared, field-assisted sintering and selective laser melting, to achieve the desired microstructure. These novel stainless steels were created to meet the needs of power plants, but they can also be used in a variety of other applications.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765551

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** High temperature Materials

Author : Mr Ribeiro Bernardo (LAETA|INEGI - Institute of Science and Innovation in Mechanical and Industrial Engineering, Portugal)

Co-author(s) : Dr Ing Santos Rúben, Dr Ing Sequeiros Elsa (LAETA|INEGI - Institute of Science and Innovation in Mechanical and Industrial Engineering, Portugal), Dr Ing Barbosa Maria (Faculty of Engineering - University of Porto, Portugal)

Title : Alloying Effect On The Mechanical And Microstructural Properties Of Rheas Based On The System MoNbTaWX (X=Al|Ti|V)

Keyword(s) :
CALPHAD; Direct Energy Deposition; Mechanical and Microstructure Characterization; MoNbTaWX; RCCAs; RHEAs

Abstract :
In recent years, High Entropy Refractory Alloys (RHEAs) have been presented as possible alternatives to the state-of-art Ni-Superalloys, due to an outstanding combination of properties under high-temperature service conditions. The MoNbTaW system has been particularly explored due to its yield strength above 500 MPa at 1200 °C. Yet, these alloys present a brittle behavior at room temperature, narrowing their applications. To improve the MoNbTaW properties, in-situ alloying with additions of X=Al|V|Ti by Direct Energy Deposition (DED) assisted by thermodynamical simulations (CALPHAD) has been explored to accelerate the screening of promising compositions. In this contribution, we will present the room temperature microstructural and mechanical characterization to evaluate the influence of the alloying elements on ductility while guaranteeing a structure that allows a high yield strength at high temperatures.

Innovative Aspect(s) :
Combustion processes in aerospace and aeronautical would be more efficient, consuming less fuel and reducing CO2 emissions, if they could operate at higher temperatures. In this way, the main innovative aspect of this study is to increase the practical knowledge of RHEAs|RCCAs, accelerating the screening process through the combination of thermodynamical simulations and high-throughput processes such as DED. By these means, it is possible to evaluate a higher number of compositions of the system MoNbTaWX, discovering new strong RCCA candidates to surpass the state-of-art Ni-Superalloys, allowing the possible increase of efficiency of the combustion processes mentioned before. This work is part of the LiRAs project (FCT exploratory project) on high-throughput screening and development of RHEA|RCCAs alloys. This project explores new RCCAs.

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Paper Number : EP235753737

Requested presentation type : Poster Presentation

Topic : Materials **Subtopic :** High temperature Materials

Author : Dr Shulga Andrey (National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), Russia)

Co-author(s) :

Title : Analysis Of Boron Behavior In The High-temperature Ni-based PM HIP Superalloys By The Use Of A Firstly Proposed TTT Diagram

Keyword(s) :
Ni-Based Superalloys; PM HIP Technology; Rapidly Quenched PREP Powder; Boron; TTT Diagram; Carbon; Autoradiography; Microstructure; High Temperature Tensile and Compression Tests

Abstract :
Based on the results of a multiscale experimental study of the behavior of boron, carbon, and microstructure of HIP PM compacts of the high temperature Ni-based superalloys, during various heat treatments, as well as tensile and compression tests, performed in particular by the method autoradiography, was constructed the firstly proposed TTT diagram. Study of boron and carbon behavior in relation to microstructure was carried out by direct methods track autoradiography on boron and activation autoradiography on carbon, metallography, SEM, EDX, OIM methods. Formation of solid solution of boron, segregation of boron, and precipitation of borides, in particular, along grain boundaries as a result of heat treatment of compacts, have been revealed and analyzed. Therefore, the temperature-time conditions for the precipitation of the boride phase were determined as the main parameters of the proposed TTT-diagram of the boride phase in comparison with the TTT-diagrams of the carbide and gamma-prime phases

Innovative Aspect(s) :
High-temperature Ni-based superalloys and austenitic stainless steels for traditional, PM HIP, and AT technologies are characterized by the presence of important microalloying interstitial elements: carbon and boron.At present, only TTT-diagrams for carbide and gamma-prime phases have been constructed, which are used to optimize heat treatment parameters.The lowest content of boron and the experimental difficulty of detecting boron are the main reason for the absence of a TTT diagram for borides.High sensitivity direct nuclear method of track autoradiography on boron together with LM, SEM, OIM methods were used for revealing formation of boron solid solution, boron segregation and boride precipitation in the HIP PM compacts of the high temperature Ni-based superalloy. The temperature-time conditions for the precipitation of the boride phase were determined and TTT-diagram of the boride phase was proposedTTT-diagrams are useful for better understanding of phase transformation kinetics and optimization of heat treatment

EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235782977

Requested presentation type : Poster Presentation

Topic : Materials **Subtopic :** High temperature Materials

Author : Mrs Wrona Adriana (Łukasiewicz Research Centre- Institute of Non-Ferrous Metals, Poland)

Co-author(s) : Mrs Czech Anna, Mr Lis Marcin, Mr Mazur Jacek, Mr Pecak Krzysztof (Łukasiewicz Research Centre- Institute of Non-Ferrous Metals, Poland), Mr Kukofka Adrian (Progresja New Materials Sp. z o.o., Poland)

Title : Rhenium-Modified Spherical Molybdenum Powders For Additive Technologies

Keyword(s) :
Molybdenum; Rhenium; Spherical Powders; Plasma Spheroidization; Additive Technologies

Abstract :
One of the problems of the AM technology market is low availability of powder materials, particularlythe high-melting ones. On the other hand, due to the characteristics of this materials, it is difficult toobtain printouts with optimal density and a small number of cracks. There are many ways to avoidthese types of problems. One of them is input materials modification. The paper presents a solutionusing the phenomenon called "the rhenium effect", based on molybdenum powders modification withrhenium. Different processes of thermal reduction and plasma spheroidization were used. Physicalproperties, microstructure, homogeneity, chemical and phase composition of produced powders wereinvestigated.

Innovative Aspect(s) :
The use of plasma technologies in production of high-melting spheroidal powders for additive technologies.

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EURO PM2023 CONGRESS & EXHIBITION

Technical Programme Committee
15th February 2023

MATERIALS

OTHER PM MATERIALS

european powder metallurgy association

EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235746379

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Other PM materials

Author : Dr Jahangiri Hadi (Koç University, Turkey)

Co-author(s) : Mr Asghari Alamdari Armin, Prof Unal Ugur, Dr Motallebzadeh Amir (Koç University, Turkey),

Title : Development And Characterization Of CoCuFeNiMnMox (x=0.5, 1.0, And 1.5) High Entropy Alloys Prepared By Mechanical Alloying And Spark Plasma Sintering Method

Keyword(s) :
High-Entropy Alloy; Spark Plasma Sintering; Mechanical Alloying; Nanoindentation

Abstract :
In this investigation, CoCuFeNiMnMox (x=0.5, 1.0, and 1.5) high entropy alloys (HEA) were prepared by mechanical alloying followed by spark plasma sintering (SPS) at 850 °C temperature. The powders were produced by high energy ball milling (HEBM) after 20 h with a speed of 400 rpm. SPS was performed at 850 C with a uniaxial pressure of 55 MPa. The heating rate was 100 C|min up to 850 C. The maximum temperature and pressure were held for 3 min, before allowing the furnace to cool down. The phase and microstructure of the as-sintered samples were studied by SEM and XRD and the effect of Mo amount alteration was studied. More addition, TOPAS 4.2 was employed for the phase fraction calculation by Rietveld refinement analysis of XRD spectra. Following the microstructural analysis of the as-sintered mechanical properties including hardness, modulus of elasticity, and stress-strain response were measured using the nanoindentation method.

Innovative Aspect(s) :
CoCuFeNiMnMox (x=0.5, 1.0, and 1.5) high entropy alloys (HEA) were prepared by mechanical alloying followed by spark plasma sintering for the first time.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235756908

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Other PM materials

Author : Dr Wimbert Lars (GKN Powder Metallurgy Engineering GmbH, Germany)

Co-author(s) : Dr Lindsley Bruce, Mr McQuaig Kylan (Hoeganaes Corporation, USA)

Title : Introduction Of Advanced Lubricants Into Serial Production Processes

Keyword(s) :
PM Lubricants; Compaction; Powder Blending

Abstract :
Modern compaction lubricants must address a wide range of key properties through the entire powder metallurgical process flow. These include not only compaction density requirement but also the ability to mix uniformly at scale, good powder flow and fill in powder premixes, ejection, compaction as well as clean burn-off during sintering. Modern lubricant developments, such as AncorLube LV, provide excellent processability in all process steps and are far more clean-burning and environmentally friendly as previous materials. This lubricant has now been used in several production settings and new applications for an extended period with positive results. The benefits and opportunities of using advanced lubricants will be discussed in this paper for various parts geometries and powder compositions with respect to the whole PM process chain.

Innovative Aspect(s) :
After sucessfull lab-scale development of a new compaction lubricant this paper documents the impact of the improved material on several serial production processes. The manuscript aims to give a comprehensive overview about all relevant processes from powder blending to sintering and the impacts of the new lubricant on process robustness and parts quality.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235762930

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Other PM materials

Author : Mr Valsecchi Giorgio (TAV VACUUM FURNACES, Italy)

Co-author(s) : Mrs Mortalò Cecilia, Mrs Deambrosis SIlvia Maria, Mr Montagner Francesco, Mrs Zin Valentina, Mr Miorin Enrico (National Research Council of Italy - CNR Institute of Condensed Matter Chemistry and Technologies for Energy – ICMATE, Italy), Mrs Fabrizio Monica (CNR Engineering ICT and Technologies for Energy and Transportation Department, National Research Council of Italy, Italy), Mrs Colombini Elena, Mrs Lassinantti Gualtieri Magdalena, Mr Veronesi Paolo (Department of Engineering "Enzo Ferrari", University of Modena and Reggio Emilia, Italy)

Title : Conventional Powder Metallurgy Process To Synthetize Multi Principal Element Alloys

Keyword(s) :
Multi Principal Element Alloys; MPEA; High Entropy Alloys; HEA; Sintering; Vacuum Furnace; Vacuum Sintering

Abstract :
Multi-principal element alloys (MPEAs) have drawn the attention of many research and industrial fields, thanks to their extraordinary properties including high strength, toughness, wear resistance, fatigue resistance and corrosion resistance. However, the fabrication of MPEA parts with desired microstructures and properties using conventional powder manufacturing techniques is still challenging. This work focuses on the development of a simple powder metallurgy route, including cold uniaxial pressing of powder mixtures followed by pressureless vacuum sintering, for the preparation of cylindrical samples and sputtering targets made of FeNiCrMn, FeNiCrCo and FeNiCrCo +10%wt. Al. Green pellets were heated up to 400°C in high vacuum and then under Ar atmosphere up to selected sintering temperatures, i.e. 1200°C and 1300 °C.Relative densities (RD) of the green and sintered samples were determined and discussed. Finally, the microstructure of the sintered targets was evaluated using a scanning electron microscope (SEM) equipped with an energy-dispersive X-ray spectroscope (EDS).

Innovative Aspect(s) :

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764645

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Other PM materials

Author : Dr Ing Kovacova Zuzana (RHP-Technology GmbH, Austria)

Co-author(s) : Dr Stelzer Nils, Dr Baca Lubos, Dr Merstallinger Andreas (Aerospace & Advanced Composites GmbH, Austria), Dr Toufine Alain (OPTÁLM Additive Manufacturing Options, France), Dr Makaya Advenit (ESTEC, Netherlands), Dipl-Ing Kitzmantel Michael, Dr Neubauer Erich (RHP-Technology GmbH, Austria)

Title : Assessment Of Bulk Metallic Glasses (BMGs) Manufactured By Powder Based Methods

Keyword(s) :
BMG; Amorphous Metals; Additive Manufacturing

Abstract :
BMGs represent an interesting class of materials for structural and functional applications. Due to their extraordinary properties such as ultra-high strength, high hardness, soft magnetic properties along with a high corrosion and wear resistance they can be used in a wide range of applications.Within this study, the manufacturing of Zr-based amorphous alloys (AMZ4 and VIT105) using atomised powders but also mechanically alloyed powders have been investigated. The processability of starting powders by hot-pressing as well as by additive manufacturing methods (laser melting deposition and plasma metal deposition) was studied. Materials were characterised with respect to XRD analysis, microstructure and corrosion resistance. Although the individual processing routes were quite challenging, it was possible to prepare fully amorphous samples. While additional future work is required to remove the residual porosity, the present results contribute to the development of Zr-based bulk metallic glasses parts with complex geometry via powder based methods.

Innovative Aspect(s) :
Typically liquid phase processing (melting+quenching) show certain limiations in the size of components which can be manufactured. Therefore, within this study various powder based processing techniques have been assessed in order to allow to form metallic glasses with larger geometrical dimensions. In addition, possible applications have been identified.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765118

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Other PM materials

Author : Dr Quilter Connor (University of Liverpool, United Kingdom)

Co-author(s) : Dr Head Michael, Prof Black Kate (University of Liverpool, United Kingdom), Dr Neveu Aurélien, Mr Francqui Filip (Granutools, Belgium)

Title : Iron Ore As A Suitable Candidate For AM: Relation Between Rheology And Spreadability

Keyword(s) :
Iron Ore; Spreadability; Rotating Drum; Rheology

Abstract :
Powder bed-based methods are common in additive manufacturing (AM), where successive thin layers are created using a ruler or rotating cylinder. The homogeneity of the layers determines the mechanical quality of the built parts. However, the layer quality is directly related to the spreading properties of the feedstock, which relies mainly on the cohesiveness and rheology of the powder. Despite wide availability, iron ore has never been considered a suitable feedstock material for AM. If a viable iron ore feedstock could be produced for AM, it would enable the manufacture of bespoke agglomerates which could be used in blast furnaces to produce steel. This could reduce the thermal budget and considerably lower CO_2 emissions in the steel sector.In this study, the spreadability of iron ore powders has been evaluated in a binder jet printer and correlated with its flowability and rheological properties evaluated in a rotating drum (GranuDrum, Granutools).

Innovative Aspect(s) :
In this study, iron ore is evaluated for additive manufacturing applications. This could lead to opening futur processing applications for this material, reducing cost in the steel sector.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765342

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Other PM materials

Author : Prof Veronesi Paolo (University of Modena and Reggio Emilia, Italy)

Co-author(s) : Prof Colombini Elena, Dr Lassinantti Gualtieri Magdalena (University of Modena and Reggio Emilia, Italy)

Title : Recycling Of Spent Powders From Additive Manufacturing Processing Of Inconel 625 For The Synthesis Of CoCrFeNiMoxNb0.4x (x=0-0.1) Multi-Principal Element Alloys (MPEAs) By Spark Plasma Sintering (SPS) Of Mechanically Alloyed Powders

Keyword(s) :
Recycling; Spark Plasma Syntering; MPEAs

Abstract :
Sieve residues from the powder recycling stream in Laser powder bed fusion (L-PBF) processing of Inconel 625 are currently disposed of as hazardous waste which is in conflict with circular economy thinking. Here, the synthesis of equimolar CoCrFeNi Multi-Principal Element alloys (MPEAs) doped with the 4d transition metals (i.e. Nb and Mo) is proposed as a valid recycling option of these powders. In particular, mixtures of virgin powders and a spent Inconel 625 powder were mechanical alloyed and subsequently consolidated by Spark Plasma Sintering (SPS). By carefully controlling the powder mixture compositions, MPEAs with various contents of Nb and Mo were obtained. The bulk samples were thoroughly characterized by metallographic analyses, X-ray powder diffraction and preliminary mechanical analyses using instrumented indentations. The results will show that spent powders of Inconel 625 is a valuable source of 4d transition metals for the synthesis of CoCrFeNiMoxNb0.4x (x=0-0.1) with enhances solid solution.

Innovative Aspect(s) :

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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Technical Programme Committee
15th February 2023

MATERIALS

ULTRAHARD MATERIALS

EPMA european powder metallurgy association

EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765276

Requested presentation type : Oral Presentation

Topic : Materials **Subtopic :** Ultrahard Materials

Author : Dr Ing Lagerbom Juha (VTT, Finland)

Co-author(s) : Prof Huttunen-Saarivirta Elina (VTT, Finland), Dipl-Ing Lindroos Tomi (VTT, Finland), Dr Laukkanen Anssi (VTT, Finland), Dr Honkanen Mari (Tampere University, Finland), Prof Mohanty Gaurav (Tampere University, Finland),

Title : High-entropy Carbides: Design And Processing

Keyword(s) :
High Entropy Carbide; Mechanical Milling; Sintering; Refractory

Abstract :
High entropy carbides (HEC) are multi-metal carbides involving at least four types of metal atoms at near-equal concentrations. They exhibit crystalline periodicity and a precise carbon sublattice but display disorder in terms of metal cation packing, therefore they also have unconventional mechanical and physical properties. Up till now, the high entropy carbide compositions presented in literature have been rich in critical raw materials (CRM), such as tungsten (W) and hafnium (Hf). In this research, we aim to design and process sustainable high-entropy carbide compositions free of CRMs. The design of HEC chemistries is performed utilizing high-throughput CALPHAD analyses and further property data is extracted using density functional calculations. Equiatomic metal powder mixtures with carbon were ball milled and conventionally sintered at high 2000°C temperature to verify the single-phase high entropy carbide formation. XRD, SEM and EBDS techniques were used to characterize the materials and verify HEC formation.

Innovative Aspect(s) :
High entropy carbides (HEC) are multi-metal carbides involving at least four types of metal atoms at near-equal concentrations. They exhibit crystalline periodicity and a precise carbon sublattice but display disorder in terms of metal cation packing, therefore they also have unconventional mechanical and physical properties. Up till now, the high entropy carbide compositions presented in literature have been rich in critical raw materials (CRM), such as tungsten (W) and hafnium (Hf). In this research, we aim to design and process sustainable high-entropy carbide compositions free of CRMs. The design of HEC chemistries is performed utilizing high-throughput CALPHAD analyses and further property data is extracted using density functional calculations. Equiatomic metal powder mixtures with carbon were ball milled and conventionally sintered at high 2000°C temperature to verify the single-phase high entropy carbide formation. XRD, SEM and EBDS techniques were used to characterize the materials and verify HEC formation.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

Technical Programme Committee
15th February 2023

CONSOLIDATION TECHNOLOGIES

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EURO PM2023 CONGRESS & EXHIBITION

Technical Programme Committee
15th February 2023

CONSOLIDATION TECHNOLOGIES

AM BEAM BASED TECHNOLOGIES

EPMA
european powder metallurgy association

EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235734093

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Beam Based Technologies

Author : Ms Mthembu Noluthando (Stellenbosch University, South Africa)

Co-author(s) : Prof Sacks Natasha (Stellenbosch University, South Africa)

Title : Process Development Of A Ti-6Al-4V-10wt%WC Metal Matrix Composite Using Selective Laser Melting

Keyword(s) :
Selective Laser Melting; Ti6Al4V; Metal Matrix Composite; Deposition Analyses; Tungsten Carbide

Abstract :
In this study the influence of laser power, scanning speed and hatch spacing was investigated on the development of a Ti-6Al-4V alloy reinforced with 10wt%WC to form a metal matrix composite. Response surface methodology was used for both the design of experiments and results analysis. The laser power was varied between 87 and 104 W, while scanning speed and hatch spacing were varied between 500 and 700 mm|s, and 77 and 94 µm, respectively. Cube samples were deposited using a continuous meander scanning pattern which was selected after initial optimisation of the Ti-6Al-4V alloy. Density, porosity, and Vickers micro-hardness were measured, while the microstructure was studied using x-ray diffraction, scanning electron microscopy and energy dispersive spectroscopy. Properties were measured in both the transverse and longitudinal directions, and relationships established with the deposition parameters in order to find the optimal deposition parameters for the composite.

Innovative Aspect(s) :
The addition of tungsten carbide (WC) particles to a Ti-6Al-4V alloy to form a metal matrix composite using laser powder bed fusion is new. The carbides are being added to improve the strength and wear properties of the titanium alloy.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235735468

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Beam Based Technologies

Author : Dr Botero Carlos (Mid Sweden University, Sweden)

Co-author(s) : Mr Sjöstrom William, Mr Jiménez-Piqué Emilio, Mr Şelte Aydin, Dr Rännar Lars-Erik (Mid Sweden University, Sweden)

Title : E-PBF For Manufacturing Of 3D Metal-metal Multi Material Assemblies

Keyword(s) :
Multimaterials; E-PBF. Tool Steels; Stainless Steels

Abstract :
Most Powder Bed Fusion (PBF) methods for the Additive Manufacturing (AM) of metals are based on manufacturing components by the melting of powder feedstock of one kind; either of pure-elemental or pre-alloyed compositions. Although the AM of multi-materials has recently gained a lot of attention, it is still not commercially available for metal PBF. In the specific case of Electron-beam based PBF (E-PBF), it is possible to precisely control the beam parameters such as speed, spot size and current in each site of the build area. By doing this for each manufactured layer, the melting and solidification process can be steered throughout the build. This, together with the hot-nature of E-PBF occurring in a protective vacuum atmosphere, opens great possibilities for adaptive processes that allows melting of feedstock powders of different nature in the same build. In this investigation, different steel-based powders are used to create metal-metal multimaterial assemblies,

Innovative Aspect(s) :
The additive manufacturing (AM) of metal multimaterials is of great interest nowadays. Although the Powder Bed Fusion (PBF) technologies represent the largest portion of the metal AM market, the manufacturing of multimaterials by PBF is still not commertially available. In this work an innovative experimental setup is proposed for the E-PBF technology to achieve steel-based multimaterials in different layer assemblies and configurations. The novel materials obtained and properties evaluated are promising in a wide range of applications.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235741167

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Beam Based Technologies

Author : Dr Li Xiaoshuang (Aerosint SA, Belgium)

Co-author(s) :

Title : Multi-Material Laser Powder Bed Fusion Of Steels And Ni-based Superalloy

Keyword(s) :
Multi-Material LPBF; Superalloy; FGM

Abstract :
The invention of Selective Powder Deposition (SPD) enables creating a thin layer of multiple powders with customized patterns. Its successful integration into Laser Powder Bed Fusion (PBF-LB) machines opens the door to additive manufacturing of multi-material parts with not only geometry but also functionality complexity in 3 dimensions.The present work focuses on the combination of ferrous alloys and a high temperature Ni-based superalloy. Unique machine learning assisted Design of Experiment (DoE) was applied to accelerate the development of processing parameters for achieving high density as well as production speed. Special scanning strategies were introduced to ensure sound metallurgical bonding at the interface. The microstructure especially at the material interface was characterized using OM and SEM.

Innovative Aspect(s) :
1. Multi-material parts by fully automated LPBF
2. Function Graded Materials
3. For the first time, machining learning was introduced to speed up process development for multi-material LPBF.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235746744

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Beam Based Technologies

Author : Mr Jabir Hussain Ahmed Fardan (Chalmers University of Technology, Sweden)

Co-author(s) : Dr Brodin Håkan (Siemens Energy AB, Sweden), Dr Hryha Eduard (Chalmers University of Technology, Sweden)

Title : PBF-LB|M Of A Non-weldable Ni-base Superalloy: Role Of Processing Parameters On Hot Cracking

Keyword(s) :
Superalloy; Non-Weldable; CM247LC; Hot Cracking; Solidification Cracking

Abstract :
Additive manufacturing of non-weldable CM247LC by powder bed fusion – laser beam of metals (PBF-LB|M) is challenging due to the high cracking susceptibility of the alloy. The objective of this study was to find a processing window that leads to dense parts with low porosity and crack density. A full factorial design of experiments (DOE) was done to study the influence of laser powder, scan speed, and hatch spacing on porosity and crack density. The obtained results show that minimal porosity and crack density was obtained for parameters with low hatch spacing and high scan speeds. The study shows that it is possible to print the so-called 'non-weldable' alloy with minimal defects.

Innovative Aspect(s) :
The innovative aspects include the effect of processing parameters on hot cracking and residual stresses. Residual stresses are often overseen in such crack sensitive materials which can be problematic in high gamma-prime stregnthened materials like CM247LC. This study tries to find a parameter with minimal defect s well as residual stress.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235761708

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Beam Based Technologies

Author : Mr Özeren Emre (Tusas Engine Industries, Inc. (TEI), Turkey)

Co-author(s) : Mr Ünver Çaglar, Mr Bilgin Güner Mert, Mrs Ertekin Beyzanur, Mr Tas Alican, Mrs Cavcar Zehranur, Mr Gökcan Muhammed Baybars, Mr Orhangül Akin, Mr Dilektasli Emre (Tusas Engine Industries, Inc. (TEI), Turkey)

Title : Investigations Of Powder Reuse On Flowability And Mechanical And Metallurgical Behavior Of Alloy 718 For L-PBF

Keyword(s) :
Laser Powder Bed Fusion; Powder Reuse; Powder Characterization; Powder Rheology; Fatigue; Alloy 718

Abstract :
In L-PBF, metal powders are used as feedstock material and can be reused for successive productions. The reused powder usage requires attention in high-quality and reliable part production since the reused powder may affect flowability and built-part properties. In this study, Alloy 718 powder was produced over 40 series of L-PBF build cycles without rejuvenating the powder. The powder characterization was performed in order to investigate the flow behavior of reused powder using several methods. Besides, tensile tests, fatigue tests, Archimedes, and image processing density measurements were performed in order to investigate the behavior of built-part produced by reused powders. Furthermore, chemical composition analyses were carried out over both bulk and powder samples. The results showed that no significant and meaningful difference was seen among 40 cycles in some powder characteristics and built parts behavior while there are prominent differences in some powder characterization methods and in metallurgical behavior.

Innovative Aspect(s) :
Alloy 718 powder featured over 40 series of L-PBF build cycles with no rejuvenation. The powder characterization was performed in order to investigate the flow behavior of multiple times reused powders applying several methods such as powder rheology analysis with both shear and powder cell, particle size distribution (PSD), quantitative morphology analysis and Hausner Ratio calculation. Together with these, mechanical tests such as tensile and fatigue were performed on the reused cycles. Moreover, chemical composition analyses were performed on both powder and bulk samples. Since there are contradictory results in the literature and powder handling procedures vary from user to user, exploring of reused powder behavior requires more attention. This study aimed to help users to explore the reused powder behavior by reusing powder over 40 cycles using different methods with novel approaches. To the best of the authors' knowledge, there are no such reuse cycles performed in literature.

Reviewer's name : ....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235762547

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Beam Based Technologies

Author : Prof Dr Gromov Alexander (University of Ulsan, Korea, Republic of)

Co-author(s) : Prof Dr Kim Jin-Chun, Mr Cong Dinh Van, Mr Lee Dong Wan (University of Ulsan, Republic of Korea)

Title : Metal And Ceramic Nanopowders Application In Metal Matrix Composites Manufacturing By 3D Printing By Laser Powder Bed Fusion Technology

Keyword(s) :
Nanopowders; Additive Manufacturing; Laser Powder Bed Fusion; Aluminum Matrix Composites; Superalloys

Abstract :
The era of quality optimization for micron-sized spherical powders application in 3D Printing (Laser Powder Bed Fusion, LPBF) technology is on its fast development. However, for many applications the high level of mechanical properties for 3D printed metal-matrix composite materials was achieved by nano-metal and nano-ceramic additions to the metals|alloys matrix application. For example, in the case of oxide-dispersed-strengthened (ODS) superalloys or aluminum matrix composites (AMC) a strength and hardness of the nano-strengthened 3D materials could achieve 120-130 % in comparison with alloys|composites strengthened by micron-sized additives. In this work we summarized our experience in nano-ceramics and nano-metals (nAlN, nBN, nWC, nAl) applications at AMC as well as nano-ceramics (nAl2O3, nSiO2) application in Inconel by 3D printing (LPBF technology). The dependence of 3D samples properties from the composition of initial powdery mix and 3D printing regimes was comprehensively studied.

Innovative Aspect(s) :
The new effects on nano-strengthening of AMC and superalloys were studied. Phases segregation by melting pool solidification and in-situ or ex-situ mixing of metal matrix powders with metal and ceramic nano-additives play the crucial role in the mechanical characteristics of the 3D printing materials. Comprehensive experimental study of these phenomenas was executed and discussed in detail.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235782991

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Beam Based Technologies

Author : Dr Ordas Nerea (Ceit-BRTA and Tecnun (Universidad de Navarra), Spain)

Co-author(s) : Ing Schiopetto Maria Flor, Ing Lopez-Lopez Josu, Ing Perez-Casero Iñigo, Dr Aristizabal Miren, Dr Veiga Angela, Dr Ausejo Sergio (Ceit-BRTA and Tecnun (Universidad de Navarra), Spain)

Title : Laser-Directed Energy Deposition Processing As A Tool To Repair Or Obtain Hybrid Complex-Shape Components

Keyword(s) :

Abstract :
Laser-Directed Energy Deposition offers the possibility to combine traditional and additive manufacturing processes, boosting the flexibility during repairing damaged parts and manufacturing of complex-shaped components.This work demonstrates the potential of powder L-DED as an effective tool in hybrid processes. Two use cases are presented. The first one is a mounting lug built with a Ni-base superalloy, Astroloy, on a turbine case of the same material, previously produced by PM-HIP (Hot Isostatic Press of encapsulated powder), for aero-engines. The second one refers to repairing of two railroad components, a rail of a pearlitic steel (R260), and a crossroad of a high Mn steel. Gas atomized powders are used in all cases, being the chemical composition for railway specifically designed for this application. L-DED parameters were selected to avoid defects like pores or cracks. Microstructural and mechanical characterization were performed to verify that the AM parts meet the required specifications.

Innovative Aspect(s) :
L-DED is a process of increasing interest in maintenance and repairing operations of parts of high complexity or difficult to repair, or where service suspension must be minimized, as occurs with railroad components. Moreover, when combined with conventional manufacturing technologies, it offers a number of benefits over L-DED or conventional approaches alone, like the possibility to enhance functionalities or reduce costs associated to material consumption or machining operations. Some of the advantages of the process presented in this work, compared to welding, are: (1) fewer substrate affection and residual stresses, thanks to the use of less energy, (2) feasibility to work with mixtures of powders, (3) possibility to control the process temperature during deposition by means of a pre-heating system to avoid phase transformations into brittle phases (like martensite in R260 steel), and (4) enhanced precision and reproducibility in the quality of the repairs or the complex subcomponents built.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235762584

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Beam Based Technologies

Author : Dr Mancisidor Ane Miren (LORTEK, Spain)

Co-author(s) : Mr Gómez Raúl, Dr Dos Santos Rafael Eugenio, Ing Garciandia Fermin, Dr San Sebastián María, Dr Gil Emma (LORTEK, Spain)

Title : Cracking Susceptibility Assessment Of L-PBF CM247LC Alloy Based On Composition And Process Parameter Modifications

Keyword(s) :
LPBF; CM247LC; Cracking Susceptibility; Composition; Process Optimization; Metallographic Characterization

Abstract :
CM247LC alloy is a precipitation strengthened nickel-based superalloy commonly used in aeronautic sector due to its outstanding mechanical, oxidation, creep and wear properties at room and at high temperatures. However, there is a big challenge in obtaining a crack free material during L-PBF processing. High contents of Al and Ti induce cracking. Four batches of CM247LC powders with different compositions were analysed and processed by L-PBF. In this study, different approaches were employed to mitigate crack susceptibility of the alloy, namely, alloy modification, process modification and post-processing by HIP. The influence of the elements on cracking was assessed as well as the process parameters modification, including modification of the laser scanning strategies. Microstructure before and after post-processing, namely heat treatments and HIPping, was evaluated and cracking mechanism was studied in the light of microstructural observations.

Innovative Aspect(s) :
CM247LC is a nickel base super alloy used in aeronautical applications where the component should withstand harsh conditions. Thus, it is of great importance to achieve a defect free material. When processing CM247LC by L-PBF its chemical composition should be controlled in order to reduce the tendency to cracking. In this work, the alloying elements that have a higher influence in cracking during L-PBF process have been analysed. Moreover, process modification includes an innovative laser scanning strategy to reduce the microcrack density.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235762606

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Beam Based Technologies

Author : Mr Venkatesh Kumaran S (IMDEA Materials, Spain)

Co-author(s) : Mr Malladi Sri Bala Aditya, Prof Dr Hryha Eduard (Chalmers university of technology, Sweden), Prof Dr Torralba José Manuel (Universidad Carlos III de Madrid, Spain)

Title : Effect Of Process Parameters And Heat Treatments On Non-equiatomic CoCrFeNiMoxAly HEAs Manufactured By PBF-LB|M Via In-situ Alloying

Keyword(s) :
Laser powder bed fusion, high entropy alloys, commercial commodity powders, annealing

Abstract :
Manufacturing high entropy alloys (HEAs) using powder bed fusion-laser beam|Metal (PBF-LB|M) enables their production with minimal elemental segregation due to its inherently fast cooling rates resulting in excellent properties. So far, HEAs have been fabricated with fully pre-alloyed gas-atomized powders which makes it expensive and slower to explore new alloy compositions. In this work, for the first time, instead of pre-alloying, blended powders of CoCrF75, Ni625, Invar36, and pure Al powders were used as feedstock to develop a CoCrFeNiMoxAly HEA which consists of FCC phase in the metastable state. The process was successfully optimized, achieving relative densities greater than 99.8%. Moreover, annealing at various temperatures and times is performed to study its effect on precipitating new phases such as BCC, sigma, and μ. This method of mixing powders for PBF-LB|M enables rapid exploration of new HEAs and this work is expected to contribute to its successful application in the future.

Innovative Aspect(s) :
Blending commercial commodity alloy powders with elemental powders to produce feedstock instead of fully pre-alloyed powders for powder bed fusion - laser beam|Metals (PBF-LB|M).
Lowering the cost of manufacturing High entropy alloys (HEAs) to enable their commercialization.
Studying the effect of SLM process parameters on homogeneity, cracking, and microstructure on Al and Mo-based dual-phase HEAs produced via in-situ alloying by mixing Al powders with commercial commodity powders containing Mo.
The use of powders of different densities is a challenge in powder bed fusion processes and this work studies the effect of lighter elements like Al on the homogeneity of the distribution of elements.
Studying the effect of heat treatments on the metastable microstructure obtained from PBF-LB|M to precipitate secondary phases.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235762610

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Beam Based Technologies

Author : Dr Ing Vecchi Giuseppe (Politecnico di Torino, Italy)

Co-author(s) : Prof Atzeni Eleonora, Prof Iuliano Luca, Prof Salmi Alessandro (Politecnico di Torino, Italy)

Title : Control Of The Substrate Heating In Laser Powder Directed Energy Deposition Repairing By Bi-directional Spiral Deposition Strategy

Keyword(s) :
Directed Energy Deposition; Repairing; Thermal cycling; Deposition Strategy

Abstract :
Recent improvements in the Laser Powder Directed Energy Deposition (LP-DED) process for repair applications shift the focus to the analysis of possible alterations in the substrate, which is subjected to repeated thermal cycling during deposition of the material. In general, thermal loads can be controlled by changing process parameter. In this work, a two-step bi-directional spiral deposition strategy, alternating between deposition from inward to outward and backfill, is analyzed to evaluate the heating of the substrate and the resulting porosity of the added material. The outcomes indicate the potential of this strategy to control heat flow and achieve a more uniform thermal field. Porosity is minimized by optimizing the hatch spacing, and benefits are observed also in terms of top surface roughness.

Innovative Aspect(s) :
At the state of the art, research on LP-DED technology is focuses mainly on the properties of the deposited features and adhesion with the substrate. However, in repair applications, it is of paramount importance to preserve the microstructural properties of the substrate material, avoiding the creation of internal stresses and distortions. Attention to these aspects is the main innovative aspect of the work, in which an attempt is made to control the thermal loading of the substrate by managing the deposition strategy.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235762626

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Beam Based Technologies

Author : Ing Felicioni Stefano (Politecnico di Torino, Italy)

Co-author(s) : Prof Padovano Elisa, Prof Marchese Giulio, Dr Quercio Michele, Prof Canova Aldo, Prof Biamino Sara, Prof Bondioli Federica (Politecnico di Torino, Italy)

Title : Optimization Of Process Parameters For CuCrZr Alloy Manufactured By Electron Beam Powder Bed Fusion Technology

Keyword(s) :
EB-PBF; Electron Beam Melting; Copper; CuCrZr; Additive Manufacturing; Topology Optimization

Abstract :
The CuCrZr alloys show advantageous mechanical properties and high electrical conductivity which make them promising for many applications in the electrical and aerospace engineering industries. Unfortunately, these two important properties are in opposition to each another; however, additive manufacturing technologies are good candidates to balance these two aspects to achieve high performance parts. The Powder-Bed-Fusion (PBF) techniques involve rapid heating and cooling rates which allow to obtain huge microstructural refinements, thereby improving the mechanical properties without any significant loss in the electrical conductivity. This study concerns the process parameter optimization for CuCrZr alloys produced by means Electron-Beam-PBF technology using a trial-and-error approach. The material was characterized by porosity analysis, tensile and electrical conductivity measurements. The effect of process parameters on microstructure and densification behavior was also investigated.This work was performed within the project "IMplementazione della Produzione Additiva CompetiTiva IMPACT co-financed by POR-FESR Piemonte 2014-2020".

Innovative Aspect(s) :
The present work concerns an innovative processing way for the CuCrZr alloy, allowing to enlarge the number and the effectiveness of its applications. It is widely known that this alloy is suitable in vacuum electronics, fusion energy research, and heat transfer systems. All the aforementioned implementations require very complex and time-consuming design optimizations; therefore, the possibility to remove geometrical constraints become crucial. The additive manufacturing makes it possible, and the Electron Beam-PBF is a very promising technology to process the materials, such as copper and its alloys, which show high reflectivity, leading to almost fully dense parts (>99.95%) free of internal stresses.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235762866

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Beam Based Technologies

Author : Mr Paiotti M. G. Rafael (Metalpine GmbH, Austria)

Co-author(s) : Dipl-Ing Graf Eva, Dipl-Ing Arneitz Siegfried, Prof Dr de Traglia Amancio-Filho Sergio (TU Graz, Austria)

Title : A Printability Study Of In Situ Alloyed NiTi Shape Memory Alloy By Laser-powder Bed Fusion In Non-heated Ti Substrate Plate

Keyword(s) :
Laser Powder Bed Fusion; In Situ Alloying; Shape Memory Alloys; Niti; Nitinol; Cost Reduction; Versatility

Abstract :
NiTi is the most employed Shape Memory Alloy. The biomedical and aerospace sectors have successfully employed it because of its biocompatibility, functional shape memory, and superelastic effects. However, drawbacks, such as lack of machinability, have made additive manufacturing an alternative for processing NiTi. Laser powder bed fusion (LPBF) showed the feasibility of printing functional and defect-free NiTi parts using pre-alloyed powder as feedstock material. Nevertheless, due to its reactivity, this powder is challenging (thus costly) to atomize, thus hindering NiTi application. An alternative relies on in situ alloying, where elementally blended Ni and Ti powder is used to form NiTi locally. This work investigates the LPBF of Ni-rich Ni51(at%)Ti by in situ alloying built on a Ti plate without prior heating. Although in situ alloying of NiTi showed susceptibility to defects, it was possible to determine a process map to attain functional, defect-less parts on a non-pre-heated Ti substrate.

Innovative Aspect(s) :
For the first time, in situ alloyed NiTi was printed in a non-heated substrate Ti plate. It reduces the feedstock (in situ alloying) and operative (non-heated substrate plate) costs - by in situ alloying, it was obtained already Ni4Ti3 reinforced parts with superior mechanical properties if compared to the conventional use of pre-alloyed powdershis technique allows versatility to tailor the composition and well as the addition of ternary elements to change the properties in house.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235762947

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Beam Based Technologies

Author : Ms Nilsson Åhman Hanna (Swerim AB, Sweden)

Co-author(s) : Ms Larsson Lisa, Dr D'Elia Francesco, Prof Persson Cecilia (Uppsala University, Sweden), Dr Mellin Pelle (Swerim AB, Sweden)

Title : Effect Of Part Thickness On The Microstructure Of A Mg-Y-Nd-Zr Alloy Processed By L-PBF

Keyword(s) :
L-PBF; Mg Alloys; WE43; Microstructure

Abstract :
Laser – powder bed fusion (L-PBF) of Mg-Y-Nd-Zr alloys enables the production of complex biodegradable orthopaedic implants, for patient-specific designs with enhanced biocompatibility. However, the effect of part geometry on the microstructure is yet to be investigated. Thus, here the microstructure in walls of varying thickness (0.2 mm to 3 mm) was investigated. It was found that for wall structures thinner than 1 mm, a significant amount of keyhole porosity was present, and a dendritic microstructure was primarily observed. For the thicker wall structures (> 1 mm), the dendritic structure was only present at the edges of the samples. In the bulk, a cellular structure with large basal grains was observed. The difference is microstructure was ascribed to the change in thermal conditions, a major factor being an increased insulating effect of the unmelted powder surrounding the samples.

Innovative Aspect(s) :
Mg and its alloys have been gaining increasing attention for its low weight and high biocompatibility in the last couple of decades. However, the research surrounding the processing of Mg alloys by L-PBF remains limited in general. Specifically, the relationship between process parameters, microstructure and material properties are largely unknown. Moreover, the influence of geometry has not been explored at all. This study highlights the importance of considering wall thickness when developing process parameters, especially for thinner structures. In turn, producing thinner structures is highly relevant for developing orthopedic implants, as lattice structures with relatively fine details are typically explored for that kind of applications.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235763233

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Beam Based Technologies

Author : Dr Ing Pereira Juan Carlos (LORTEK, Spain)

Co-author(s) : Ing Telleria Iosu, Dipl-Ing Aguilar David, Dipl-Ing Dos Santos Rafael, Dr Ing San Sebastian Maria (LORTEK, Spain)

Title : Semi-continuous Functionally Graded Material Austenitic To Super Duplex Stainless Steel Obtained By Laser-based Directed Energy Deposition

Keyword(s) :
Laser Metal Deposition; Directed Energy Deposition; FGM; Super Duplex; Stainless Steel

Abstract :
In this work a functionally graded material between an austenitic and a super duplex stainless steel has been fabricated. These materials are of great interest for the chemical and oil & gas sectors, since the austenitic stainless steel is inexpensive and super duplex stainless steels have better mechanical and corrosion resistance but are more expensive. Using direct laser metal deposition process, it is possible to efficiently combine two or more powders of different chemical composition by automated mixing prior to their delivery it into the nozzle, coaxial to the laser beam for melting. It has been possible to obtain a dense material via additive manufacturing, with minimum defectology and semi-continuous and controlled composition gradient. The resulting microstructure and hardness variations with different composition proportions in the manufacturing direction have been evaluated, starting from stainless steel AISI 316L and with discontinuous increments until achieving 100% of super duplex SAF 2507.

Innovative Aspect(s) :
Obtaining functionally graded materials (FGMs) has been challenging so far, however, with the emergence of metal additive manufacturing processes like directed energy deposition (DED) technologies, it is possible to fabricate complex parts with functional gradients. A major advantage of DED technology is its ability to produce multi-material components, with key importance in solving long-standing problems in dissimilar metal welding and alloys development. Since some laser-based DED processes rely on the use of blown powder as raw material, the ability to mix various powders (in a controlled manner) in situ (i.e., during powder feeding and|or delivery) easily enables the production of complex functional gradients, multi-material layers, and even composites that can include many classes or types of materials. This opens a new horizon for alloys development and innovative industrial applications. In this work, we delve into how the FGM has been obtained and how microstructure and strengthening mechanisms evolves.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235763603

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Beam Based Technologies

Author : Mr Bilgin Guney Mert (Tusas Engine Industries Inc. (TEI), Turkey)

Co-author(s) : Ms Gulcan Yesim Nur, Mr Pehlivanogullari Baris, Mr Yilmaz Rifat, Mr Orhangul Akin (Tusas Engine Industries Inc. (TEI), Turkey)

Title : Comparison Of The Mechanical Properties And The Microstructures Of ΓTiAl Fabricated By Electron Beam Melting And Powder Metallurgy Route

Keyword(s) :
Additive Manufacturing; Electron Beam Melting; Powder Metallurgy; Ti48Al2Cr2Nb Alloy; Microstructure; Mechanical Properties; Heat Treatment; Hot Isostatic Pressing

Abstract :
Titanium aluminide based alloys stand out especially for aerospace applications due to their low density, high temperature strength and corrosion resistance. However, due to high reactivity and low ductility at room temperature, various problems are encountered in conventional manufacturing methods. Therefore, great interest has been shown in its near net shaping fabrication by electron beam melting (EBM) additive manufacturing and powder metallurgy (P|M) technologies. In this study, samples were produced from pre-alloyed Ti48Al2Cr2Nb powder using both EBM and P|M methods. As-built EBM Ti48Al2Cr2Nb mechanical properties significantly differ from those of the parts produced by P|M depending on manufacturing direction due to several issues including microstructural instabilities, porosity and residual stresses. The present study was conducted to characterize the microstructure, high temperature tensile strength behavior of EBM and P|M fabricated Ti-48Al-2Cr-2Nb samples in the as-built, HIP'ed and heat-treated conditions within the purpose of utilizing this alloy for structural aerospace applications.

Innovative Aspect(s) :
The existing studies in the literature mainly focused on a single mechanical property of the material by applying heat treatment at a certain temperature to the Ti48Al2Cr2Nb alloy produced by EBM. However, in this proposed study, the final properties were compared with each other to the samples fabricated by EBM and P|M. A serious knowledge has been created for structural aerospace applications by evaluating the microstructural examinations, phase analyzes and high temperature tensile tests for the both EBM and P|M production. For all these reasons, it is thought that the proposed study differs from the existing studies and will contribute to the literature.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235763947

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Beam Based Technologies

Author : Ing Rodriguez Sanchez Marcos (IMDEA Materials, Spain)

Co-author(s) : Ing Sadanand Saumya, Dr Perez Prado Maria Teresa (IMDEA Materials, Spain), Ing Ghavimi Amirhossein, Dr Busch Ralph, Dr Gallino Isabella (Saarland University, Germany), Dr Tilberto Paola Maria, Dr Ferrera Enzo, Dr Barrera Gabriele (INRIM Istituto Nazionale

Title : Laser Powder Bed Fusion Of Soft Magnetic Bulk Metallic Glasses For Energy Saving Applications

Keyword(s) :
Laser Powder Bed Fusion; LPBF; SLM; Bulk Metallic Glasses; BMG; Soft Magnetic Materials; AM2SoftMag

Abstract :
Fe-based soft magnetic Bulk Metallic Glasses (BMG's) have shown unprecedented coercivity and magnetization saturation values and present the possibility of creating more efficient electromagnetic components, if successfully built. Laser Powder Bed Fusion (LBPF) allows to manufacture relatively large BMG parts while retaining an amorphous microstructure due to high local cooling rates. However, in practice, the thermal cycles generated in the LBPF layer-wise process tend to cause undesired crystallization.This work aims to find the optimal processability window of a commercial water-atomized Fe-based BMG powder using a Renishaw AM400 system with a pulsed-wave laser for fine microstructure control. A complex parameter optimization process is carried out to achieve dense enough prints while retaining the beneficial amorphpus microstructure. Experimental techniques such as X-Ray Diffraction, Differential Scanning Calorimetry, image analysis, magnetic and micromechanical testing were used to evaluate print quality find the best compromise between amorphous fraction and low number of defects.

Innovative Aspect(s) :
Use of LPBF with soft magnetic amorphpus powder for energy saving applications.Processing parameter optimization and thorough microstructural, mechanical and magnetic characterization to achieve prints with a superior soft magnetic behavior. Full use of a pulsed-wave laser LPBF system to achieve a higher amorphous fraction.

Reviewer's name : ....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : ....

Notes to author : ....

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235763995

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Beam Based Technologies

Author : Prof Dr Schwanekamp Tobias (Rheinische Fachhochschule Koeln, Germany)

Co-author(s) : Mr Zimmer Leon, Prof Dr Reuber Martin (Rheinische Fachhochschule Koeln, Germany)

Title : Additive Manufacturing Of TiC-Ni Cermets By Laser-based Powder Bed Fusion

Keyword(s) :
Additive Manufacturing; PBF-LB; Laser-Based Powder Bed Fusion; Cermet; TiC-Ni; Cutting Tool

Abstract :
Laser-based powder bed fusion (PBF-LB) offers significant potentialities for the design of innovative cutting tools with complex inner and outer shape. Therefore, a lot of research on PBF-LB of tungsten carbide-cobalt (WC-Co) hard metals has been published in recent years. However, a material quality similar to conventionally sintered WC-Co is still not achieved and high cobalt content is required to counteract the intrinsic issues in PBF-LB of WC-Co, resulting in hardness values significantly below those of typical carbide grades for machining. TiC-Ni based cermets could be an interesting alternative, since TiC has a higher hardness than WC. The melting point is also higher, resulting in higher thermal stability during laser exposure. Furthermore, TiC is more robust to variations in stoichiometry than WC. However, PBF-LB of TiC-based cermets is only sparsely investigated. Therefore, the current study focuses on fundamental investigations on processing of TiC-Ni by PBF-LB.

Innovative Aspect(s) :
Additive manufacturing of cutting tools is an innovative field of research and of great industrial interest. In particular, the qualification of new materials for AM of cutting tools is important to expand the range of applications.The most innovative aspect of this study is that today there is only very sparse information of AM of cermets in general. In particular, the authors are not aware of any specific literature on PBF-LB of TiC-Ni, which makes this topic quite new and also of scientific interest.

Reviewer's name : ....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : ....

Notes to author : ....

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764059

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Beam Based Technologies

Author : Dr Ing Cordova Laura (Chalmers University of Technology, Sweden)

Co-author(s) : Dr Ing Raza Ahmad, Prof Dr Hryha Eduard (Chalmers University of Technology, Sweden)

Title : Analysis Of Processability And Reusability Of Ti6Al4V Powders For PBF-EB

Keyword(s) :
Powder Bed Fusion Electron Beam (PBF-EB); Powder Reuse; Processability; Ti64; Rheology; XPS

Abstract :
Processability in Powder Bed Fusion Electron Beam (PBF-EB) depends on the interaction of the electron beam with the metal powder. For a good, consolidated part to be processed, the powder must be smoothly applied on the powder bed and the beam transmits the electrons throughout the powder layers. Only with powder of specific characteristics, this is possible (narrow PSD, smooth and spherical morphology, high chemical purity). In this study two different TI6Al4V powder batches are analyzed, one batch presented challenges with processability even in virgin state. For both powders, an assessment of the morphology, particle size, rheology, and chemistry will determine the feasibility to achieve optimal processability and the possibility to reuse in consecutive cycles.

Innovative Aspect(s) :
This study covers the most critical aspect of PBF-EB, processability. When the process starts several challenges can take place as charging -producing the so-called smoke-, recoating issues, etc. When reusing the metal powder for PBF-EB a layer of complexity is added which is the pristine, spherical, high-purity powder is oxidized making it more difficult the processability. In this study two batches of Ti64, a critical material for EBM, is studied. One of the batches had serious issues with processability, making the process cost efficiency low due to it could not be reused more than one time. This work analyzes the root cause of this issue from different perspectives. Characterization of rheology, chemistry, morphology, and particle size gives a complete picture of the potential of these powder batches.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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Withdraw ☐ Reason : ……………………………………………………………………………………

Notes to author : ……………………………………………………………………………………………

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Paper Number : EP235764236

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Beam Based Technologies

Author : Dr Kaserer Lukas (University of Innsbruck, Austria)

Co-author(s) : Dr Braun Jakob, Mr Brennsteiner Daniel, Prof Leichtfried Gerhard (University of Innsbruck, Austria), Dr Leitz Karl-Heinz, Dr Kestler Heinrich, Dr Schafbauer Wolfgang (Plansee SE, Austria)

Title : Comparison Of Different Alloying Concepts For Mo And W For Improving Component Strength And Quality In LPBF

Keyword(s) :
Laser Powder Bed Fusion; Molybdenum; Tungsten; Alloying Strategies

Abstract :
The production of Mo and W components using the additive manufacturing process Laser Powder Bed Fusion (LPBF) makes it possible to produce Mo and W components with highly complex geometries in a resource-efficient way. Such complex components enable optimal functionalization and are of considerable industrial interest.The disadvantage of LPBF is that it is currently impossible to produce pure Mo and W components that achieve a similar strength and quality compared to their traditionally powder-metallurgically produced counterparts. Pure Mo and W components suffer from a coarse-grained, columnar, and cracked microstructure. Material adaptation to tolerate the unique solidification-boundary conditions in LPBF is necessary to improve component quality.In the present work, different alloying concepts to trigger grain refinement, to engineer grain boundary chemistry, and a combination of both are discussed for both Mo ans W. Furthermore, the effects on the microstructure and component quality are compared based on experimental results.

Innovative Aspect(s) :
Presentation of different alloying concepts to counteract the main defect-initiating mechanisms in LPBF of Mo and W.
Experimental results showing the effect on the microstructure.
Experimental results showing the effect on the mechanical properties at room temperature and at elevated temperatures.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION
01-04 October 2023

Paper Number : EP235764401

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Beam Based Technologies

Author : Dr Batalha Rodolfo (ISQ - Instituto de Soldadura e Qualidade, Portugal)

Co-author(s) : Mr Feliciano Francisco, Dr Morais Paulo (ISQ - Instituto de Soldadura e Qualidade, Portugal), Prof Dr Cruz Maria, Prof Dr Evans Guiomar (University of Lisbon, Portugal)

Title : Development And Characterization Of Fe-Based Soft Magnetic Material Produced By PBF-LB

Keyword(s) :
Additive Manufacturing; Soft Magnetic Materials; Microstructure; Magnetic Properties

Abstract :
Magnetic materials are becoming increasingly important due to the development of renewable energy sources. Soft magnetic components are used in electric machines such as motors, generators, inverters, converters, transformers, and sensors. In this work, we processed Fe-Si-based soft magnetic materials with powder bed fusion-laser beam (PBF-LB), additive manufacturing (AM) technology. The work considered the development of Fe-Si alloys by powder mixture, additive manufacturing of samples, post-processing heat treatments, and the measurement of magnetic properties. The results showed that the thermal history associated with the processing route leads to a notable change in the magnetic properties of the Fe-Si alloys. It is also seen that the microstructure and therefore magnetic properties of the Fe-Si alloy may be tailored by changing the laser scanning strategy in the PBF-LB process.

Innovative Aspect(s) :
The present work is aimed at pushing the current boundaries to a more efficient manufacturing route for producing high-performance Fe-based soft magnetic materials. The impacts are related to the availability and processability of new material compositions for the production of highly efficient electric machines.

Reviewer's name : ....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : ....

Notes to author : ....

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Paper Number : EP235764654

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Beam Based Technologies

Author : Dr Ing Baffie Thierry (CEA-LITEN, Univ.Grenoble Alpes, France)

Co-author(s) : Dr Ing Peyrouzet Florian, Dr Ing Navone Christelle, Dr Ing Maisonneuve Julie (CEA-LITEN, Université Grenoble Alpes, France), Dr Ing Gorsse Stéphane (Université Bordeaux, CNRS, Bordeaux INP, ICMCB, UMR 5026, France)

Title : Microstructure And Mechanical Properties Of As-built And Heat-treated Laser Powder Bed Fusion Al0.3CoCrFeNi High Entropy Alloy

Keyword(s) :
Additive Manufacturing; Laser-Powder Bed Fusion; High Entropy Alloy; Microstructure; Heat treatment; Tensile Properties

Abstract :
High entropy alloys (HEAs) are metallic materials composed of a concentrated mixture of multiple principal elements. The Al0.3CoCrFeNi alloy, produced by arc melting and subsequent thermomechanical treatments, is one of the most studied HEAs due to the wide range of microstructures accessible and the associated high mechanical performances. Thanks to Laser Powder Bed Fusion technology (L-PBF) and the high as-built dislocation density obtained, the room-temperature yield strength of this alloy is largely improved compared to as-cast or wrought counterparts while maintaining significant ductility [1].This paper highlights the effect of the control of L-PBF process parameters and of heat treatments on the alloy microstructural components (texture, dislocation density, secondary phases) and tensile properties. Analyses were carried out by X-ray Diffraction (XRD), Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM) and Atom Probe Tomography (APT). [1] F.Peyrouzet et al., JOM, 71 (10) (2019) 3443-3451

Innovative Aspect(s) :
The hierarchical microstructure is characterized by elongated columnar grains along the building direction (BD), sub-grains, solidification cells, a high dislocation density and a small amount of nano-particles. Two preferential crystallographic orientations <100> and <110> are observed. APT analyses in the as-built FCC supersaturated solid solution revealed a chemical short range ordering via the formation of nanometric NiAl-rich clusters.By increasing the L-PBF Volumetric Energy Density, the melt pool morphology can be controlled, thus the <110> fibre texture along the BD can be favoured.A thermal treatment at 620°C leads to the formation of L12 nano-precipitates. At higher temperature, a needle-shaped B2 phase precipitates. These phases contribute to the alloy hardening. The achieved tensile properties surpass those obtained with the same alloy produced by other processes. The range of tensile properties are the following: YS ≈ 625-780 MPa, UTS ≈ 725-1100 MPa and Elongation ≈ 22-46%.

Reviewer's name : ....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : ....

Notes to author : ....

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764661

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Beam Based Technologies

Author : Mr Deckers Tobias (Linde GmbH, Germany)

Co-author(s) : Dr Dubiez-Le Goff Sophie, Mr Forêt Pierre (Linde GmbH, Germany), Prof Dr Witt Gerd (University Duisburg-Essen, Germany)

Title : Effects Of A Helium Containing Process Gas Mixture On Laser-Based Powder Bed Fusion Of Metals: A Comparative Study On A Large-Scale Prototype

Keyword(s) :
Additive Manufacturing; Laser Powder Bed Fusion; Process Gas; Argon; Helium; Oxygen Content; Alloy 718; Sustainability

Abstract :
Previous research could prove that argon-helium mixtures are beneficial to mitigate the formation of process-by products deleterious for the quality and the reproducibility of laser-based powder bed fusion of metals (PFB-LB|M). This study was conducted on Alloy 718 to transfer previous research results to a part reaching machine volume capabilities. During printing, the process was analyzed through different process monitoring and quality assurance tools such as EOSTATE Exposure OT, EOSTATE MeltPool Monitoring and time-lapse photography. Those tools and the direct visual observation revealed next to less defects, less process by-products also less discolored spatter while using an argon-helium mixture. Consequently, due to the reduction of by-products generated, a significant reduction of machine filter clogging was observed.The part dimension allowed the quantification of the process sustainability: A reduction in powder loss, less defective parts, and increased longer powder reusability was detected.

Innovative Aspect(s) :
Process Sustainability; Decrease Powder Loss; Decrease Maintenance|Service Intervalls; Improve Surface & Part Quality; Extend Filter Life; Extend Powder Use

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764682

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Beam Based Technologies

Author : Mr Rosito Michele (Politecnico di Torino, Italy)

Co-author(s) : Mr Vanzetti Matteo, Dr Padovano Elisa, Prof Bondioli Federica, Prof Badini Claudio (Politecnico di Torino, Italy), Ing Gili Flavia, Ing Dellacà Valentina, Ing Tedesco Michele Maria (Stellantis, Italy)

Title : Investigation On LPBF Processability Of An In-situ A6061 Matrix Composite

Keyword(s) :
LPBF; A6061; MMC; Metal Matrix Composite; Grain Refiners; High Strength Aluminium Alloys

Abstract :
The interest in laser powder bed fusion (LPBF) has grown in the last decades because of the possibility to obtain near-net shapes parts with high performance. However, the main issue in this process is the limited availability of materials. For instance, A6061 alloy has a wide application range but it is hardly processable for LPBF because of a severe solidification cracking. This critical issue can be overcome through the introduction of nucleants in the system, which induce an equiaxed solidification and avoid the solidification cracks. A6061 RAM2 is a mixture of A6061, Ti and B_4C particles capable to react with each other to synthetise TiC and TiB_2, grain refiners for Al alloys. A parameters optimization to produce dense samples was performed. Microstructural characterization of these specimens was carried out to investigate the evolution of the system in the processed material. Then, preliminary evaluation of mechanical properties was performed.

Innovative Aspect(s) :
High-strength aluminium alloys have a wide range of applications but their processability for laser powder bed fusion (LPBF) is very challenging. Indeed, these alloys have a wide solidification range and show a columnar-dendritic grain growth, which lead to a severe solidification cracking and a dramatic fall of mechanical properties. Currently, different approaches to improve the processability of these alloys for LPBF are verified: the increasing of Si content of the alloy, the preheating of the platform, and the use of grain refiners, usually with nanometric size. The innovative approach of this study consists of the combination of the synthesis of an in-situ metal matrix composite and the introduction of grain refiners in the system. The in-situ production of the reinforcement provides auxiliar heat, due to the exothermic reaction, and inoculant phases with a strong interfacial bond, leading to an equiaxed solidification and avoiding solidification cracking.

Reviewer's name : ....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : ....

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764712

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Beam Based Technologies

Author : Dr Tobar Maria Jose (Universidade Da Coruña, Spain)

Co-author(s) : Dr Amado Jose Manuel, Dr Camba Carolina, Dr García Ana Isabel, Dr Mier Jose luis, Dr Luaces Alan, Dr Yañez Armando (Universidade Da Coruña, Spain)

Title : Characterization Of Compositionaly Graded A316L|Inconel 625 Profiles Manufactured By Laser Direct Energy Deposition Using Different Precursor Powders

Keyword(s) :
AM; Laser DED; Inconel 625; 316L; Functionally Graded Material; Multimaterial

Abstract :
Multimaterial additive manufacturing allows to obtain near-net-shape components with local customized properties. Combining different alloys, significant increased life service, functionality and cost savings are to be expected if mechanical, thermal, electric|magnetic properties can be tailored to specific demands. The laser DED technology provides with a natural environment for multi-material manufacturing with steels and high performance alloys. They can be mixed along the process with custom mixing ratios, although this is usually performed by developing compositionally graded interfaces between different materials. As when processing single alloys, laser DED deposits often suffer from known detrimental features as porosity, micro-segregation, cracks and|or directional grain growth. In this work this features will be examined in compositional graded A316L|Inconel 625 laser DED samples manufactured with powders from different providers. It will be analysed whether the morphology or minor elemental composition of the powders might influence the microstructure and mechanical characteristics of the deposited material.

Innovative Aspect(s) :
The feasibility of multi-material additive manufacturing with metal o metal-ceramic alloys provides a unique opportunity for material selection of customized characteristics. Any successful initiative in this respect, combining different material properties, is expected to expand the development of metal structures that cannot be achieved with traditional manufacturing techniques. The success of the multi-material structure, especially in hard service conditions applications, depends on the strength and integrity of the metallurgical interface between materials. Ultimately, the performance of additive manufactured parts is known to depend in many factors, including the characteristics of the raw feedstock material. This aspect should be further studied in order to advance on the standarization of the process. In this work we aim to provide with experimental evidence in the specific case of multimaterial additive manufacturing.

Reviewer's name : ....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : ....

Notes to author : ....

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Paper Number : EP235765041

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Beam Based Technologies

Author : Prof Azadbeh Maziyar (Sahand University of Technology, Iran)

Co-author(s) : Ms Eslami Samira, Ms Golchinfard Mahsa, Ms Gaffari Faezeh (Sahand University of Technology, Iran), Prof Danninger Herbert, Prof Gierl Mayer Christian (Vienna University of Technology, Austria)

Title : Comparing Microstructure And Properties Of Ti And Ti-10Mo Alloys Prepared By Selective Laser Melting

Keyword(s) :
Ti-10Mo; Selective Laser Melting; Beta Phase; Molten Pool

Abstract :
This study focuses on the influence of adding Molybdenum to Ti on properties, microstructure and presumably formation of beta phase. For this purpose, specimens from plain Ti powder and Ti-10Mo mixed elemental powders, respectively, were fabricated by selective laser melting (SLM) under the same parameters in argon atmosphere. The laser power, scanning speed and hatch distance were 95 W, 600 mm.s-1 and 0.088 mm, respectively. Ti-10Mo alloy was prepared successfully by SLM of elemental powder mix, a few undissolved Mo particles remaining, the distribution of which in the Ti matrix was fairly uniform. The molten pools are clearly visible in the micrographs of Ti-10Mo, but surprisingly not in Ti. The UTS of Ti was 624 MPa, and Mo addition caused an increase to approx. 940 MPa and of the hardness to 467 HV30, whereas the elongation of Ti was considerably higher than of Ti-10Mo.

Innovative Aspect(s) :
Ti-10Mo alloy was prepared successfully by SLM of elemental powder mix; a few residues of Mo particles are still contained. In the micrographs of Ti-10Mo the molten pools are clearly visible, while surprisingly not in Ti, although the manufacturing parameters for both were the same. The UTS of Ti was 624 MPa, and Mo addition caused an increase to approx. 940 MPa, indicating effective Mo distribution, whereas the elongation of Ti was considerably higher than Ti-10Mo. Relatively higher elongation of Ti may be related to the lamellar structure produced in additive manufacturing.

Reviewer's name : ....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : ....

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765159

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Beam Based Technologies

Author : Dr Batalha Rodolfo (ISQ - Instituto de Soldadura e Qualidade, Portugal)

Co-author(s) : Mr Carvalho André, Prof Dr Evans Guiomar (University of Lisbon, Portugal), Dr Morais Paulo, Dr Cabral Ana (ISQ - Instituto de Soldadura e Qualidade, Portugal)

Title : Laser-Powder Bed Fusion Of Ti-Based Alloys For Biomedical Applications

Keyword(s) :
Laser-Powder Bed Fusion; Additive Manufacturing; Ti Alloys; Biocompatible

Abstract :
The focus of this work is to process new biocompatible Ti alloys solely constituted of non-toxic elements by laser-powder bed fusion (L-PBF), a metal additive manufacturing (AM) technology. The main L-PBF processing parameters such as laser power and scanning speed were defined to obtain highly dense samples. The effects of the addition of a second particle and the influence of the scanning strategy on the microstructure of the Ti-based alloys were investigated, showing the possibility for in-situtailoring the material properties in the L-PBF process. Finally, some prototypes were manufactured proving the feasibility of manufacturing parts of Ti-based biocompatible alloys with complex geometry by L-PBF.

Innovative Aspect(s) :
The impacts of the present work are related to the availability of new biocompatible Ti alloys produced by additive manufacturing. The envisioned benefits are a microstructure designed for enhanced functional performance, improved biomechanical compatibility, and the realization of implant designs with increased functionality.

Reviewer's name : ....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : ....

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EURO PM2023 CONGRESS & EXHIBITION
01-04 October 2023

Paper Number : EP235765271

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Beam Based Technologies

Author : Miss Lerda Serena (Politecnico di Torino, Italy)

Co-author(s) : Dr Marchese Giulio, Dr Bassini Emilio, Prof Lombardi Mariangela, Prof Ugues Daniele, Prof Fino Paolo, Prof Biamino Sara (Politecnico di Torino, Italy)

Title : Microstructure And Heat Treatment Investigation Of Inconel 625|TiC Composite Produced By Laser Powder Bed Fusion

Keyword(s) :
Inconel 625; Laser Powder Bed Fusion; Recrystallization; Microstructure; Ni-Based Superalloy; Composites

Abstract :
Inconel 625 (IN625) is a Ni-based superalloy characterized by good mechanical performance and excellent oxidation resistance up to 1000°C. In order to enhance the mechanical performances of the IN625, ceramic particles can be added to the alloy. In the current work, the IN625 powder was mixed with submicrometric TiC particles and then processed by the laser powder bed fusion (LPBF) process. The microstructure of the as-built and heat-treated composite was compared to the base alloy in order to investigate the variations in terms of microstructure. The as-built condition of the IN625 and composite exhibited columnar grains with very fine dendritic structure along the building direction. Differently, a high-temperature solution annealing involved recrystallization of the IN625 samples while the composite still presented columnar grains, thus showing higher microstructure stability at elevated temperatures.

Innovative Aspect(s) :
The production of Ni-based composites by laser powder bed fusion (LPBF) can be an effective way to fabricate materials with high mechanical performance. In this work, Inconel 625 alloy was reinforced by TiC particles to improve mechanical properties and microstructure stability under heat treatments. This work investigates the beneficial effect of the reinforcement of TiC particles inside the Inconel 625 alloy. For this purpose, the microstructure of both IN625|TiC composite and Inconel 625 was characterized and compared in the as-built and heat-treated conditions.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765364

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Beam Based Technologies

Author : Dipl-Ing Khademzadeh Saeed (Chalmers University of Technology, Sweden)

Co-author(s) : Ing Pigato Mirko (University of Padova, Italy), Prof Nyborg Lars (Chalmers University of Technology, Sweden)

Title : Laser Powder Bed Fusion Of H13 Tool Steel|CuSn10 Bimetallic Structures: Improvement Of Interfacial Bonding And Mechanical Strength

Keyword(s) :
Multimaterials; Laser Powder Bed Fusion; Mechanical Strength; Tool Steel

Abstract :
H13 hot work tool steel and CuSn10 multi-material structures were fabricated via laser powder bed fusion. Aiming at higher bonding strength, a transition layer was considered either through employing modified process parameters for interfacial layers or by using a transition material e.g., Ni-based alloy. Interfacial characteristics were analyzed using X-ray diffraction, scanning electron microscopy, energy dispersive spectroscopy and electron back-scattered diffraction techniques. Relationships among process parameters (laser power, scanning speed, and scanning strategy) and mechanical performance were elucidated. The bonding strength of bimetallic structures was evaluated through uniaxial tensile tests. The highest strength reached 450 MPa, which is higher than that of the CuSn10 and corresponds to a structure with a defect-free transition layer induced by optimum process parameters as well as smooth hardness change at the interface.

Innovative Aspect(s) :
This works presents innovative approaches in AM of defect-free multimaterials using LPBF.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765447

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Beam Based Technologies

Author : Dr Braun Jakob (University of Innsbruck, Austria)

Co-author(s) : Dr Kaserer Lukas, Prof Dr Leichtfried Gerhard (University of Innsbruck, Austria)

Title : Possibilities For Reducing The Moisture Content In Metallic Powders And Its Effect On The LPBF Process

Keyword(s) :
LPBF; Impurities; Moisture Content; Defect Generation; Powder Cleaning

Abstract :
In this paper, the authors present the influence of moisture in metal powder on the LPBF process for selected alloys, based on the effect on microstructure and mechanical properties. Methods for measuring moisture content in metallic powders are presented and, as the focus of the study, methods for reducing moisture in the metal powder are presented. The methods of vacuum drying, oven treatment and a specially developed plasma cleaning for metallic powders in the LPBF process are compared. The achievable value of powder drying is put in relation to its applicability in the industrial LPBF process environment and user recommendations are given for the necessity and type of powder drying of as-delivered, stored and recycled LPBF powders.

Innovative Aspect(s) :
- First comparison of different drying methods for reducing moisture in the metal powder for LPBF.- Unveiling a new plasma cleaning method for moisture and other contaminants in metal powders, which offers an improvement in component properties of parts made from stored and recycled powders.- The effects of improper transport conditions on the side of the powder manufacturer and improper storage|handling by the user on the achievable component quality.- Characterization of defects caused by small moisture impurities in the powder that do not affect the flowability of the powder, but still lead to cracks, porosity or inclusions in the respective alloy system.

Reviewer's name : ....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : ....

Notes to author : ....

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765625

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Beam Based Technologies

Author : Miss Lupi Giorgia (Politecnico di Milano, Italy)

Co-author(s) : Dr Teixeira Oliveira de Menezes João, Dr Belelli Filippo, Prof Castrodeza Enrique Mariano, Prof Casati Riccardo (Politecnico di Milano, Italy), Mr Bruzzo Francesco (Fraunhofer IWS, Germany), Prof Volpp Joerg (Luleå University of Technology, Sweden)

Title : Fracture Toughness And Fatigue Properties Of AlSi10Mg Alloy Produced By Direct Energy Deposition With Different Crack Plane Orientations

Keyword(s) :
AlSi10Mg Alloy; Direct Energy Deposition; Tensile Properties; Fracture Toughness; Fatigue Properties; Crack Orientation Anisotropy

Abstract :
In this work, fracture, fatigue, and tensile properties of AlSi10Mg alloy processed by Direct Energy Deposition (DED) in atmospheric conditions were assessed. Fracture SE(B) and fatigue ESE(T) specimens were printed and machined having the cracks in three different crack plane orientations for evaluating the performance and influence of crack orientation on mechanical properties. Samples were subjected to different heat treatments routes. Microstructural and fractographic analyses were performed by FE-SEM. It was observed that the mechanical and fracture behavior of the material is strongly affected by the crack plane orientation and porosity distribution. Moreover, fatigue crack growth studies were backed by EBSD analyses, the results shed light on the effect of melt pool boundaries, grain boundaries and crystallographic orientation of grains on the crack path for the different crack plane. orientations.

Innovative Aspect(s) :
The DED of Al alloys is challenging due to their high reflectivity, high thermal conductivity, and high residual stresses. Manufacturing of Al parts characterized by sound microstructure is still rather challenging. To the best of authors knowledge, no studies on fracture toughness and fatigue crack growth of AlSi10Mg alloy produced by DED are available in the open literature. Such data are extremely interesting from an industrial standpoint. A complete set of mechanical tests was coupled with an in-depth study of the microstructural features, leading to a comprehensive understanding of the material behavior.

Reviewer's name : ……………………………………………………………………………………………………….

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : ……………………………………………………………………………………….

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764626

Requested presentation type : Poster Presentation

Topic : Consolidation Technologies **Subtopic :** AM Beam Based Technologies

Author : Ms Soares Barreto Erika (Leibniz-Institute for Materials Engineering - IWT, Germany)

Co-author(s) : Ms Soares Barreto Erika, Prof Dr Mädler Lutz, Dr Ing Ellendt Nils (University of Bremen, Germany), Mr Kaja Mohideen Nabeel Ahamed, Prof Dr Mädler Lutz (Leibniz-Institute for Materials Engineering - IWT, Germany)

Title : Increasing The Powder Yield On The Additive Manufacturing Of Cu47Ti34Zr11Ni8 Metallic Glass

Keyword(s) :
Metallic Glasses; Gas-Atomization; Laser-Based Powder Bed Fusion of Metals (PBF-LB|M); Powder Yield

Abstract :
Additively manufactured (AM) Cu-Ti-based metallic glasses represent advantages to developing low-cost alloys that meet performance requirements for industrial applications. With high-strength and reasonable glass-forming ability, they possess economically attractive starting materials and small oxygen sensitivity. It is also of economic interest to increase the usable powder fraction of the AM feedstock. Larger particles are preferred because they uptake less oxygen during the gas-atomization, as they have a lower surface-to-volume ratio. Nonetheless, the drawback is seen in the higher chance of defect formation and reduced cooling rates, which may cause crystallization as thicker layers are required. Here, the processability of commercial purity, argon-atomized Cu47Ti34Zr11Ni8 alloy via laser powder bed fusion (PBF-LB|M) is investigated using a powder feedstock with up to 90 µm particles. Suitable laser parameters and strategies are investigated to enhance vitrification and reduce defect generation. The present contribution enables significant knowledge gains to the processability of economical metallic glasses.

Innovative Aspect(s) :
By increasing the powder fraction used as feedstock for PBF-LB|M, a higher yield is obtained from the gas-atomization process. This is associated with a reduced production cost, better usage of resources (such as the material feedstock, gas, crucible, and others), and energy-saving. The consequences are the better efficiency of the powder metallurgy production chain and the enhanced competitiveness of metallic glasses towards conventional crystalline alloys. In addition, new scanning strategies support also the processability of metallic glasses with a reduced glass-forming ability, which normally faces (partial) crystallization during additive manufacturing.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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Paper Number : EP235765420

Requested presentation type : Poster Presentation

Topic : Consolidation Technologies **Subtopic :** AM Beam Based Technologies

Author : Ms Soares Barreto Erika (Leibniz-Institute for Materials Engineering - IWT, Germany)

Co-author(s) : Ms Soares Barreto Erika, Prof Dr Mädler Lutz, Dr Ing Ellendt Nils, Mr Kaja Mohideen Nabeel Ahamed, Prof Dr Mädler Lutz (Leibniz-Institute for Materials Engineering - IWT, Germany)

Title : Increasing The Powder Yield On The Additive Manufacturing Of Cu47Ti34Zr11Ni8 Metallic Glass

Keyword(s) :
Metallic Glasses; Gas-Atomization; Laser-Based Powder Bed Fusion of Metals (PBF-LB|M); Powder Yield

Abstract :
Additively manufactured (AM) Cu-Ti-based metallic glasses represent advantages to developing low-cost alloys that meet performance requirements for industrial applications. With high-strength and reasonable glass-forming ability, they possess economically attractive starting materials and small oxygen sensitivity. It is also of economic interest to increase the usable powder fraction of the AM feedstock. Larger particles are preferred because they uptake less oxygen during the gas-atomization, as they have a lower surface-to-volume ratio. Nonetheless, the drawback is seen in the higher chance of defect formation and reduced cooling rates, which may cause crystallization as thicker layers are required. Here, the processability of commercial purity, argon-atomized Cu47Ti34Zr11Ni8 alloy via laser powder bed fusion is investigated using a powder feedstock with up to 90 µm particles. Suitable laser parameters and strategies are investigated to enhance vitrification and reduce defect generation. The present contribution enables significant knowledge gains to the processability of economical metallic glasses.

Innovative Aspect(s) :
By increasing the powder fraction used as feedstock for PBF-LB|M, a higher yield is obtained from the gas-atomization process. This is associated with a reduced production cost, better usage of resources (such as the material feedstock, gas, crucible, and others), and energy-saving. The consequences are the better efficiency of the powder metallurgy production chain and the enhanced competitiveness of metallic glasses towards conventional crystalline alloys. In addition, new scanning strategies support also the processability of metallic glasses with a reduced glass-forming ability, which normally faces (partial) crystallization during additive manufacturing.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : ....

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765308

Requested presentation type : Poster Presentation

Topic : Consolidation Technologies **Subtopic :** AM Beam Based Technologies

Author : Dr Ing Smolina Irina (Wroclaw University of Science and Technology, Poland)

Co-author(s) : Dr Ing Gruber Konrad, Dipl-Ing Stopyra Wojciech, Dipl-Ing Kasprowicz Marcin, Dr Ing Kobiela Karol (Wroclaw University of Science and Technology, Poland)

Title : Challenges In PBF-LB|M Processing Of Al5052 Aluminium Alloy

Keyword(s) :
Aluminium; PBF-LB|M; Microstructure; Porosity; Additive Manufacturing

Abstract :
The interest in laser beam powder bed fusion (PBF-LB|M) additive manufacturing (AM) of aluminium is constantly growing. Currently, the most popular aluminium' AM-dedicated alloys are based on Al-Si (4xxx series), while other Al-alloy groups are in the minority. One of the least widespread groups of Al alloys is the Al-Mg 5xxx series. Currently, only two modified alloys can be processed by PBF-LB|M. In this work, we present the main technological challenges in PBF-LB|M processing, and the Al5052 alloy of the 5xxx series is used as an example. Discussions include hot and liquation cracking. The analysis process parameters impact porosity, cracks, and microstructure are presented to illustrate the above-mentioned challenges. Potential directions to overcome the challenges are also introduced.

Innovative Aspect(s) :
Challenges In PBF-LB|M Processing Of Al5052 Aluminium Alloy as an example of processing 5xxx series of aluminium alloys.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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Paper Number : EP235765321

Requested presentation type : Poster Presentation

Topic : Consolidation Technologies **Subtopic :** AM Beam Based Technologies

Author : Dr Ing Montealegre-Melendez Isabel (Universidad de Sevilla, Spain)

Co-author(s) : Dr Arevalo Cristina, Dr Ing Perez-Soriano Eva María (Universidad de Sevilla, Spain), Ing Ariza Enrique, Dipl-Ing Kitzmantel Michael, Dr Ing Neubauer Erich (RHP Technology GmbH, Austria)

Title : Manufacturing Of Hastelloy C22 Specimens Via Plasma Metal Deposition To Determinate The Influence Of The Processing Parameters On The Final Properties

Keyword(s) :
Plasma Metal Deposition; Hastelloy C22; Processing Parameters

Abstract :
The starting material was powder manufactured via Plasma Atomization Process; the composition of this powder was the standard Hastelloy C-22. The device employed was a Plasma Metal Deposition one. The argon atmosphere was constant in the manufacturing cycles.In previous studies this material has been processed via PMD varying the granulometry of the powders, however, the parameters remained constant. Therefore, it seeks to provide an answer to the optimal manufacturing parameters depending on the fixed demands.This work aims to investigate the effect of the processing parameters of specimens made from Hastelloy C-22 powder fabricated via Plasma Metal Deposition (PMD), with the objective of deepening the knowledge of this material regarding the composition and microstructure related with the goodness of this additive manufacturing technique.The obtained results confirmed the influence of the parameters on the final properties.

Innovative Aspect(s) :
Regarding the innovative aspects of this work, the development of specimens from Hastelloy C-22 powder via Plasma Metal Deposition offered the possibility of reducing the cost of material and energy. To manufacture components the fewer resources spent, the best sustainability and the rentability of a technique achieved.In the framework of metals, Hastelloy C-22 is a nickel-based austenitic alloy. It presents excellent corrosion resistance, in addition to good mechanical properties. Among its properties, it can include high resistance to pitting and crevice corrosion, in addition to stress corrosion cracking. Therefore this alloy is attractive when long-live durability is demanded. There is a need for studying the relationship between the processing parameters and the final properties of the components produced in order to obtain specimens under the requirements.In summary, this work contributed to increasing the knowledge of PMD and Hastelloy C22.

Reviewer's name : ....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765348

Requested presentation type : Poster Presentation

Topic : Consolidation Technologies **Subtopic :** AM Beam Based Technologies

Author : Ms Schwerz Claudia (Chalmers University of Technology, Sweden)

Co-author(s) : Prof Dr Nyborg Lars (Chalmers University of Technology, Sweden)

Title : In-situ Monitoring Targeted To Macroscopic Deviations In Laser Powder Bed Fusion

Keyword(s) :
Process Monitoring; Defects; Distortion; Powder Bed

Abstract :
The application of laser powder bed fusion (LPBF) as a reliable manufacturing technology still faces obstacles, thanks partly to the frequent occurrence of process defects. Delamination and geometric deviations from the nominal model are examples of issues that may occur in the process. In-situ monitoring can potentially be employed to identify diverse anomalies during manufacturing. In this work, the use of optical tomography and powder bed monitoring for the identification of macroscopic deviations is assessed. The manufactured parts were affected by factors such as irregularities in the powder spreading and inadequate supporting, which induced distortions, surface deviations and large voids. The monitoring systems are used to flag different errors by identification of trouble spots that culminated in deviations that severely compromised the integrity of the parts. Three-dimensional reconstruction of the parts based on the layerwise output of the monitoring system and comparison to the nominal model is also performed.

Innovative Aspect(s) :
There is a consensus that in-situ monitoring has great potential to identify anomalies in laser powder bed fusion. Many are the sources of anomalies in the process, but the most relevant ones are those that lead to part scraping. We show how some macroscopic anomalies that severely compromise the integrity of the parts can be flagged by in-situ monitoring.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : ....

Notes to author : ....

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Paper Number : EP235765663

Requested presentation type : Poster Presentation

Topic : Consolidation Technologies **Subtopic :** AM Beam Based Technologies

Author : Miss Maia Mariana (FEUP, Portugal)

Co-author(s) : Miss Fernandes Adriana, Miss Oliveira Elsa (FEUP, Portugal), Mr Costa José, Dr Sequeiros Elsa (LAETA|INEGI, Portugal)

Title : Dimensional, Surface, Microstructural, And Mechanical Characterization Of A Topologically Optimized Aluminum Bicycle Pedal Crank Produced By Laser Powder Bed Fusion

Keyword(s) :
Bike Crank; AlSi10Mg; LPBF; DfAM; Topology Optimization

Abstract :
AM technologies have unlocked new methods of creating new products, allowing a wide range of geometric shapes that are impossible or highly costly through conventional ways. This work explores the topology optimization and characterization of a bicycle pedal crank in AlSi10Mg produced by LPBF. The design for AM was developed using Fusion 360 and nTopology. It reduced 20% of the initial mass, and the component was validated according to ISO 14781. AlSi10Mg powders were evaluated. The part was produced, and surface roughness and dimensions, microstructure, and Vickers hardness were assessed in the final part. The dimensional analysis showed a mean deviation of 7%. The final part presents a hardness of 134±3 HV0.3. The component accomplishes all main requirements expected for product applications; however, finishing procedures are needed due to high roughness. AM proved to be an alternative process for manufacturing a lightweight component, thus similar performance to conventional.

Innovative Aspect(s) :
This study mostly demonstrates the strengths of using AM technologies, especially LPBF, in producing add-value components. It explores the procedure for a new add-value component based on a “conventional” component. It includes not only the topology optimization but also the manufacturing and characterization of the component. It is a complete study from the design to the final part, including material characterization.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

Technical Programme Committee
15th February 2023

CONSOLIDATION TECHNOLOGIES

AM SINTER BASED TECHNOLOGIES

EPMA
european powder metallurgy association

EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235730662

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Sinter Based Technologies

Author : Dr Mueller Christian (Emery Oleochemicals, Germany)

Co-author(s) : Mr Folkert Patrick (Emery Oleochemicals, Germany)

Title : Influence Of Printing Parameters In FFF Of Metal Filaments

Keyword(s) :
Additive Manufacturing; 3D Printing; Metall FFF; Feedstock Filaments

Abstract :
For the reason described under "innovative aspects", when printing with metal feedstock filaments it is important to understand the influence of printing parameters such as nozzle temperature, flow and others and the aspect and mechanical properties of the printed green part for different metals.Printing is performed on a 3DGence MP260 printer which allows free adjustment of various printing parameters. The results were evaluated visually and by mechanical testing of tensile and elongation.This is to understand the effect of shaping technology and its parameters on the characteristics of a part made as a prototype by Metal FFF and big scale series production by PIM.

Innovative Aspect(s) :
Metal FFF as a feedstock- and sinter-based AM technology has gained huge interest in recent years. In contrast to powder bed-based technologies, the printers are affordable and widely used. Even small companies and universities can easily invest in a decent FFF printer.That is why metal feedstock based filaments prepare the ground not only for sinter-based AM, but powder metallurgy in general. This is supported by the fact that the binder system used in the metal filaments which are analyzed in this presentation has been used in PIM for the last three decades. Individual prototypes and small lot series by metal FFF and large series production by PIM are possible with the same binder system just by another shaping technology.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235735787

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Sinter Based Technologies

Author : Dr Ing Daoud Haneen (Neue Materialien Bayreuth, Germany)

Co-author(s) : Ms Mese Esma (Neue Materialien Bayreuth, Germany), Mr Hofmann Wlofgang, Mr Würtele Peter (Peter Würtele GmbH, Germany), Prof Dr Glatzel Uwe (University of Bayreuth, Germany)

Title : Additive Manufacturing Of Non-weldable Ni-based Alloy MAR-m247 By Fused Filament Fabrication: Microstructure And Mechanical Properties

Keyword(s) :
Non-Weldable Alloys; MAR-m247; Fused Filament Fabrication; Sintering; Mechanical Properties

Abstract :
Non-weldable materials such as various Ni-based superalloys exhibit high thermo-mechanical properties as well as a good corrosion resistance at high temperatures. However, the advantages of additive manufacturing processes are not yet profited for difficult and non-weldable alloys due to their poor weldability. In this paper, fused filament fabrication (FFF) is applied for manufacturing complex components from non-weldable Ni-based superalloy (MAR-m247). The elimination of the high cracking susceptibility of MAR-m247 during filament fabrication and sinter-based process will be highlighted. The fabrication of highly filled filaments with 94 wt.% of metal is described. The effects of process parameters, debinding and sintering on the tensile strength and fatigue behavior at room and high temperatures are discussed. The microstructure of the sintered specimens after post-heat treatment was investigated by electron microscopy. The porosity in the sintered specimens is less than 2%, while the total shrinkage is about 14%.

Innovative Aspect(s) :
Additive manufacturing of non-weldable Ni-based alloy MAR-m247 by fused filament fabrication with porosity in the sintered specimens is less than 2%, without HIP process.
Fabrication of highly filled filaments with 94 wt.% of metal without cracks.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235740488

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Sinter Based Technologies

Author : Ing Reineke Lea (Fraunhofer IFAM, Germany)

Co-author(s) : Dr Hein Sebastian Boris (Fraunhofer IFAM, Germany)

Title : Influence Of Powder Packing Density On Binder Saturation And Wetting Behavior In Metal Binder Jetting

Keyword(s) :
Metal Binder Jetting; Powder-Binder-Interaction; Wetting Behavior; Powder Characteristics; Binder Saturation

Abstract :
Metal Binder Jetting (MBJ) has an increasing attention in Additive Manufacturing because of its serial production potential. The aim of this work is to get a better understanding of the powder-binder-interaction for better process control and consequently a reduction in the number of iteration stages in material-specific process development, which saves costs, effort as well as material resources and printing capacity. Depending on the powder packing density the equilibrium saturation and wetting behavior changes. A better understanding of capillary forces, the effect of powder agglomeration and powder bed porosity distribution on the powder-binder-interaction will improve the part quality. A suitable parameterization of the MBJ printing processes for specific powder-binder combinations, based on the powder characteristics and the powder-binder interaction will improve the part density, accuracy and surface quality.

Innovative Aspect(s) :
The innovation of this work is the analysis of binder saturation and wetting behavior depending on the powder packing density.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235742275

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Sinter Based Technologies

Author : Dr Ing Rahmani Ramin (Centro de Interface Tecnológico Industrial (CITIN), Portugal)

Co-author(s) : Dr Silva Hugo, Mr Pinto André, Dr Ing Ivan Lopes Sérgio, Mr Lomba Emanuel (Centro de Interface Tecnológico Industrial (CITIN), Portugal), Prof Resende Pedro, Prof Abrantes João (Escola Superior de Tecnologia e Gestão, Instituto Politécnico de Viana do Cas

Title : Additive Manufacturing And Powder Metallurgy Integrated Technologies Applied To Antiviral|antibacterial Human Machine Interfaces: An Industry 5.0 Use Case

Keyword(s) :
Powder Bed Fusion; Selective Laser Melting; Powder Metallurgy; Spark Plasma Sintering; Virucidal Materials; Human Machine Interface

Abstract :
The 5th industrial revolution seeks for digital transformation, smarter and valuable connection of operator-device and human machine interface (HMI). Compared to Industry 4.0, the 5th industrial revolution is more technology-driven and more focused on automation approach. To tackle the problem of keeping the frequently touched surfaces disinfected, compact design of components (part manufacturing instead of assembly), and lightweight design of complicated structures, new high-tech materials have been developed via combined powder bed fusion-PBF and spark plasma sintering-SPS techniques. The approach undertaken is based on two processes: first, the fabrication of porous structures (lattice, scaffolds, triply periodic minimal surfaces, hierarchical gradient) of copper alloys (CuNi2SiCr or Cu15Ni8Sn) by laser powder bed fusion, was carried out, and second, the filling of the base material with Ag|TiO2 for virucidal material by plasma sintering or isostatic pressing (SPS or HIP) for biomedical applications, was performed. CuNi2SiCr?Ag|TiO2 metal?ceramic composites will have antibacterial properties.

Innovative Aspect(s) :
CuNi2SiCr–Ag|TiO2 metal–ceramic composites will have antiviral, antibacterial and antiadhesive properties, which aim to reduce deposition of bacteria and viruses on various applications, such as laboratory surfaces, doorknobs, elevator panels, with mechanical and tribological properties. Effectiveness of these materials can be proved against the bacteriophage Phi6 (known model system for RNA–enveloped viruses) or Covid19 survival|spreadability for a wide range of vitro applications. Self-cleaning parts, such as laboratory equipment surfaces, buttons, panels, with desired and durable design, are the outcomes of the present work.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235761118

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Sinter Based Technologies

Author : Mr Zissel Kai (Linde GmbH, Germany)

Co-author(s) : Mr Bhattacharya Sankhya, Mrs Bernardo Quejido Elena, Mr Forêt Pierre (Linde GmbH, Germany), Prof Hryha Eduard (Chalmers University of Technology, Sweden)

Title : Key Aspects Of The Debinding & Sintering Atmosphere For 17-4 PH Stainless Steel Fabricated Via Binder Jetting

Keyword(s) :
Binder Jetting; Processing Atmosphere; Debinding Atmosphere; Sintering Atmosphere; Gas Composition; 17-4 PH; Stainless Steel; Thermal Decomposition; Thermal Analysis; Shrinkage; Microstructure

Abstract :
Binder Jetting (BJT) of metals is a multi-step process that relies on the sintering of printed parts to reach the intended material properties. A crucial but often overlooked step after printing is debinding, which is impacted by the processing atmosphere and strongly determines the efficiency of the following sintering process. A tailored processing atmosphere composition and flow can facilitate decomposition of the binder and efficient removal of the decomposition products. The success of debinding and sintering is closely correlated, and both require a specific processing atmosphere in terms of purity and composition in order to achieve the required material properties and tolerances of the sintered component. In this study, different atmospheres for the debinding and sintering of 17-4 PH stainless steel manufactured via BJT were studied utilizing thermal analysis followed by microstructural examination to determine the effectiveness of debinding and sintering processes.

Innovative Aspect(s) :
Investigation of different debinding atmospheres for 17-4 PH green parts manufactured via Binder Jetting.
Investigation of different sintering atmospheres for 17-4 PH green parts manufactured via Binder Jetting Correlation between successful debinding and sintering for 17-4 PH stainless steel.
Investigation of densification behavior based on the processing atmosphere for BJT 17-4 PH.
Investigation of decomposition behavior by thermal analysis for Binder Jetting of 17-4 PH.
Microstructure investigation based on different processing atmospheres for 17-4 PH stainless steel.
Guideline for proper debinding & sintering atmospheres for 17-4 PH fabricated by Binder Jetting.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235761372

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Sinter Based Technologies

Author : Ing Zanon Matteo (Ecka Granules Germany GmbH | Kymera International, Germany)

Co-author(s) : Mr Müller Armin, Mr Kossakowski Darek (Ecka Granules Germany GmbH | Kymera International, Germany), Dr Ing Roch Aljoscha (AM Extrusion GmbH, Germany), Ing Croteau Joseph, Mr Pelletiers Tom (SCM Metal Products | Kymera International, USA)

Title : Fused Filament Fabrication Of Non-Ferrous Alloys

Keyword(s) :
Fused Filament Fabrication; Aluminium; Copper

Abstract :
Among the sinter-based technologies, Fused Filament Fabrication (FFF) is proving itself as a low capital investment, small series approach to 3D printing. Firmly established for plastics, it can be extended to metals by composite filaments with around 60% metal loading by volume. The large quantity of binder, necessary for the filament compounding and extrusion, poses special challenges to the debinding process. This becomes especially true with reactive materials such as aluminium, but also when targeting high electrical conductivity in copper, which is extremely sensitive to residual impurities. Metal powder and binder expertise must then be brought together to enable this technology to compete in the 3D printing market. The current joint work presents results with both aforementioned classes of non-ferrous powders, highlighting the impact of debinding procedure and powder characteristics on the final sintered and microstructural properties. Effect of heat treatment is also investigated for aluminium-based grades.

Innovative Aspect(s) :
First paper ever on successful Al-based-FFF. On copper over 90% IACS conductivity is demonstrated.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION
01-04 October 2023

Paper Number : EP235762089

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Sinter Based Technologies

Author : Dipl-Ing Vogel Lucas (University Pforzheim, Germany)

Co-author(s) : Prof Dr Zimmermann Martina (TU Dresden, Germany), Prof Dr Burkhardt Carlo (University Pforzheim, Germany)

Title : Impact Of Printing Parameters On Shrinkage And Densification Behaviour Of 316L Stainless Steel Parts Produced By Lithography-based Metal Manufacturing

Keyword(s) :
Sinter Based AM; Lithography-Based Metal Manufacturing; Sintering; 316L Stainless Steel; Densification Behavior; Sintering Behavior

Abstract :
The need for additive manufactured parts with high dimensional accuracy and high surface quality leads to innovation in sinter-based AM. A promising approach is the emerging lithography-based metal manufacturing (LMM) which combines powder metallurgy and stereolithography. As this is a novel technology, this study aims to investigate the printing parameters: degree of powder filling of the feedstock, layer thickness, coating speed, coating mode and size of the material roll, with the help of a DoE. Building on previously published investigations of green part characteristics, the samples are debinded and sintered. The parts are analysed with focus on geometrical accuracy and densification. The DoE enables analysis of correlations between printing parameters and densification behaviour. The study improves the understanding of the technology significantly, enabling further optimization.

Innovative Aspect(s) :
This study is the follow-up research building to last year's published study on the green part characteristics. As the LMM technology is a novel approach only little information on specific parameter-property-correlation is published. Therefore, this article describes correlation between parameters and final part properties and shows the capabilities of the novel technology. These correlations can be used to fine tune the process and bring it closer to its potential. So far the technology is capability to manufacture parts with high surface quality and filigree structures is outstanding and can only be improved with greater understanding of these correlations. Furthermore, limitations and correlations of the process are explained and suggestions for further improvements are shown.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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Paper Number : EP235762586

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Sinter Based Technologies

Author : Dipl-Ing Staudigel Christian (Headmade Materials GmbH, Germany)

Co-author(s) : Dipl-Ing Fischer Christian (Headmade Materials GmbH, Germany)

Title : ColdMetalFusion - Reliable Serial Production In Metal AM

Keyword(s) :
ColdMetalFusion; Sinter-Based AM; Reproducibility; Reliability; Dimensional Accuracy

Abstract :
Headmade Materials pushes the Powder Metallurgy further into the Metal AM market with its sinter-based AM-technology ColdMetalFusion and partners with industry leaders in the ColdMetalFusion Alliance to leverage the potential of reliable serial production in Metal AM. Since the ColdMetalFusion process runs on standard machines of AM and PM the robustness and reliability of the process is unmatched and is proven by investigations on dimensional accuracy and reproducibility in this study. Multiple jobs with the same part arrangement consisting of test bars aligned in X-, Y-, and Z-direction over the whole build volume were built and characterised. Outstanding results were achieved due to the combination of mature SLS technology and low, homogeneous shrinkage during sintering in all three dimensions.

Innovative Aspect(s) :
With the ColdMetalFusion technology the sinterbased approach in Additive Manufacturing was transferred for the first time successfully to plastic laser sintering machines (SLS) by Headmade Materials. Also for the first time the green parts from CMF can be successfully machined as well as debinded and sintered with conventional green parts from MIM or powder pressing, allowing an easy integration in existing manufacturing chains. Compared to other sinterbased technologies CMF stands out with its combination of green part strength, materials properties, output and efficiency.

Reviewer's name : ……………………………………………………………………………………………….

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION
01-04 October 2023

Paper Number : EP235762850

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Sinter Based Technologies

Author : Ing Norda Michael (Fraunhofer IFAM, Germany)

Co-author(s) : Ing Reineke Lea, Dr Hein Sebastian Boris (Fraunhofer IFAM, Germany), Ing Wonn David (ExOne GmbH, Germany)

Title : Investigation Of Binder Droplet Impact In Metal Binder Jetting

Keyword(s) :
Metal Binder Jetting; Saturation; Powder; Binder; Interaction

Abstract :
The metal binder jetting (MBJ) process is a powder bed based Additive Manufacturing process, which is attracting growing interest. In this process, a liquid binder deposited by a print head is bonding the powder particles to create green parts, which are then consolidated by a subsequent sintering step. The parameters of this liquid deposition are crucial for high quality parts because the droplet impact influences the quality. In this work, different droplets volumes are investigated by using two individual print heads in order to describe the influence of size, weight and amount of the droplets on the parts´ quality. The experiments are conducted using 316L Stainless Steel in two different sizes and Titanium alloy Ti6Al4V. Several properties of powders and parts are analyzed such as powder size distribution, green part density, powder bed density and dimensional tolerances. Furthermore, all samples are sintered and porosity as well as shrinkage are measured.

Innovative Aspect(s) :
The goal of the project is to improve the understanding of the binder particle interaction in Metal Binder Jetting. The innovative aspects are the simultaneously investigated properties of the binder droplets. Due to two individual print heads, which burst 10 and 30 pL, respectively, it is possible to analyse the effect of size, weight and amount of the droplets. It will show the impact of the binder onto the powder bed and individual powder particles. The final vision is to create an understanding for end users, powder suppliers and system manufacturers, how the quality of the parts can be improved efficiently and to push the technology forward.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235763064

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Sinter Based Technologies

Author : Ms Abando Nerea (Laboratory for Nanometallurgy, Department of Materials, ETH Zürich, Switzerland)

Co-author(s) : Mr Pellin Raphael, Prof Dr Spolenak Ralph (Laboratory for Nanometallurgy, Department of Materials, ETH Zürich, Switzerland), Dr Hadian Amir, Dr Clemens Frank (Laboratory for High Performance Ceramics, Empa, Switzerland)

Title : Nb As A Sintering Aid In Functional NiTi Filaments For Additive Manufacturing

Keyword(s) :

Abstract :
The combination of active materials with complex geometries as enabled by additive manufacturing techniques facilitates access to unprecedented mechanical responses. Among different printing methods, filament-based materials extrusion grants extraordinary design freedom for a wide range of metals. Yet, the final properties are often corrupted by poor sintering behavior. Current filament compositions are tailored towards performance improvement via polymeric additives. However, the effect their metallic counterparts is still unexplored.Here, we propose functional filaments as a solution for poor sintering performance showed by NiTi shape memory alloys processed through powder metallurgy approaches. By adding Nb powder as a sintering aid to prealloyed NiTi feedstock, the final density of the printed parts is significantly improved. This is obtained due to the formation of a eutectic during liquid phase sintering. Whereas the phase transition temperature responsible for the shape memory effect is shifted and the hysteresis widened, the Nb-NiTi systems preserve actuation capabilities.

Innovative Aspect(s) :
The innovation in this study can be considered two-fold: the addition of Nb as a sintering aid and the use of angular Nb powder in contrast to the more common spherical one. The introduction of elemental Nb as a filament constituent showcases the possibility to include additional purpose within the feedstock allowing for a fine adjustment according to the specific needs. In this case, the metallic additive is used for enhanced sintering performance while ensuring the martensitic transformation present in NiTi alloys that is responsible for the actuation.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235763105

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Sinter Based Technologies

Author : Ms Kancharla Deekshitha (Fraunhofer IWS, Germany)

Co-author(s) : Mr Greifzu Moritz (Fraunhofer IWS, Germany), Mr Marquardt Axel (TU Dresden, Germany), Ms Eckardt Joanna (Fraunhofer IWS, Germany)

Title : Evaluation Of Grain Growth Using Master Sintering Curve And Dilatometry Data For Binder Jetted Parts

Keyword(s) :
Metal Binder Jetting; SS316L; Sintering; Master Sintering Curve; Dilatometry; Grain Growth

Abstract :
Metal Binder jetting (BJ) is an additive manufacturing technology that requires a series of post-processing steps to obtain the final product, with sintering being one of the important steps. Multiple coupled phenomena such as densification, coarsening, grain growth, and evolution of microstructure, influence sintering. Grain growth during sintering impacts the final mechanical properties and the densification of a material. The most common method to evaluate the grain growth behaviour is conducting interrupted-sintering analysis followed by microscopy which is a time-consuming process. This work intends to estimate the grain growth during sintering from the shrinkage data obtained from dilatometry. The concept of integrating a master sintering curve (MSC) into the Skorohod-Olevsky-based model is explored to predict grain growth and sintering behaviour. The main aim is to evaluate the adaptability of this approach to BJ to reduce the time and effort to understand the sintering behaviour.

Innovative Aspect(s) :

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235763690

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Sinter Based Technologies

Author : Dr Tabares Eduardo (Group of Powder Technology - UC3M, Spain)

Co-author(s) : Ing García de la Camacha Ángela, Dr Jiménez-Morales Antonia, Dr Gordo Elena (Group of Powder Technology - UC3M, Spain), Dipl-Ing Schsuchnigg Stephan, Dr Kukla Christian, Dr Cano Cano Santiago (Montanuniversitaet Leoben, Austria)

Title : Validation Of Alternative Binders For Pellet Extrusion 3D Printing Of 316L Steels

Keyword(s) :
Composite Extrusion Modelling; 3D Printing; Additive Manufacturing; 316L

Abstract :
Composite Extrusion Modelling (CEM) is an attractive group of Additive Manufacturing processes which starts from the material in pellet form. The pelletised feedstocks are extruded through a nozzle and deposited in layers to create the desired sample. In this work, a novel water-soluble binder, based on a combination of PEG and CAB, is used to develop 316L feedstocks and compared to two different feedstocks that are used in Metal Injection Moulding (MIM) and Fused Filament Fabrication (FFF). The study and comparison is based on: 1) A viscosity characterisation of the feedstocks to study the influence of the three binder compositions; 2) the optimisation of the printing parameters of the different feedstocks ; 3) the optimisation of the debinding and sintering process of the printed samples. Finally, the microstructural properties of the sintered parts are analysed to validate the new binder system.

Innovative Aspect(s) :
Composite Extrusion Modelling (CEM) as an alternative for layer-by-layer deposition of materials.Alternative water soluble binders PEG|CAB based.

Reviewer's name : ....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235763808

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Sinter Based Technologies

Author : Dipl-Ing Antikainen Atte (VTT Technical Research Centre of Finland, Finland)

Co-author(s) : Dr Ing Kaunisto Kimmo, Dipl-Ing Hakanen Fanni, Dipl-Ing Lintunen Pertti, Dipl-Ing Lagerbom Juha, Dipl-Ing Lindroos Tomi (VTT Technical Research Centre of Finland, Finland)

Title : Master Sintering Curve Determination For Binder Jetted Metal Alloy

Keyword(s) :
Additive Manufacturing; Metal Binder Jetting; Sintering; Master Sintering Curve

Abstract :
Metal binder jetting (MBJ) is a sinter-based additive manufacturing method known for rapid build rates. Since MBJ is a net or near net shape process, and the pieces are usually weak and brittle, compaction of powder by external force is not possible. Therefore, the final strength is attained by sintering of the relatively loosely packed green pieces. Sintering time and temperature can be optimized by using so called master sintering curve (MSC) to determine optimal parameters for maximum densification. In this paper the formulation of MSC for binder jetted metal alloy is described and experimentally investigated. The results help researchers and companies to optimize their sintering process parameters for metal binder jetted components as a function of material and green piece density. Using MSC allows investigators to take limitations, such as maximum furnace temperature, into account or to minimize energy consumption when designing sintering cycles.

Innovative Aspect(s) :
Master sintering curve allows comparison of sintering behavior between different thermal paths. The behavior of master sintering curve is a function of particle size distribution (PSD) and green density (GD). Both PSD and GD can vary based on manufacturing method and raw material. Therefore, it is beneficial to develop means for determining MSC which further allows the optimization of sintering process on a material and process basis. More information on MSC of binder jetted materials will be provided by this research.

Reviewer's name : ....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235763812

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Sinter Based Technologies

Author : Dr Kukla Christian (Montanuniversitaet Leoben, Austria)

Co-author(s) : Mr Momeni Vahid, Dipl-Ing Schuschnigg Stephan (Montanuniversitaet Leoben, Austria), Dr Ing Riecker Sebastian, Dr Ing Poehle Georg (Fraunhofer Institute for Manufacturing Technoogy and Advanced Materials IFAM, Germany)

Title : Filament Development For Metallic Fused Filament Fabrication Of Aluminium Alloys

Keyword(s) :
Material Extrusion; Fused Filament Fabrication; Additive Manufacturing; Aluminium

Abstract :
Material Extrusion with filaments, Fused Filament Fabrication – FFF, is the most widespread additive manufacturing technology. This counts mainly for polymers, since the use of this technology for metal and ceramic powders is still in its early days. For several metals, filaments can be bought in the market. Aluminium has a low sintering temperature already in the range of the temperatures for thermal debinding of many feedstocks and needs special sintering regimes. To meet these special requirements, a feedstock for the production of highly filled aluminum filaments was developed. The printed parts are debinded by solvents. Here, the following results are presented: 1) rheological behaviour of the feedstock, 2) debinding behaviour with emphasis on the selection of solvents and 3) printing performance.

Innovative Aspect(s) :
New feedstock for additive manufacturing of aluminium

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Paper Number : EP235763845

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Sinter Based Technologies

Author : Dr Ing Riecker Sebastian (Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM, Germany)

Co-author(s) : Dipl-Ing Teuber Robert, Dr Ing Studnitzky Thomas (Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM, Germany), Prof Dr Weißgärber Thomas (Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM & Technisch

Title : Investigations On The Surface Quality Of Parts Produced Via Gel Casting

Keyword(s) :
Hybrid Process Chain; Gel Casting; Sinter Based AM; Surface Quality; Surface Roughness

Abstract :
Developments in the sinter-based additive manufacturing of metal components are progressing rapidly and the quality of the AM parts is steadily increasing. However, there are always process-related limitations with regard to surface roughness, which may make post-processing necessary. Within this context, the hybrid process chain of gel casting with AM molds can offer advantages, as the surface quality of the mold is transferred to the metal part and smoothing of the polymer mold is possible without effort. In this study, surface roughness was evaluated using different mold qualities. The surfaces in the green and sintered states were investigated and related to the given process conditions such as the mold surface quality and the powder used. It is found that the surface roughness values Ra and Rz can range below the mean particle size of the powder used, which saves post-processing of the metal component in relevant applications.

Innovative Aspect(s) :
The hybrid process chain gel casting into AM molds is relatively new. A unique selling point is the high surface quality that can be achieved. To date, there have been no investigations into the roughness values achievable in the "as sintered" state and how these compare with other processes, or how they are linked to the surface quality of the molds used. These aspects are to be illuminated for the first time and may also provide indications for other processes as to the extent to which a rough surface is smoothed|rounded off by the sintering process.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235763906

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Sinter Based Technologies

Author : Dipl-Ing Teuber Robert (Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM, Germany)

Co-author(s) : Dr Ing Riecker Sebastian, Dr Ing Pöhle Georg, Dipl-Ing Herzer Niklas (Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM, Germany), Prof Dr Weißgärber Thomas (Fraunhofer Institute for Manufacturing Technology and Advanced Materi

Title : Printing Of Porous Structures With The New MoldJet Process

Keyword(s) :
Porous Structures; Sinter-Based Additive Manufacturing; MoldJet; Sintering

Abstract :
The work deals with the printing of porous, metallic structures using the MoldJet technology. The MoldJet process is a novel, sinter-based additive manufacturing process, which enables the production of a wide range of geometries, ranging from small filigree to large-volume metal components without the need of support structures. The high productivity of up to 1600 cm^3|h also enables series production of components. These process advantages are now to be exploited in the manufacture of porous structures. The technical limits in terms of porosity, pore size and design freedom will be highlighted. The aim of the study is to transfer and investigate the feasibility on the basis of various applications from industry, such as medical applications, tool stamps, filter solutions or acoustic emissions. In particular, the different requirements for the component design will be illuminated.

Innovative Aspect(s) :

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235763952

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Sinter Based Technologies

Author : Ing Badin Sophie (CRITT - Matériaux Innovation | Centrale Lille, UMR 9013 - LaMcube, France)

Co-author(s) : Prof Dr Najjar Denis, Prof Dr Magnier Vincent, Dr Ing Witz Jean-François (Uniersité. Lille, CNRS, Centrale Lille, UMR 9013 - LaMcube - Laboratoire de Mécanique, Multiphysique, Multiéchelle, France), Dr Ing Marou-Alzouma Ousseïni, Ing Auzène Delphine, Ing

Title : Impact Of Sintering Atmospheres On Mechanical Properties And Microstructures Of 316L Stainless Steel Parts Produced By Material Extrusion Additive Manufacturing

Keyword(s) :
Additive Manufacturing; Extrusion; Pellets; Stainless Steel; Sintering Atmospheres; Mechanical Properties; Microstructures

Abstract :
Material Extrusion Additive Manufacturing (MEAM) is increasingly used to produce metal parts thanks to its simplicity and advantageous cost. It is similar to the conventional Metal Injection Moulding (MIM) process. In both cases, the feedstock is a mixture of polymer binder and metal powders and the parts produced are debinded to remove the polymer and sintered in a furnace. When the material is sensitive to oxidation, the sintering must be done in a protective environment. This is the case for steel, for which most suppliers recommend a dihydrogen atmosphere. However, dihydrogen is prohibited in many institutions because of its dangerousness. In this work, different gases were studied to replace it: nitrogen; a mixture of nitrogen (95%) and dihydrogen (5%); argon and primary vacuum. This study aims to understand the impact of these sintering gases on the mechanical properties and microstructures of 316L stainless steel parts printed by pellets extrusion.

Innovative Aspect(s) :
To date, there are no comprehensive studies regarding the impact of sintering atmospheres on parts produced by Material Extrusion Additive Manufacturing (MEAM), especially for 316L stainless steel. Most research focused on sintering temperatures, dwell times, and temperature ramps, but not on the environments used. This work aims to provide a comprehensive view of the effect of sintering environments (nitrogen, a mixture of nitrogen (95%) and hydrogen (5%), argon and vacuum) on the mechanical properties, in relation to the microstructures and in comparison with MIM injected samples. The final goal is to avoid the use of hydrogen, usually recommended for the sintering of steels. Thus, the use of less dangerous and less expensive gases, for the most part, than hydrogen will make metal additive manufacturing more accessible, by reducing the cost of the necessary equipment.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION
01-04 October 2023

Paper Number : EP235763986

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Sinter Based Technologies

Author : Dipl-Ing Azurmendi Naiara (TECNALIA, Spain)

Co-author(s) : Dr Agote Iñigo, Dr Lores Asier (TECNALIA, Spain), Dr Fernandes Cristina, Dipl-Ing Figueiredo Daniel (PALBIT, S.A., Portugal)

Title : Feasability Study Of Using Tungsten Carbide Thermal Sray Powders For Binder Jetting Technology

Keyword(s) :
Binder Jetting; Hard Metals; Sintered and Agglomerated; WC-12%Co; Sinter-Hip

Abstract :
Additive manufacturing of hard metals is gaining attention due to the possibility of fabricating complex shaped parts and new functional designs. Among all of them, Binder jetting appears to be the most promising technology due to its low-cost, fast manufacturing process that produces stress and crack-free parts with isotropic properties. In the present work, Tungsten carbide (WC-12%Co) powders originally produced for thermal spray processes have been tested in Binder Jetting technology in order to assess their suitability for this technology. have been studied. Properties of two different agglomerated and sintered powders (AMPERIT 519.059 from Höganäs and WOKA 3111FC from Oerlikon Metco) have been analysed and compared. In addition, final properties (density, hardness, microstructure) of the printed parts (cutting inserts for machining applications with internal cooling channels) sintered in a sinter-hip-furnace at 1455°C have been evaluated and compared. The obtained results demonstrated the feasibility of using this type of powders.

Innovative Aspect(s) :
Additive manufacturing of Hard metals is still unsolved and needs further efforts to implement this process and obtain good quality parts. One of the main challenges is to have a good starting WC-Co raw material for the technology, which presents high bulk and tap density, good flowability, sintering activity, homogenous WC grain size as well as adequate PSD. The main aim of the present study is to assess the feasibility of using Tungsten carbide (WC-12%Co) thermal spray powders for Binder Jetting technology in order to overcome some of the drawbacks that have been found on the literature regarding BJ of hardmetals (difficulties to work with RTP granules, obtained final non homogeneous microstructure with the presence of coarse WC clusters, the need of higher sintering temperatures…). Although, few studies of binder jetting of hard metals have been published, up to the knowledge of the authors this is the first study.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764032

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Sinter Based Technologies

Author : Mr Shang Naiqi (Technical University of Denmark, Denmark)

Co-author(s) : Dr Dahmen Thomas, Dr Nadimpalli Venkata Karthik, Dr Christiansen Thomas Lundin (Technical University of Denmark, Denmark)

Title : Impact Of Powder Feedstock Preparation, Saturation, Layer Thickness And Part Orientation On Compressive Green Strength In Metal Binder Jetting Additive Manufacturing

Keyword(s) :
Metal Binder Jetting; Sinter Based Additive Manufacturing; Spray Forming; Green Strength; 3D Printing

Abstract :
Low green strength of binder-jetted parts can lead to potential damage during depowdering and complicates green part handling. Understanding and optimizing green strength is therefore essential for the overall control and repeatability of the processes. This study systematically investigates the effect of different powder feedstocks, saturation levels, layer thicknesses and part orientation on the compressive green strength of binder-jetted cylinders. Stainless steel powders of similar particle size distributions were obtained by Gas Atomization and Spray Forming as an alternative powder feedstock production method. The results show that spray-formed powders are highly suitable for Binder Jetting due to high flowability, packing density and green strength in comparison to gas-atomized powders. Additionally, higher saturation levels, higher layer thicknesses and build directions perpendicular to the direction of loading are found to improve the compressive green strength.

Innovative Aspect(s) :
Systematic study to understand and increase the green strength of binder-jetted parts.
Spray forming is introduced as an alternative manufacturing process to gas atomization to produce highly spherical powder particles.
Spray-formed powders exhibit excellent flowability and suitability for binder jetting.

Reviewer's name : ....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764265

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Sinter Based Technologies

Author : Dr Mariani Marco (Politecnico di Milano, Italy)

Co-author(s) : Prof Lecis Nora (Politecnico di Milano, Italy)

Title : Effects Of Feedstock Morphology And Composition On Binder Jetting Of 316L Stainless Steel: A Perspective On Circular Economy

Keyword(s) :
Binder Jetting; 316L Stainless Steel; Recycling; CALPHAD Modelling; Nickel Content

Abstract :
Binder jetting is a sinter-based technique that allows the production of application-oriented designs with a reduced consumption of raw materials. The employment of powders from scrap metal recycling would minimise the lifecycle impact of the process.In our work, gas atomised powders tailored for binder jetting are compared to a feedstock obtained by recycling of 316L waste. The morphological features of particles, especially sphericity and size distribution, are measured by granulometry and scanning electron microscopy. Printed components are studied at the green and sintered state to observe the influence of each feedstock and the comparative analyses on density and final microstructures (residual porosity, grain size and phases distribution) allows to determine which are the most beneficial properties of the powders. CALPHAD modelling highlights the feedstock chemical composition effects on densification mechanisms: Ni and C content are responsible for d phase formation and solidus temperature, thus affecting diffusive processes during sintering.

Innovative Aspect(s) :
The study of binder jetting of 316L has been consolidated leading to the achievement of high density (>98%). However, the comprehension of the effects of feedstock properties, as particles morphology and chemical composition, on the mechanisms of formation of the green bodies and diffusion during sintering is still limited.The analyses of powders from different suppliers and sources allowed to identify the most influential properties. CALPHAD modelling by Thermocalc© software underlined the importance of the initial concentration of the alloying elements and the carburization of the material during the initial steps of the thermal treatments (curing|debinding|sintering). It was highlighted the importance of nickel content on the formation of δ phase, which affects the diffusion rates of alloying elements during sintering, and additional carbon that determines the onset of supersolidus liquid phase sintering. The results provide guidelines for the preparation of feedstocks by conventional and recycling routes.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764456

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Sinter Based Technologies

Author : Dr Daudt Natalia (Universidade Federal de Santa Maria, Brazil)

Co-author(s) : Dr Bevilaqua William (Colégio Técnico Industrial - Santa Maria - UFSM, Brazil), Dr Limberger Inacio, Ing Signor Fernanda (Universidade Federal de Santa Maria, Brazil)

Title : Fabrication Of Copper Parts By 3-D Extrusion Of Highly Viscous Paste

Keyword(s) :
D Extrusion; Cooper; Paste Extrusion; AM Sinter-Based Technology

Abstract :
The fabrication of copper parts by 3D-extrusion of highly viscous paste was studied. This technology is classified as sinter-based AM technology. 3D-extrusion allows printing of metallic components with a low anisotropy index, by deposition of layers of a paste composed of polymeric solution loaded with metal powder. Extrusion-based 3D printing have been often reported in literature for production of ceramics components, however there are still few studies on metal components. In the present study, we evaluated the effect of paste composition on the microstructure and compressive strength behavior of cooper parts. For that three different composition of water based polymeric pastes loaded with copper particles were used as feedstock. Green parts were printed by feedstock extrusion at room temperature. Afterwards the parts were debinded and sintered. Extrusion-based 3D printing of metals pastes is an attractive route for cost effective production of small batches of complex shaped parts.

Innovative Aspect(s) :
In this study we applied Extrusion-based 3D printing of highly viscous pastes for production of copper parts. This technology was originally developed for ceramic materials and recently was adapted for metal particles.There are very few reports on the production of copper parts with similar approaches which are mainly focused on the use of MIM feedstocks and hot extrusion. In our study we investigated the effect of water based polymeric pastes in the 3D printing at room temperature of Cooper parts.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764652

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Sinter Based Technologies

Author : Dr Ing Wieland Sandra (Fraunhofer IFAM, Germany)

Co-author(s) : Ing Reineke Lea, Mr Giel Jonathan, Dr Hein Sebastian Boris (Fraunhofer IFAM, Germany),

Title : Curing Behaviour Of Non-corrosion-resistant Tool Steels In Metal Binder Jetting

Keyword(s) :
Metal Binder Jetting; Tool steel; Curing

Abstract :
Along the Metal Binder Jetting process chain, the metal powder is subjected to interactions with the binder, which is often water-based, and with air at elevated temperature during the curing step. This can lead to corrosion or oxidation reactions, especially for non-corrosion-resistant materials like typical tool steels. In order to investigate the interaction of non-corrosion resistant steels and different binders as well as the curing behaviour, two commonly used tool steels (FeCrV10 and M2) are combined with three different binders. Measurements are carried out on the wetting behaviour of all powder-binder combinations by determining the saturation rate and equilibrium binder saturation. Curing temperatures are set according to the respective binder composition, and both curing in air as well as in protective atmosphere is tested.The evaluation includes the stability of the resulting green parts and the density, microstructure, and carbon and oxygen content of parts after debinding and sintering.

Innovative Aspect(s) :
Metal Binder Jetting of tool steels FeCrV10 and M2- Focus on powder-binder interaction and curing behaviour.
Three different binders are tested.
Investigation of wetting behaviour by determining the saturation rate and equilibrium binder saturation.
Comparison of curing in air and in protective atmosphere.

Reviewer's name : ....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : ....

Notes to author : ....

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EURO PM2023 CONGRESS & EXHIBITION
01-04 October 2023

Paper Number : EP235764658

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Sinter Based Technologies

Author : Dr Ing Poehle Georg (Fraunhofer IFAM, Branch Lab Dresden, Germany)

Co-author(s) : Prof Dr Quadbeck Peter (Offenburg University of Applied Sciences, Germany), Dr Ing Riecker Sebastian (Fraunhofer IFAM, Branch Lab Dresden, Germany), Dr Kukla Christian, Mr Momeni Vahid, Dipl-Ing Schuschnigg Stephan (Montanuniversitaet Leoben, Austria)

Title : Debinding And Sintering Strategies For Fused Filament Fabrication Of Aluminium Alloys

Keyword(s) :
Material Extrusion; Fused Filament Fabrication; Additive Manufacturing; Aluminium; Sintering; Process Gas Analysis; Debinding

Abstract :
Fused Filament Fabrication (FFF) is a widespread additive manufacturing technology, mostly in the field of printable polymers. The use of filaments filled with metal particles for the manufacture of metallic parts by FFF presents specific challenges regarding debinding and sintering. For aluminium and its alloys, the sintering temperature range overlaps with the temperature range of thermal decomposition of commonly used "backbone" polymers, which provide stability to the green parts. Moreover, the high oxygen affinity of aluminium necessitates the use of special sintering regimes and alloying strategies. Therefore, it is challenging to achieve both low porosity and low levels of oxygen and carbon impurities at the same time. Feedstocks compatible with the special requirements for aluminium were developed. We present results on the investigation of debinding|sintering regimes by FTIR-based In Situ Process Gas Analysis and discuss optimized thermal treatment strategies for Al-based FFF.

Innovative Aspect(s) :
Development of novel feedstocks tailored for optimal solvent|thermal debinding Optimization of debinding and sintering for Al alloys by in situ process gas analysis .
Precise determination of required temperature steps and holding times.
Novel approaches to optimum thermal debinding by atmosphere composition and pressure control.

Reviewer's name : ……………………………………………………………………………………………

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764981

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Sinter Based Technologies

Author : Dr Ing Lores Asier (Tecnalia, Spain)

Co-author(s) : Ing Azrumendi Naiara, Dr Agote Iñigo, Mr Leizaola Iñaki (Tecnalia, Spain)

Title : Zero Waste Binder Jetting Process: Study Of The Reusability Of The Rejected Part Powder

Keyword(s) :
Additive Manufacturing; Binder Jetting; 17-4PH; Stainless Steel; Reusability; Recyclability; Zero Waste

Abstract :
Binder Jetting Additive Manufacturing is well known as it has near 100% of powder reusability ratio for certain alloys. This technology takes the advantage of not using thermal inputs (like laser or electron beams) which can degrade or sinter part surrounding powder particles, lowering the powder reusability ratio. Nevertheless, during the printing process setup and part production, there usually are printed parts with defects that are directly rejected. This work aims studying the viability and impact of reusing the powder from rejected green parts in order to go towards a zero waste and total usage of the metallic powders. For doing that, the rejected parts were debound, sieved, characterised and mixed in different proportions with virgin powder, in order to determine the appropriate mixing ranges were good quality material can be obtained. The study confirmed that, for the 17-4PH alloy, the use of separated debinding+sintering processes its feasible.

Innovative Aspect(s) :
There are some works in literature showing the powder reusability capabilities of the Binder Jetting technology, but to the best knowledge of the authors, there is not literature work addressing the reusability of the powder belonging to rejected green parts. Although the industry and academia are working towards a "right at the first time" or "zero defect printing" topics, it is usually unavoidable to have process variabilities which can generate certain number of defective parts. These defective parts can imply a decent amount of powder waste for large productions. Estimating a production of 1.000.000 parts|year with an average part weigh of 50 grams, a green part rejection ratio of the 5% supposes 2.500Kg of waste material that could be avoided, potentially reducing recycling and part costs.

Reviewer's name : ....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765077

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Sinter Based Technologies

Author : Dr Ing Studnitzky Thomas (Fraunhofer IFAM, Germany)

Co-author(s) : Prof Dr Weißgärber Thomas (Fraunhofer IFAM & Technische Universität Dresden, Germany), Dipl-Ing Aumund-Kopp Claus, Dr Hein Sebastian (Fraunhofer IFAM, Germany)

Title : Review Of Sinter-based Additive Manufacturing (SBAM) - Status And Prospects

Keyword(s) :
Review Sinter-based Additive Manufacturing; Fused Filament Fabrication; Binder Jetting; MoldJet; Debinding Sintering; Sinter Simulation

Abstract :
Laser powder bed fusion (LPBF) is dominating Additive Manufacturing of metals in equipment manufacturers, research, and applications. Since LPBF has still limitations in terms of geometries and materials as well as in terms of productivity, sinter-based additive manufacturing (SBAM) processes such as Metal Binder Jetting (MBJ) or Fused Filament Fabrication (FFF) are becoming increasingly important. Furthermore, new processes such as MoldJet (MJ) or Lithography-based Metal Manufacturing (LMM) continue to enter the market and are attracting widespread attention due to their promising properties. At the same time, it is becoming apparent that there is still a need for intensive development in accompanying processes such as heat treatment and sinter simulation. In this review, the status of the most important sinter-based processes is highlighted and also compared with LPBF. In addition, this paper outlines future development trends and estimates the market potential of the various SBAM processes.

Innovative Aspect(s) :
Sinter-based additive technologies such as Binder Jetting and Fused Filament Fabrication are becoming increasingly important within additive manufacturing. Due to the process chain with debinding and sintering, these technologies have a special relation to powder metallurgy. Due to the rapid development, also with new technologies, there is a need for an overall presentation of the current state of the art and an identification of development topics. Since Fraunhofer IFAM is very broadly positioned in this area with its traditional focus on powder metallurgy and a total of 6 SBAM processes, Fraunhofer IFAM is particularly suitable for this review due to KnowHow and market knowledge. The review deals explicitly with all processes, not just those available at IFAM.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765138

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Sinter Based Technologies

Author : Dr Naranjo Juan Alfonso (Universidad de Castilla La Mancha, Spain)

Co-author(s) : Ing Perez Gema, Dr Berges Cristina, Dr Hidalgo Javier, Dr Herranz Gemma (Universidad de Castilla La Mancha, Spain)

Title : New Challenges In The Development Of Hybrid Catalytic Feedstock Based On 316L Stainless Steel Master Alloys

Keyword(s) :
Feedstock; MIM; Fused Filament Fabrication; Fused Pellet Fabrication; Master Alloy; AM Sinter Based

Abstract :
The development of materials using master alloys has many advantages over pre-alloyed powders, such as better preservation of the shape of the parts at a more competitive cost. This type of alloy is commonly used for MIM, which makes its use in 3D printing very interesting. However, its use for sinter based additive manufacturing technologies is not obvious, as it requires a detailed analysis of its flowability to accomplish a unique feedstock processable by MIM and Fused Filament|Pellets Fabrication (FFF|FPF) technologies (hybrid feedstock). Rheological and experimental criteria are used in which suitable flow characteristics are pursued. The measured parameters allow the selection of the optimum metal content of the feedstock to achieve a balance between MIM, FFF and FPF requirements, guaranteeing the industrial viability of the feedstock. After green shaping, debinding and sintering, the results concerning the final density, microhardness, tensile strength, shrinkage and dimensional accuracy are discussed.

Innovative Aspect(s) :
A unique feedstock based on master alloy powder processable by MIM and Fused Filament|Pellets Fabrication (FFF|FPF) technologies (hybrid feedstock) is developed.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION
01-04 October 2023

Paper Number : EP235765215

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Sinter Based Technologies

Author : Ing Marconcini Francesco (University of Pisa, Italy)

Co-author(s) : Dr Tamburrino Francesco, Ing Giammarinaro Guido, Prof Paganucci Fabrizio, Prof Razionale Armando V. (University of Pisa, Italy)

Title : Experimental Study On The Utilization Of Inconel-718 Filament With Material Extrusion Additive Manufacturing To Produce Functional Components

Keyword(s) :
Inconel 718; Material Extrusion; Additive Manufacturing; Mechanical Properties; Printing Parameters Optimization

Abstract :
Material Extrusion Additive Manufacturing (MEAM) techniques for metals are becoming more appealing in comparison to other metal AM techniques, which are typically energy-intensive and expensive to install and maintain. In MEAM techniques a polymeric feedstock filled with metal particles is extruded through a heated nozzle at a temperature above the melting point of the binder; subsequently, the 3D printed green parts are debound and sintered. The project's goal is to validate the feasibility of fabricating functional Inconel-718 components using MEAM. Specimens were manufactured using a desktop 3D printer with a commercial Inconel-718 filament and subsequently thermally debound and sintered. To determine the best set of printing and sintering parameters, the design of experiments technique and surface response methodology were used. The mechanical and physical properties of the specimens were evaluated in accordance with Metal Powder Industries Federation (MPIF) standards.

Innovative Aspect(s) :
There are few studies in the literature that evaluate both the printability and mechanical properties of commercial Inconel 718 filaments used to make functional parts with MEAM techniques. The present work not only addresses these issues, but also evaluates different printing and sintering parameters and their effect on the mechanical properties of Inconel 718. The mechanical characterization is made in accordance with the most recent MPIF standards. Finally, the case study presented in the paper, i.e., the printing of an anode-distributor for a Hall thruster, represents an unprecedented application of MEAM techniques. Hall thrusters are one of the most commonly used electric propulsion systems in space, and the anode-distributor is a critical component for their operation. In this regard, the use of MEAM techniques for rapid prototyping and small-scale productions of electric propulsion system components can be a crucial factor in the future development of these devices.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765300

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Sinter Based Technologies

Author : Prof Barrière Thierry (FEMTO-ST, France)

Co-author(s) : Ing Charpentier Nicolas, Prof Boudeau Nathalie (FEMTO-ST, France), Prof BERNARD Frédéric (ICB, France)

Title : Influence Of Sintering On Microstructure And Mechanical Properties Of Steel-tool Alloy Parts Shaped By PIM-like MEX

Keyword(s) :
MEX; PIM-like MEX; Densification; Mechanical Properties; Microstructure; Steel Tool Alloy; ASP2023; PLA

Abstract :
PIM-like Material Extrusion (MEX) process has in the recent years been able to produce parts competing with Powder Injection Molding. However, the layered approach of MEX can be the cause of anisotropy in the part with the presence of pores along the layers. Theses porosities are reduced and rearranged during the densification step of the process.This paper explores the influence of the densification technique and parameters on both the microstructure and the mechanical properties of a steel tool alloy powder, with a comparison between traditional PIM and PIM-like MEX.

Innovative Aspect(s) :
In the PIM-like MEX process, the mechanical properties are expected to be 5 to 10% lower than in PIM due to the presence of pores. However, the understanding of the densification step is generally limited to a single setting and optimized in term of porosity only. This work is a contribution to explore the impact of the densification on the mechanical characteristics of a material.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765340

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Sinter Based Technologies

Author : Dr Harakály György (Incus GmbH, Austria)

Co-author(s) : Dr Cano Cano Santiago, Ms Mödder Denise, Dr Mitteramskogler Gerald (Incus GmbH, Austria)

Title : The Applicability Of Lithography-based Metal Manufacturing For 316L Stainless Steel

Keyword(s) :

Abstract :
The Lithography-based metal additive manufacturing (LMM) is a sinter-based additive manufacturing (AM) technology to produce metallic components using a photocurable polymeric resin, filled with metal powder. The LMM printer uses this feedstock to fabricate parts by selective polymerization with a digital light processing engine layer by layer. No support structures are needed, as the feedstock resolidifies between layers and the parts are supported with unpolymerized material. Thanks to its high feature resolution and surface quality, common to vat photopolymerization AM, the LMM process enables part qualities unmatched with other metal AM methods for applications such as jewellery, electronics and microprinting. Here, the material properties of 316L stainless steel parts were analysed, with focus on the microstructure and mechanical properties. The results show that with an optimized debinding and sintering process, the LMM process enables the manufacturing of parts with properties above the Metal Injection Molding requirements.

Innovative Aspect(s) :

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765455

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Sinter Based Technologies

Author : Mr Alves Bernardo (Universidade de Coimbra, Portugal)

Co-author(s) : Mr Gatões Daniel, Prof Dr Vieira Maria Teresa (University of Coimbra, Portugal)

Title : Material Extrusion: Shaping And Sintering Optimization Through Microtomography

Keyword(s) :
Additive manufacturing; Microtomography; Stainless Steel; Optimization

Abstract :
Indirect additive manufacturing techniques like Material Extrusion (MEX) are rising in industrial application due to the freedom of design usually attributed to additive techniques, as well as increasing accessibility of equipment and a real contribution to sustainability. This study highlights the role of µ-tomography as a core of non-destructive techniques to optimize both shaping and sintering parameters. Moreover, brings forth the possibility of continuous improvement as well as quality control without the need of creating disposable specimens. Therefore, this work aims to optimize the manufacture of metallic specimens (AISI 316L), for similar feedstock (binder|additive), by using µ-tomography to analyse the filament, the strand, the 3Dobject (green and sintered). Optimization the different MEX steps relies on setting key process variables and understanding their impact on defects using µ-tomography. This methodology allows the evaluation of quality of 3Dobjects only by non-destructive techniques.

Innovative Aspect(s) :

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765587

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Sinter Based Technologies

Author : Dr Teixeira Oliveira de Menezes João (Politecnico di Milano, Italy)

Co-author(s) : Mr de la Vega Federico Matias, Prof Castrodeza Enrique Mariano, Prof Casati Riccardo (Politecnico di Milano, Italy), Ing Zanon Matteo, Ing Pelletiers Tom (Kymera International | SCM Metal Products, USA)

Title : Effect Of Loading Direction On Tensile And Fracture Behavior Of 6061 Al Alloy Produced By Binder Jetting

Keyword(s) :
Binder Jetting; Al Alloys; Fracture Toughness; Additive Manufacturing; Microstructure

Abstract :
Binder Jetting of Al alloys is a new challenge that can open new scenarios for the additive manufacturing of many alloys that cannot be processed by laser-based printing technologies because of the susceptibility to hot cracking (e.g., 2xxx, 6xxx and 7xxx series alloys). In this work, 6061 Al alloy samples were produced by Binder Jetting. Debinding and sintering parameters were fine-tuned. Then, the tensile and fracture properties were assessed. C(T) specimens were machined having the notch in three different crack plane orientations. Microstructural and fractographic analyses were performed by FE-SEM and EBSD. It was observed that the mechanical and fracture behavior of the material is strongly affected by layer boundaries, grain boundaries, and residual porosity.

Innovative Aspect(s) :
Binder Jetting, debinding and sintering processes of Al alloys were studied and fine-tuned. This involved several challenges, including the development of a sealed Binder Jetting system, of an ad-hoc binder and a proper debinding and sintering treatment.
To the best of authors knowledge, no studies on fracture toughness and tensile properties of Al 6061 samples produced by binder jetting have been published so far.
A complete set of mechanical tests was backed by an in-depth study of the microstructure to comprehensively understand the material behavior.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765624

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Sinter Based Technologies

Author : Ing Rubiano Julian (Universidad Nacional de Colombia, Colombia)

Co-author(s) : Ing Gil Andres (SENA - Centro de Materiales y Ensayos, Colombia), Prof Dr Herrera Liz Karen (Universidad Nacional de Colombia, Colombia)

Title : Sintering Time Effect On The Mechanical And Microstructural Behavior Of A WC-10Co Hardmetal Printed By Fused Filament Fabrication

Keyword(s) :
WC - 10 Co; FFF; Hardmetals; Sintering Time

Abstract :
In the present work, three different sintering times were used in WC-10Co samples shaped by fused filament fabrication. The samples were printed in an Ender 3 V2 printer with a nozzle size of 0.6mm. The solvent debinding was carried under cyclohexane at 60 °C for 72 h. The thermal debinding and sintering processes were made in a vacuum furnace with 25% N_2 – 75% H_2 and Ar atmosphere respectively. The samples were sintered at 1500 °C for 15, 30, and 60 min. The porosity was classified as A06-B02-C02 according to ASTM B276 standard. The mean grain size and the relative density were higher as the sintering time was increased to a maximum of 1.39 µm and 99.1% respectively, nevertheless the HV30 hardness behaved inversely. The crystalline phases were identified by x-ray diffraction. A final part with different complex geometries was printed and sintered to identify the process capacity.

Innovative Aspect(s) :
AM sinter-based technologies as an alternative for low-volume production.The sintering time influence on the FFF part was studied.The technical feasibility of the process is discussed.Using low-cost and easy-access printers to obtain hardmetals.

Reviewer's name : ....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : ....

Notes to author : ....

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Paper Number : EP235766139

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** AM Sinter Based Technologies

Author : Mr Reddy Pranith (Indian Institute of Technology Bombay, India)

Co-author(s) : Dr Singh Gurminder (Indian Institute of Technology Bombay, India), Dr Gandhi Prassana (Indian Institute of Technology Bombay, India), ,

Title : Numerical Modeling Of Solid Sintering Of Alumina Fabricated By Digital Light Projection 3D Printing

Keyword(s) :
Sintering; 3D Printing; DLP

Abstract :
Digital Light Processing based additive manufacturing technique has recently emerged successful in the fabrication of ceramic intricate shapes with high accuracy. The process needs fabrication of the green body by curing of monomers and ceramic slurry layer-by-layer. Later on, debinding and sintering are required to remove polymer binders and to achieve dense ceramic parts. The dimensional changes during sintering is important to predict the production of net shape parts. In the present work, a numerical modeling simulation has been performed using COMSOL finite element method with a creep module. Thermo-viscoelasticity theory-based phenomenological model was employed to study the sintering behavior of the debound sample. The data from Alumina sintering literature were used to obtain a densification equation and axial and viscous Poisson viscosity. The cylindrical samples using Alumina and monomer slurry were fabricated with DLP and sintered at different temperatures for the verification of simulation results. The numerical results showed good

Innovative Aspect(s) :
The work contains numerical modeling for the sintering of alumina material fabricated by digital light processing.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

Technical Programme Committee
15th February 2023

CONSOLIDATION TECHNOLOGIES

METAL INJECTION MOULDING

EPMA
european powder metallurgy association

EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235763904

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** Metal Injection Moulding

Author : Dipl-Ing Limberg Wolfgang (Helmholtz-Zentrum Hereon, Germany)

Co-author(s) : Dr Ebel Thomas, Prof Dr Willumeit-Roemer Regine (Helmholtz-Zentrum Hereon, Germany)

Title : Effect Of Oxygen Scavenging By Yttrium Addition On Fatigue Properties Of MIM Ti-6Al-4V Using HDH-Powder

Keyword(s) :
Metal Injection Moulding; Ti-6Al-4V; Fatigue; Oxygen Scavenging

Abstract :
For this study, tensile test specimens and rectangular shaped fatigue test specimens were produced by MIM, using a mixture of hydride de-hydride (HDH) Ti-6Al-4V powder with high oxygen content (4200 µg|g) and 20% gas atomized Ti-6Al-4V powder with 1600 µg|g oxygen. Due to the oxygen-scavenging effect, the addition of 0.5 wt.% yttrium powder with a particle size < 45 µm to the powder mixture led to an strong increase of ductility from 4.5% to 13.5%. The results of the fatigue tests, conducted by 4-point bending at room temperature with a load ratio of 0.2 shown a total different behaviour. While the ductility is increasing, the fatigue endurance limit drops from 420 MPa for the pure Ti-6Al-4V down to 350 MPa by the addition of yttrium. This decrease of fatigue strength is caused by the large irregular shaped Y_2O_3 filled pore clusters, which are forming during sintering.

Innovative Aspect(s) :
Further studies have shown that an addition of a small amount of yttrium to titanium powder with high oxygen content increases the ductility of sintered specimens made from these powders. However, for many applications, fatigue resistance of Titanium alloys is as important as the quasi-static mechanical properties. Therefore, it is necessary to know how the addition of yttrium to Ti-6Al-4V influences the fatigue properties.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764055

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** Metal Injection Moulding

Author : Dr Hein Sebastian (Fraunhofer IFAM, Germany)

Co-author(s) : Mr Luoto Mikael, Mr Kramer Lutz, Dr Hartwig Thomas (Fraunhofer IFAM, Germany), Mr Min Doo-Sik (Kolon Plastics, Inc., Republic of Korea)

Title : Use Of High Melt Flow Rate Poly(oxymethylene) In Binders For Metal Injection Moulding Feedstocks

Keyword(s) :
Poly(oxymehtylene) (POM); Metal Injection Moulding (MIM); Feedstock Preparation; Process Evaluation; High Melt Flow Rate

Abstract :
Poly(oxymethylene) (POM) is widely used in binders for metal injection moulding (MIM) feestocks, due to its high strength and clean removability. The intent to use high melt flow rate POM was to improve processability, enabling more intricate parts, or processing at lower process temperatures.The processability of different feedstocks, prepared with such a POM-type, was investigated regarding the effects of metal powder type (316L, 17-4PH), particle morphology (gas- and water-atomized), as well as different mixing procedures (ZX-blade mixer with and without subsequent shear roll extrusion). Feedstocks of all variations could be processed properly, but the most promising results were shown by feedstocks using gas-atomized powders and both mixing procedures. In that case, due to the good flowability, the feedstock injection step was very smooth and lead to the smallest process deviations. This was shown by analyzing the process data and the characterization of green and sintered parts.

Innovative Aspect(s) :
Improvement of the flowability of POM-based MIM-feedstocks for improved processability.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765012

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** Metal Injection Moulding

Author : Dr Meza Alberto (IMDEA Materials Institute, Spain)

Co-author(s) : Mr Barbosa Adrián, Dr Yang Xiaomei, Prof Dr Torralba José Manuel (IMDEA Materials Institute, Spain), Dr Tabares Eduardo (University Carlos III of Madrid, Spain)

Title : Developing CoCrFeNiMox High Entropy Alloys Using Commodity Powders By Powder Injection Moulding

Keyword(s) :
High Entropy Alloys; Powder Injection Moulding; Sustainable Feedstock

Abstract :
High Entropy Alloys (HEAs) have increasingly attracted the scientific community's attention due to their unique microstructures and mechanical performance. However, one of the HEAs' main drawbacks to being developed by powder metallurgy is the need for prealloyed powders with the specific composition of the HEA, which increases the overall cost. Thus, in this work, commercial commodity powders like Ni625, CoCrF75, or 316L were employed to manufacture HEAs by Powder Injection Moulding (PIM). These powders were mixed with a multi-component binder to produce sustainable feedstocks using a combination of low CO2-emitting and water-soluble polymers. The critical solids content was determined, and the rheological properties, debinding conditions, and sintering parameters were adjusted to obtain samples with low porosity. In addition, all PIM stages were thoroughly characterized to control the porosity of the end parts and to ensure a single FCC solid solution with promising mechanical properties in the developed CoCrFeNiMox-type HEAs.

Innovative Aspect(s) :
The main novelty of this work is the development of High Entropy Alloys (HEAs) by Powder Injection Moulding (PIM) using commercial commodity powders. Usually, commercial powders are prepared at a large scale and used for press and sinter, spark plasma sintering, or 3D-printing technologies manufacturing components with commercial alloy composition. However, because these powders contain different alloying elements in certain percentages, it is possible to use different commercial powders as the source of specific elements in creating a HEA, even if this was not their initial purpose. Hence, it is possible to tailor the composition and reduce the cost of HEA development by using these powders instead of prealloyed powders with the final composition that are processed in small batches and, so, with higher prices. Furthermore, the processing of HEAs through PIM has yet to be explored extensively. Therefore, using sustainable binders with these commodity powders is another innovative aspect.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765175

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** Metal Injection Moulding

Author : Mr Mansfeld Tobias (SIGMA Engineering GmbH, Germany)

Co-author(s) :

Title : Digitalisation And Optimization Along The Process Chain For MIM|CIM Materials

Keyword(s) :
Virtual Molding; Simulation; Optimization; Green Part; Brown Part; Sintert Part

Abstract :
SIGMASOFT Virtual Molding does not only allow virtual filling studies and its optimizations. Rather, the holistic simulation approach of molded part and mold leads to optimal sintered parts with short cycle times and less post-processing.The digitalization of real process parameters and their simulation helps to optimize filling pressures, segregation, green part distortion and other design criteria. The process window for injection moldingis just as important as the knowledge of temperature control in the sintering furnace. The current possibilities are shown here.

Innovative Aspect(s) :
Realistic simulations and their improvements are only possible if the models (physical, mathematical and geometrical models) fit reality. Continuous improvements in material models e.g: Herschel-Bulkley Cross-WLF, segregation models or heat radiation model for sintering furnace are an important part of it. This is the only way to improve processes and save resources.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765299

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** Metal Injection Moulding

Author : Dr Herranz Gemma (Universidad de Castilla La Mancha, Spain)

Co-author(s) : Dr Berges Cristina, Dr Hidalgo Javier, Dr Naranjo Juan Alfonso (Universidad de Castilla La Mancha, Spain)

Title : Opportunities Of Powder Injection Molding For The Processing Of Graphene Reinforced Cordierites For High Temperature Applications

Keyword(s) :
Ceramic Injection Moulding; Graphene; CMC; Composites; Cordierite; High Temperatura; Aerospace

Abstract :
The main objective of this work is to process complex ceramic parts with remarkable thermal shock resistance for high temperature applications using ceramic injection molding (CIM) and, on the other hand, to analyze possible improvements in mechanical properties or changes in thermal expansion processes with the introduction of reinforcement elements such as graphene. Powder injection moulding (PIM) is an economic, jet unexplored, alternative for processing such composites. This work explores the use of PIM for the production of cordierite with reduced graphene oxide. Several addition methods are scrutinized by determining the homogeneity of the resulting feedstocks and drawing conclusions on how it affects their rheological behavior to combine adequate flow behavior with the changes in mechanical and in the target functional properties.

Innovative Aspect(s) :
Ceramics reinforced with reduced graphene oxide (RGO) are a group of families of materials of great interest at high temperature applications that have never been processed by PIM, being a novel material to explore due to its interesting applications with complex geometries.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765406

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** Metal Injection Moulding

Author : Mr Lidman Linus (Höganäs AB, Sweden)

Co-author(s) :

Title : Improved Properties On MIM Components With Special-WA Powders

Keyword(s) :
MIM; 17-4PH; Water Atomized Powders

Abstract :
17-4PH is the most used alloy in the metal injection molding (MIM) industry due to its high strength and hardness combined with modest corrosion resistance. Particle size distribution (PSD) of the powder used in a feedstock is key in how the end product will perform mechanically, feedstock processability and the appearance of the final components produced. Therefore, choosing a relevant powder fraction for a certain application becomes vital.This work focused on a special water atomized powder lot of the alloy 17-4PH sieved in different size fractions. A catalytic feedstock with identical powder loading were used for all grades. Properties evaluated were Sintered Density (SD), Melt Flow Index (MFI) and surface roughness. A simple way to boost the ductility and the repeatability in static properties of hydrogen sintered 17-4PH was successfully implemented.

Innovative Aspect(s) :
Improving hydrogen sintered 17-4PH ductility. Exploring the unique ways PSD of water atomized powder changes many properties of sintered MIM parts which goes against common believes.

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EURO PM2023 CONGRESS & EXHIBITION
01-04 October 2023

Paper Number : EP235763084

Requested presentation type : Poster Presentation

Topic : Consolidation Technologies **Subtopic :** Metal Injection Moulding

Author : Dr Lee Wonsik (Korea Institute of Industrial Technology, Korea, Republic of)

Co-author(s) : Mr Jang Jin-Man, Dr Lee Ho-Nyun, Mr Hwang Se-Hoon (Korea Institute of Industrail Technology, Republic of Korea)

Title : Fabrication Of PZT Micro Pin Array With High Aspect Ratio By Powder Injection Molding Using SU-8 Polymer Mold

Keyword(s) :
Micro Pin Array; SU-8 Mold; High Aspect Ratio; Powder Injection Molding; PZT

Abstract :
In this study, powder injection molding (PIM) of a PZT micro pin array was performed using a SU-8 polymer mold fabricated by only UV lithography without electroplating, and the applicability of SU-8 as a mold was evaluated. The SU-8 mandrel mold on the silicon wafer was manufactured by UV lithography to have 1,296 (36x36) micro pin cavities with a pitch of 190 um. The size of each pin cavity was 120x120x650 um (aspect ratio about 5.4) and the draft angle of about 0.5o for easy ejection was formed. After PIM at the injection and mold temperatures of 125 oC and 70 oC, respectively, all 1,296 micro pin arrays were pulled out without any fracture, and the SU-8 polymer mold could be used repeatedly without damage up to 10 times or more. After sintering, the micro pins with a size of 90x90x466 (the pitch 150) um were obtained.

Innovative Aspect(s) :
A mold manufactured by the LIGA process has been generally used for PIM of micro parts. The electroplating is a rate-limiting step in the LIGA process and requires high cost and long process time (about 2-3 weeks). In the case of PIM for a micro pin array part, some pins that are fractured in the pre-test to optimize the process parameters make it impossible to use the micro mold any more, although it took a long time to make the LIGA mold. In this study, the applicability as a PIM mold of SU-8 photoresist polymer with high rigidity and thermal stability was confirmed without the electroplating, and at the same time, the ejection parameters for a perfect micro pin array were investigated.

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EURO PM2023 CONGRESS & EXHIBITION

Technical Programme Committee
15th February 2023

CONSOLIDATION TECHNOLOGIES

COMPACTION AND SINTERING

EPMA
european powder metallurgy association

EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235763596

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** Compaction and Sintering

Author : Dipl-Ing Ganthaler Elias (Free University of Bozen, Italy)

Co-author(s) : Prof Peer Angelika (Free University of Bozen, Italy)

Title : Drucker-Prager Cap Model Within Plasticity Constitutive Law For Granular Media Represented In Haight-Westergaard Coordinate System

Keyword(s) :
Drucker-Prager Cap Model; Powder Metallurgy; Haight-Westergaard Coordinates; Plasticity; Finite Element Method

Abstract :
In this paper we show and demonstrate the advantages of using the Drucker--Prager cap yield surface inside an isotropic plasticity constitutive applied to granular media in the Haight--Westergaard coordinate. This constitutive model can be used for all types of granular media such as metal powder, ceramics and pharmaceutical industries.A typical compaction process starts with the filling of a cavity, followed by the compaction process and the extraction of the produced item. During the compaction phase, loose powder is compacted under high-pressure loads to a dense and compact material, also known as green part. Modeling the compaction process is challenging and involves the formulation of a proper constitutive law with multi-failure surfaces for finite-element analyses. This paper investigates the modeling of granular media using an extended Drucker--Prager cap model in plasticity. We first time present its implementation in the Haight--Westergaard coordinate system.

Innovative Aspect(s) :
This paper investigates the modeling of granular media using an extended Drucker - Prager cap model in plasticity. We first time present its implementation in the Haight - Westergaard coordinate system.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION
01-04 October 2023

Paper Number : EP235764659

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** Compaction and Sintering

Author : Dr Zago Marco (University of Trento, Italy)

Co-author(s) : Ing Rambelli Alex, Ing Foschi Davide (Powder Metal B.U. - Sacmi Imola s.c., Italy), Prof Dr Cristofolini Ilaria (University of Trento, Italy)

Title : Influence Of Powder Transfer On Density Distribution And Dimensional Precision In Multilevel Axi-symmetric Parts

Keyword(s) :
Powder Transfer; Powder Compaction; Filling Strategy

Abstract :
Previous studies have systematically investigated densification in ring-shaped parts. Additionally, the effect of filling parameters on filling and green density was explored, demonstrating the strong influence of the die cavity on the origin of inhomogeneous powder distribution. A uniform density is mandatory for industrial production, so further investigation is necessary, also including the contribution of powder transfer.This work aims at investigating the effect of powder transfer on the density distribution and the dimensional precision in 2-level axi-symmetric parts. Sample geometry was compacted by varying: the filling parameters, powder transfer strategies, and compaction forces. Reference samples were produced by excluding the powder transfer step from the compaction cycle. Green and sintered density distribution were derived, highlighting the effect of filling, powder transfer, and compaction strategies.

Innovative Aspect(s) :
Literature studies have investigated powder rearrangement during powder transfer by numerical simulation and empirical approaches. The experimental results were mostly validated at laboratory scale, involving die with a glass face. By contrast, the powder transfer is poorly examined at industrial scale. For this reason, this work aims at assessing the influence of geometry, filling parameter and powder transfer strategies on the green and sintered density distribution in 2-level axi-symmetric parts. An industrial press was employed in the experimental procedure in order to identify results closely related to real production.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765257

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** Compaction and Sintering

Author : Mr Gupta Nitin (Indian Institute of Science Bangalore, India)

Co-author(s) : Mr Dawara Vineet, Dr Kumar Aloke, Dr Viswanathan Koushik (Indian Institute of Science Bangalore, India)

Title : Synthetic Space Bricks: Understanding Sintering Processes In Extra-terrestrial Soils

Keyword(s) :
Sintering; Extraterrestrial Habitation; Martian Soil Simulant; Lunar Soil Simulant

Abstract :
Sintering has been used to form ceramic objects since ancient history. Classical examples of sintered ceramics are almost always pottery-derived artifacts that have their origins in soils and|or clays. Term synthetic distinguishes the sintered bricks from their naturally formed cousins that have been the subject of other investigations. In this work, motivated by significant recent interest in space exploration, we present investigations of sintering experiments with extra-terrestrial soil simulants into brick-shaped objects termed synthetic space bricks. Two different families of these space bricks are produced, corresponding to lunar and martian soil simulants. The bricks possess significant unconfined compressive strengths (40 MPa), justifying their potential use as structural blocks for extraterrestrial habitats. Further, a lattice-based numerical model investigates micromechanics of their formation and failure. This model is shown to accurately simulate the failure of bricks (in a statistical sense) and the effect of various sintering process parameters on their failure properties.

Innovative Aspect(s) :

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235766208

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** Compaction and Sintering

Author : Ing Nogueira Gilmar (Univ. Grenoble Alpes, France)

Co-author(s) :

Title : Digital Twin Of Ceramic Composite Powder For Compaction And Sintering Using Discrete Simulation

Keyword(s) :
Powder Compaction; Sintering; Discrete Element Method; Digital Twin; Composite

Abstract :
A digital twin using DEM (Discrete Element Method) simulation of the compaction and sintering of ceramic composite powder is presented. The process kinematics follow a standard ceramic powder process: loading (double action compaction), unloading, and ejection of the pellet. The relative density distribution in the pellet is the main output of this step. After compaction, the pellet is sintered up to nearly full density and a final shape is obtained. This final shape depends on the process kinematics (maximum loading pressure, intermediate pressure and friction coefficient) and the die geometry. This industrial process introduces many variables and represents a challenge for the generation of a digital twin. The objective of this work is to present the step-by-step method to create a digital twin of a ceramic powder in an efficient way by using a machine learning (ML) approach. This ML approach is illustrated here on a composite powder example.

Innovative Aspect(s) :

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EURO PM2023 CONGRESS & EXHIBITION
01-04 October 2023

Paper Number : EP235763938

Requested presentation type : Poster Presentation

Topic : Consolidation Technologies **Subtopic :** Compaction and Sintering

Author : Dr Shishkina Yulia (I.M.Frantsevich Institute for Problems of Materials Sciences (IPMS NASU), Ukraine)

Co-author(s) : Dr Baglyuk Genadii, Mr Kyryliuk Stepan, Dr Kyryliuk Yevheniia (I.M.Frantsevich Institute for Problems of Materials Sciences (IPMS NASU), Ukraine)

Title : Influence Of Stress-strain State On Structure Formation Of Al-TiC Aluminum Composites During Hot Deformation

Keyword(s) :
Hot Forging; Porous Powder Blanks; Aluminum-Based Composite Materials

Abstract :
The results of simulation of the process of hot forging of porous powder blanks in a die providing action of active friction forces on the side surface of the deformed blank, which are realized due to internal connections of matrix-material system, are presented.

Innovative Aspect(s) :
Developing the design of an experimental stamp, which was used to produce composite materials based on aluminum, as well as the technological process of hot forging of porous powder blanks, which is important for the solution of one of the central problems – determining the optimal shape, size and porosity of blanks for forging, as well as deformation schemes during its implementation, because these parameters not only determine the manufacturability and technical and economic efficiency of the process, but also to – the quality of the future parts.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764218

Requested presentation type : Poster Presentation

Topic : Consolidation Technologies **Subtopic :** Compaction and Sintering

Author : Mr Fatangade Y. P. (COEP Tech., India)

Co-author(s) : Dr Dhokey N. B. (COEP Tech., India)

Title : Effect Of Process Variables On Seamless Fabrication Thin Iron-based Powder Metallic Strip And Its Mathematical Analysis

Keyword(s) :
Powder Roll Compactor (PRC); Metallic Strip; Green Density; Sintered Density; Mathematical Model; Surface Response

Abstract :
Metallic strip fabrication involves traditional production techniques such as melting, casting, hot and cold rolling, further finishing operations. However, it may be convenient to follow powder metallurgical route for strip fabrication, wherever process exhibits limitation on feasibility in traditional practices. The objective of this paper focuses on the manufacturing of iron-based powder metallic strips using powder roll compaction technology. The powder rolling was performed on iron powder particles size fraction viz. (53 to 150 μm) with a variable back pressure powder feeder and roll mill dimensions of 100 mm x 62 mm (width x diameter) was employed. The mathematical model was used to investigate the influence of process variables on the strip's uniform densification. The green strip obtained with a roll compactor undergone further sintering at 1120°C (N_2:H_2: 9:1). For the consistent and flawless manufacturing of the strip, a correlation between the process densification parameter has been established.

Innovative Aspect(s) :
Thin metallic strip fabrication is attempted with direct powder rolling technology with minimizing finishing operations with an inbuilt roll cavity.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235762595

Requested presentation type : Poster Presentation

Topic : Consolidation Technologies **Subtopic :** Compaction and Sintering

Author : Dr Jeong Haguk (Korea Institute of Industrial Technology, Korea, Republic of)

Co-author(s) : Dr Lee Jongbeom (Korea Institute of Industrial Technology, Republic of Korea)

Title : Effects Of Pre-annealing And Sintering Process On Cubic-tetragonal Transformation Of Hydrothermally Synthesized BaTiO3 Nanopowders

Keyword(s) :
BaTiO3; Nanopowder; Pre-Annealing; Sintering; Crystalline Structure Transformation

Abstract :
Commercial hydrothermally synthesized BaTiO3 powder with a cubic structure was annealed in a temperature range of 750–900 ?, and the cubic-tetragonal structure transition and microstructure evolution of the powder were investigated in relation to the annealing process. The BaTiO3 powder used had a cubic structure below an annealing temperature of 900 ? and a tetragonal structure above 900 ?. Particle growth occurred under a low activation energy of ~33.2 kJ|mol because of the nanocrystalline size effect, while the crystallite size slightly decreased in the powder with the cubic structure and sharply increased in that with the tetragonal structure. This was because the OH group in the powder with the cubic structure influenced the lattice extension on the particle surface. The hydrothermally synthesized BaTiO3 nanopowders pre-annealed up to 900 ? for 4 hr in air were sintered at 1200 ? for 2 hr in N2 atmosphere, and then their properties

Innovative Aspect(s) :
The pre-annealing process in air increased the ratio of O2 to O bonding of Ba element for the BaTiO3 nanopowders and then it contributed to retard the cubic-tetragonal transformation from the results of differential scanning calorimetry.

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EURO PM2023 CONGRESS & EXHIBITION

Technical Programme Committee
15th February 2023

CONSOLIDATION TECHNOLOGIES

FIELD ASSISTED SINTERING TECHNOLOGIES

EPMA european powder metallurgy association

EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235785696

Requested presentation type : Oral Presentation

Topic : Consolidation technologies **Subtopic :** Field Assisted Sintering Technologies

Author : Dr Ing Milenkovic Srdjan (IMDEA Materials Institute, Spain)

Co-author(s) : Dr Alvaredo Paula, Mr Biedma Angel (UC3M, Spain)

Title : Influence Of The Processing Method On The Microstructure And Mechanical Properties Of Eutectic High Entropy Alloys

Keyword(s) :
Eutectic High-Entropy Alloys; Casting; Powder Metallurgy; Microstructure; Hardness

Abstract :
The processing method influences the microstructure and therefore, properties of High Entropy Alloys (HEA). In this work, two eutectic high entropy alloys (EHEA) were processed by two different processing methods: arc casting (AC) and powder metallurgical (PM) route comprising powders gas atomization and their consolidation by field-assisted sintering (FAST). The obtained microstructures and properties are compared in order to establish the influence of the processing route on the microstructure of eutectic alloys and the relationship between microstructure, properties, and solidification rate has been established. The processed EHEA were AlCoCrFeNi2.1 and CrFeNi2.2Al0.8. The AlCoCrFeNi2.1 was the first proposed EHEA, which has been thoroughly studied. The CrFeNi2.2Al0.8 EHEA was derived from AlCoCrFeNi2.1 by removing the Co element. Results show that the alloys prepared by the PM possess finer microstructure and higher hardness. The Co-free CrFeNi2.2Al0.8 alloy and AlCoCrFeNi2.1 alloy have similar properties at room temperature when processed by the same method.

Innovative Aspect(s) :
The manuscript reports comparative study of two eutectic high entropy alloys (EHEA) processed by two different processing methods: arc casting (AC) and powder metallurgical (PM) route comprising powders gas atomization and their consolidation by field-assisted sintering (FAST). The obtained microstructures and properties are compared in order to establish the influence of the processing route on the microstructure of eutectic alloys and the relationship between microstructure, properties, and solidification rate which will be a basis for future research.The innovative aspect is that the Co-free EHEA CrFeNi2.2Al0.8 alloy has been preocessed for the first time by the Field Assisted Sintering method and its microstructure and properties compared with the same alloy in the as cast state as well its counterpart alloy with the Co AlCoCrFeNi2.1.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235751774

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** Field Assisted Sintering Technologies

Author : Dr Fregeac Arnaud (Norimat, France)

Co-author(s) : Dr Mackie Jennyfer, Ing Beynet Yannick, Dr Epherre Romain (Norimat, France)

Title : Why FAST|SPS Technology Will Explode And Become A Mainstream Production Process During The 10 Next Years?

Keyword(s) :
FAST|SPS; Hybridization; AdditiveManufacturing; 3D

Abstract :
FAST|SPS is well-known as an R&D process capable of making high performance parts in a wide range of materials. The technologies two main constraints, production scalability and geometry limitations, have been shattered in the last few years thanks to strong R&T work.The conference will focus on the development of fully dense 3D complex shapes by FAST|SPS with various ceramic and metal materials, the recent results on the capability of the process opening the way to large scale production and the improvement of multi-physics modeling to help users at each step of the FAST|SPS process from conception to production.

Innovative Aspect(s) :
For the 1st time we are able to make 3D complex shapes by hybridization of FAST|SPS and additive manufacturing process with a strong level of control in terms of geometry and performance.We will develop how we built our R&D project to master these conditions and how we expand this know how to generalize for several material.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235752352

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** Field Assisted Sintering Technologies

Author : Dr Neirinck Bram (Aerosint SA, Belgium)

Co-author(s) : Dr Huang Shuigen, Prof Dr Vleugels Jozef (KULeuven, Belgium)

Title : Nickel-Zirconia Laminates Prepared By Selective Powder Deposition And SPS|FAST Sintering

Keyword(s) :
Laminates; Multi-Material; SPS|FAST Sintering; Selective Powder Deposition (SPD)

Abstract :
Co-fired devices were developed in the late 50's as a robust option for electronics. As the name suggest, they were obtained by simultaneously sintering different materials, often an insulating ceramic substrate with a conductive metal on top. Since these devices were first conceived there have been significant developments in processing and sintering technologies. This paper addresses a potential alternative approach to create High temperature Co-fired Ceramics (HTCC's). Commercially pure nickel and yttria-stabilized zirconia powder layers with a controlled thickness were deposited in graphite dies using Selective Powder Deposition (SPD). These layers were subsequently pre-compacted in the die and consolidated using SPS|FAST sintering. The results show that crack-free laminates of fully dense metal and ceramics can be obtained. The metal sections are electrically insulated from one another, demonstrating the possibility to generate conductive tracks|circuits, while using a relatively uncomplicated deposition process and high speed sintering.

Innovative Aspect(s) :
By direct sintering of selectively deposited powders the use of binders, and subsequently the need for a debinding treatment, can be avoided. However since in essence loose powder is sintered a pressure assisted sintering technique is required.To ensure proper densification and joining of different materials an overlap in the sintering window is required. The Field Assisted Sintering Technology generally results in larger applicable sintering windows, facilitating both the consolidation and joining. By controlling the applied pressure during sintering and cooldown cracking can furthermore be avoided.As such combining the SPD technology and FAST sintering a wider range of multi-material combinations can potentially be processed, opening opportunities to demanding applications.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235753924

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** Field Assisted Sintering Technologies

Author : Dr Lagos Miguel (TECNALIA, Spain)

Co-author(s) : Dr Agote Iñigo, Dr Lores Asier, Ing Azurmendi Naiara, Mr Leizaola Iñaki (TECNALIA, Spain)

Title : Dense Complex Copper Parts Obtained By Binder Jetting And Spark Plasma Sintering

Keyword(s) :
FAST; SPS; Binder Jetting; 3D Printing; Complex Shapes

Abstract :
Binder Jetting is capable of cost-effectively producing complex metal and ceramic components without the need for support structures. However, printed parts typically contain porosity due to the use of coarse powders and a loosely packed powder bed. For some materials, it is difficult to achieve full density without infiltration of a secondary lower melting point material.This work presents the post-densification of binder jetting parts by a pressure assisted sintering process, Spark Plasma Sintering. Sacrificial powder was used in other to maintain the complex geometry, Copper pieces were successfully densified using different starting conditions. Densification of the pieces was not isotropic, and some design considerations will be explained in order to obtain the right geometry. Additionally, considerations about the possible scalability and industrial application of this approach will be also presented.

Innovative Aspect(s) :
This work presents a processing route for the consolidation of "difficult to sinter" materials with complex shapes.The combination of 3D printing and FAST sintering is an interesting alternative to obtain full density pieces after binder jetting (solving one of the problems of this technology for some materials).Considerations about the scalability and final application of this approach are also presented.This work presents the specific case of pure copper, but some of the conclusions can be extended to other materials.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235756151

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** Field Assisted Sintering Technologies

Author : Mr Lister Samuel (University of Sheffield, United Kingdom)

Co-author(s) : Dr Graham Simon, Mr Simpson Craig, Mr Adams Nigel, Prof Jackson Martin (University of Sheffield, United Kingdom)

Title : A Microstructural Assessment Of The Thermal Gradient During Large-scale FAST|SPS Sintering For Tall Samples And Multi-Sample Serial Stacking Of Ti-6Al-4V Plates

Keyword(s) :
Thermal Gradient; FAST; SPS; Titanium; Ti-64

Abstract :
Field Assisted Sintering Technology (FAST) is a powder consolidation technique which is growing in popularity due its short, single-step processing cycles. However, as the process matures, more focus is being placed on the production of larger cylindrical samples (both axially and radially). For the process to be economical in production, there is a drive towards multi-part processing via serial stacking|parallel processing. In both cases, there is the potential for substantial thermal gradients within the sample|stack which could negatively impact part properties. In this work the effect of the thermal gradient (axial and radial), in both a 85mm tall x 120mm diameter Ti-64 billet and eight 7mm x 120mm diameter Ti-64 plates processed in a stack, has been studied experimentally via microstructural assessment and Vickers hardness measurements. Results were compared with the thermal profile simulated using COMSOL multi-physics modelling software and steps to minimise the thermal gradient are discussed.

Innovative Aspect(s) :
An assessment of the thermal gradient within FAST processed Ti-64 material has been made in both the axial and radial direction via microstructural assessment. The production of an atypically large billet (85mm height x 120mm diameter) has allowed the gradient to be assessed in two directions rather than just one which is most commonly presented. This assessment has been carried out for both a monolithic sample and eight plates processed in series, separated by graphite foil and graphite wear pads which further affect the thermal gradient, allowing comparisons to be made between the two cases.

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Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235761173

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** Field Assisted Sintering Technologies

Author : Miss Keszler Monica (Forschungszentrum Jülich GmbH, Germany)

Co-author(s) : Mr Grosswendt Felix, Prof Weber Sebastian (Ruhr-Universität Bochum, Germany), Dr Ing Jaeger Sebastian (Bergische Universität Wuppertal, Germany), Miss Assmann Anna-Caroline (RWTH Aachen, Germany), Prof Bram Martin (Forschungszentrum Jülich GmbH, Germany)

Title : Upcycling Of PM T15 Steel Swarf Via FAST|SPS Processing

Keyword(s) :
Recycling; FAST|SPS; High-Speed Steel; Swarf; Waste

Abstract :
PM T15, a high-speed steel containing tungsten, is a valuable material used in tools such as cutting disks. When PM T15 tools are machined, the excess swarf is disposed in landfills, and the valuable elements contained in the steel are lost. Since this swarf is often contaminated with grinding media such as SiC, cBN, and corundum, separation processes are needed to recover the steel, and direct recycling is not possible. However, FAST|SPS has the potential to generate new materials from PM T15 swarf containing these residues via the dissolving of the carbides and nitrides into the steel matrix and freezing the insoluble corundum into the matrix. Our work has shown the capability of FAST|SPS to create dense and semi-dense pellets of PM T15 steel containing grinding media from industrial waste. These pellets are analyzed for their mechanical properties and have the potential for further deformation and net-shaping into new tools.

Innovative Aspect(s) :
Upcycling of an unused and valuable waste stream
Multi-material matrices generated via field-assisted sintering
Possibility of net-shaping waste to tool in few stages

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235763918

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** Field Assisted Sintering Technologies

Author : Ing Karpowicz Damian (GeniCore Sp. z o.o., Poland)

Co-author(s) :

Title : U-FAST Technology - New Materials For Industry

Keyword(s) :
FAST; FAST Applications; FAST for Industry; FAST Made Materials; FAST Good Practices

Abstract :
Field assisted sintering technology become a good alternative for most demanding applications. During the presentation most recent examples of materials made with FAST and PPC technologies will be presented and also solutions which allows to compete with other technologies when it comes for cost-effectiveness which in most cases is the biggest disadvantage for FAST technology so far.

Innovative Aspect(s) :
Presentation includes descriptions of solutions like graphite mold multi-hole design, near-net shaping, functionally graded materials. The current market expectations related with FAST technology will be shown on real examples.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764663

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** Field Assisted Sintering Technologies

Author : Dr Garcia de la Cruz Lucia (Universidad Carlos III de Madrid, Spain)

Co-author(s) : Dr Lagos Miguel (TECNALIA, Spain), Dr Alvaredo Paula, Prof Dr Torralba José Manuel, Prof Dr Campos Monica (Universidad Carlos III de Madrid, Spain)

Title : Electrical Resistance Sintering: A Promising Tool To Process CoCrMo Alloy Samples With Harmonic Structures For Exceptional Mechanical Properties

Keyword(s) :
Electrical Resistance Sintering; Harmonic Structures; CoCrMo Alloys

Abstract :
Harmonic structures (HS) are ordered bimodal microstructures, where coarse-grained regions are surrounded by interconnected ultrafine-grained regions, that display improved mechanical properties. To retain such unique microstructure, powder superficially deformed by low energy ball-milling is used and fast sintering techniques are required. Electrical resistance sintering (ERS) is an ultrafast sintering process that uses high current densities and pressure to consolidate samples in a few seconds, making this technique a perfect candidate. CoCrMo alloy are widely used for biomedical applications and require a good combination of strength and ductility, which can be achieved with HS.This research investigates the use of ERS as a promising tool to fabricate CoCrMo samples with HS from powder processed at different milling times. Microstructures are studied by means of SEM|EBSD and XRD and mechanical properties evaluated in terms of hardness.

Innovative Aspect(s) :
The innovative aspect of this paper is the use of ERS to process harmonic structures. To date, papers refering to this type of microstructures use Spark Plasma Sintering as the consolidation technique.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764720

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** Field Assisted Sintering Technologies

Author : Dr Bolsonella Arnaud (Sintermat SAS, France)

Co-author(s) : Dr Naimi Foad, Dr Ing Ariane Mostapha (Sintermat SAS, France), Prof Bernard Frédéric (Université de Bourgogne, France)

Title : Using Hybrid-SPS To Produce Large-sized And Complex Shap Parts, Application To A Reinforced Titanium Alloy

Keyword(s) :
Spark Plasma Sintering; FLASH; Hybrid; Large Sized Materials; Near Net Shape; Titanium Alloy

Abstract :
Spark plasma sintering (SPS) technology is used to sinter, in a very short time, a large range of materials including metals, ceramics and bio-materials. One of the challenges of using this process is to limit the thermal gradient for large-sized samples (> 100 mm).At Sintermat, an external electromagnetic heater is coupled with the SPS equipment (H-HPD-300, FCT system) in order to limit thermal losses via radiation. In this study, the influence of a hybrid heating mode on the densification behavior of a reinforced-titanium powders combined with "ex-situ and in-situ" reinforcements were investigated in order to achieve a matrix sintering.These results confirm the relevance of the hybrid equipment to produce dense, homogenous and large-sized parts having a microstructure close to the initial fine powder microstructure. In addition, the relationship between the microstructure and mechanical properties is clearly highlighted.

Innovative Aspect(s) :

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765190

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** Field Assisted Sintering Technologies

Author : Prof Dr Bernard Frederic (ICB - UMR 6303 CNRS | uB, France)

Co-author(s) : Ing Bussiere Florian, Dr Le Gallet Sophie, Dr Kalfayan Greg (ICB - UMR 6303 CNRS | uB, France), Dr Ariane Mostapha (Sintermat, France)

Title : Spark Plasma Sintering Of Titanium|nanodiamond Composite Powders : Effect Of Nanodiamond Rate On The Microstructure

Keyword(s) :
SPS; Ti|Nanodiamond Composites; Hardness; Microstructure

Abstract :
Titanium is used in many applications but has a low hardness of approximately 300HV. Conversely, diamond has excellent mechanical properties, in particular, the highest hardness of any material. The latter is thus a promising reinforcement material for titanium composites and metal matrices in general.In this study, titanium|nanodiamond (ND) composite discs were sintered by spark plasma sintering (SPS). Densification was studied for different Ti+ND powder mixtures to identify the optimized SPS conditions. Microstructure, density, hardness and electrical conductivity were measured and discussed. The main results show: (1) spark plasma sintering is a promising solution to achieve, in a short time, a high level of densification at lower temperatures to avoid graphitization of diamond compared to conventional sintering; and (2) the greater the quantity of nanodiamonds, the more the hardness of the composite increases.

Innovative Aspect(s) :
Interest of SPS technology to maintain the powder microstructure in particular, the presence of nanodiamond after the sintering.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764967

Requested presentation type : Poster Presentation

Topic : Consolidation Technologies **Subtopic :** Field Assisted Sintering Technologies

Author : Prof Grigoryev Evgeny (Merzhanov Institute of Structural Macrokinetics and Materials Science Russian Academy of Sciences, Russia)

Co-author(s) : Dipl-Ing Kuznechik Oleg (SSI PM, Belarus), Prof Dr Chumakov Alexander, Dr Nikonchuk Irina (B.I.Stepanov Institute of Physics, Belarus), Prof Dr Strizhakov Evgeny, Dr Ing Nescoromniy Stanislav, Ing Ageev Stanislav (DON STATE TECHNICAL UNIVERSITY, Russia)

Title : Advances Of High-Voltage Consolidation Of Powder Materals

Keyword(s) :
High-Voltage Electric Pulse Consolidation; Refractory Powder Materials; Electrothermal Processes; High-Voltage Welding; Thermal Radiation; Pulse Photometry; Rogowski Coil

Abstract :
The method of high-voltage consolidation of powders is effective for the production of refractory composite materials that retain their strength properties at ultrahigh temperatures under aggressive external influences. The short duration of high-temperature exposure in the process of high-voltage consolidation makes it possible to preserve the structural-phase state of the initial powder material in the consolidated compact material. A feature of this method is the high density concentration of the released energy in the area of contacts between powder particles. Experimental studies of the parameters of high-voltage electrical impulse action in the process of consolidation of high-temperature powder compositions have been carried out. Registration of the parameters of a high-voltage current pulse and the intensity of thermal radiation of the consolidated powder materials was carried out using a measuring complex developed by the authors.

Innovative Aspect(s) :
The registration of electrothermal processes during high-voltage electric pulse consolidation of refractory powder materials makes it possible to establish the optimal parameters of high voltage consolidation for optimal structure in consolidated samples.

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EURO PM2023 CONGRESS & EXHIBITION

Technical Programme Committee
15th February 2023

CONSOLIDATION TECHNOLOGIES

HOT ISOSTATIC PRESSING

EPMA
european powder metallurgy association

EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235763076

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** Hot Isostatic Pressing

Author : Dr Ing Bassini Emilio (Politecnico di torino, Italy)

Co-author(s) : Dr Ing Martelli Pietro Antonio, Dr Lerda Serena, Dr Ing Marchese Giulio, Prof Biamino Sara, Prof Ugues Daniele (Politecnico di torino, Italy)

Title : Hot Isostatic Pressing Applied To Shelled Inconel 718: A Faster Approach To Densify And Heat-treat Additively Manufactured Samples

Keyword(s) :
Inconel 718; Fast Additive Manufacturing; Shelling; HIP Quench

Abstract :
The application of Hot Isostatic Pressing to additively manufactured samples is a key factor to drastically reduce the printing time. In this work LPBF IN718 was printed with two different strategies aiming to drastically reduce the leading time. The first consisted of printing a 1 mm dense shell of material leaving the powders inside completely losened. The second used two different printing speeds, a slower one for the external shell and a faster one for the core. The two strategies allowed a time saving of 60 and 45 % respectively. A further time optimization consisted in performing the following HIP process at the same temperature of the annealing treatment to get full densification and the correct microstructure at the same time thanks to a final fast gas quench. The obtained microstructures were assessed morphologically using traditional electronic microscopy and EBSD. Further more, the shell-core interface was assessed via nanoindentation.

Innovative Aspect(s) :
This paper aims to assess the viability of combining techniques from different field to shorten the overall printing procedure of Inconel 718, settling the bases for producing low weldable material as well in the next future. Firstly, the focus of this work is finding those parameter that allow a faster printing process, generating a tolerable quantity of flaws which will be eliminated with the HIP. At the same time, traditional HIP is substituted with the HIP quench, a process capable of healing the components from the retained flaws and heat treat them in a single step. The samples indeed are totally densified and the correct microstruture is obtained at the same time, tailoring the soaking temperature and time. Finally, the modulation of the cooling rate immediately after HIP allows to eliminate the formation of coarse reinforcing particles and thus the need for further heat treatment in different furnaces.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235763750

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** Hot Isostatic Pressing

Author : Mr Gårdstam Johannes (Quintus Technologies, Sweden)

Co-author(s) : Mr Beamer Chad, Mr Shipley James, Mr Magnusson Anders (Quintus Technologies, Sweden)

Title : Latest Developments In HIP And High-Pressure Heat Treatment

Keyword(s) :
Oxidization; Discoloration; Heat Treatment; Atmosphere; HIP

Abstract :
Stabilizing and improving product quality, manufacturing lead time, cost, and overall energy efficiency, calls for continuous reviewing of current state of the art technologies in each field of interest. The past year has seen a new set of capabilities presented for controlling the processing atmosphere in Hot Isostatic Pressing. This reduces discoloration and oxidation of part surfaces after HIP|HPHT processing, improving mechanical strength and chemical consistency of difficult to machine surfaces and visual appearance of surfaces not to be machined. As the HIP process continuously is developed to present new, and improved tools in the engineer's toolbox, this presentation aims to summarize the capabilities of current state of the art, high pressure heat treatment, HPHTTM, for HIP equipment and reference recent work showing how this functionality is and can be used to further improve components as produced by current PM (Powder Metallurgy) manufacturing processes.

Innovative Aspect(s) :

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235763898

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** Hot Isostatic Pressing

Author : Mr Huguet Maxime (Univ Grenoble Alpes, CEA, LITEN, DTCH, LCA, France)

Co-author(s) : Dr Moro Isabelle, Dr Gillia Olivier, Dr Briottet Laurent (Université Grenoble Alpes, CEA, LITEN, DTCH, LCA, France)

Title : Closure Of Isolated Voids During Diffusion Bonding: Modelling And Experimental Statistics Comparison

Keyword(s) :
Diffusion Bonding; Hot Isostatic Pressing; Void Closure

Abstract :
Hot Isostatic Pressing (HIP) is a process used to make compact heat exchangers. The search of a compromise between time, pressure and temperature, for a HIP cycle aiming at attaining fully bonded interfaces while preserving the designed shape of the compact heat exchanger , may lead to numerous experimental failed assemblies. Modelling of diffusion bonding occurring during the cycle might significantly reduce these runs.Void closure kinetic is the focus of the present study. Most literature models require a unique cavity representative of an interface in terms of bonded area fraction. Through the weak coupling of mechanics (finite elements resolution) and diffusion phenomena (finite differences resolution), the herein numerical model is a step toward the simulation of the closure of a variety of voids along an interface by diffusion bonding. The model is confronted to experimental kinetic closure statistics of isolated voids resulting from interrupted hot pressing cycles.

Innovative Aspect(s) :
As mentioned in the abstract, literature models require the election of a cavity shape and size which kinetic closure is representative of a macroscopic parameter on a full interface (bonded area fraction). It proved to be efficient to simulate void closure during diffusion bonding of surfaces with periodical roughness. However, the election of a representative cavity becomes very tricky when roughness is irregular. The developed model aims to simulate the effects of diffusion bonding over multiples irregular voids on an interface. This complex interface may result from the contact of two roughness profiles. To do so, the models relies on numerical methods enabling any irregular void shapes. Viscoplasticity effects are taken into account through an original coupling of the diffusion phenomena, solved by a finite difference scheme, with the use of the finite elements method.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765758

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** Hot Isostatic Pressing

Author : Prof Prikhodko Sergey (University of California Los Angeles, USA)

Co-author(s) : Dr Savvakin Dmytro, Prof Dr Ivasishin Orest, Dr Markovsky Pavlo (G.V. Kurdyumov Institute for Metal Physics of N.A.S. of Ukraine, Kyiv, Ukraine, Ukraine), Prof Janiszewski Jacek, Dr Cieplak Kamil (Jarosław Dąbrowski Military University of Technology, Wars

Title : Titanium Laminates Made Using Powder Metallurgy And Solid State Bonding

Keyword(s) :
Titanium Alloys; Composites; Ballistic Performance; Laminate; Hot Isostatic Pressing

Abstract :
Superior performance of laminate structures can be achieved by processing each layer individually, providing apiece layer optimal properties and further layer bonding. Layered structures of Ti-6Al-4V alloy composites reinforced with TiC or TiB particles were bond using hot isostatic pressing (HIP). Starting plates were made using blended elemental powder metallurgy, where the amount of reinforcement was:10, 20, 40% (wt.). When the macro-deformation at the interface is very small and the material compositions are similar, the porosity of the bonded materials likely leads to micro-deformations at each point of the interface, can likely promote diffusion bonding. Bonded structures were balistacally tested and compared to uniform titanium alloys as well as layered alloy|composite structures made by powder metallurgy. Microstructure and of material properties were analyzed to understand the contribution of HIP processing to the ballistic performance of laminates.

Innovative Aspect(s) :
The HIP bonding is proficient way to build the hybrid structures of Ti64 alloy and its TiC or TiB composites with superior harness. In addition to layer bonding and properties improving due to structure aging, HIP is also effective in increasing hardness by reducing porosity that often unavoidable in powder metalurgy fabricated materials.

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EURO PM2023 CONGRESS & EXHIBITION
01-04 October 2023

Paper Number : EP235762945

Requested presentation type : Poster Presentation

Topic : Consolidation Technologies **Subtopic :** Hot Isostatic Pressing

Author : Dr Shulga Andrey (National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), Russia)

Title : A Multiscale Comparative Study Of The Structure Features Of Rapidly Quenched REP-powders, PM HIP Compacts, Products Of Austenitic Stainless Steels And Their Traditional Counterparts

Keyword(s) :
Stainless Steels; Rapidly Quenched Powder; REP-Techniques; PM HIP; Traditional Technology; Hot Deformation; Heat Treatment; Autoradiography; Carbon; Boron; Microstructure; Mechanical Properties; Lattice Parameters; Non-Equilibrium States

Abstract :
Rapidly quenched REP-powders produced by melt atomization, evidently, can be characterized by the effect of quenching rate on structure features as in traditional solid state quenching. However, the critical cooling rate, determined in the TTT diagram for melt phase transformation: crystallization is much higher than its value for suppressing austenite transformation in carbon steels. Important features of rapidly quenched powders - high dispersity of dendrites and formation of fine subgrain structure - determine the precipitation of carbides and borides. Direct nuclear methods of activation autoradiography on carbon, track autoradiography on boron, metallography, SEM, EDX, etc were used for investigation. The structure features including the lattice parameter of a solid solution of rapidly quenched REP powders, HIP PM compacts, products of austenitic stainless steels and their traditional counterparts were revealed and analyzed taking into account the role of carbon and boron, precipitation of carbides, borides and effect of non-equilibrium states.

Innovative Aspect(s) :
The influence of quenching rate on structure features of rapidly quenched REP-powders produced by melt atomization can be characterized by the effect of quenching rate on structure features as in traditional solid state quenching. However, the critical cooling rate, determined in the TTT diagram for melt phase transformation: crystallization is much higher than its value for suppressing austenite transformation in carbon steels. Detailed structure features including the lattice parameter of a solid solution of rapidly quenched REP powders, HIP PM compacts, products of austenitic stainless steels and their traditional counterparts were revealed and analyzed taking into account the role of carbon and boron, precipitation of carbides, borides and effect of non-equilibrium states of investigated materials. These results are useful for a better understanding of the physical metallurgy of the PM HIP technology of stainless steels using rapidly quenched REP powders and optimization of PM HIP in comparison with traditional technology.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

Technical Programme Committee
15th February 2023

CONSOLIDATION TECHNOLOGIES

OTHER CONSOLIDATION TECHNOLOGIES

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765598

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** Other Consolidation Technologies

Author : Dr Chirico Caterina (Institute for Ceramic and Glass (CSIC-ICV), Spain)

Co-author(s) : Dr Sanchez Herencia Antonio Javier, Dr Ferrandez Ana, Dr Ferrari Begoña (Institute for Ceramic and Glass (CSIC-ICV), Spain)

Title : Rheological Behavior Of A Colloidal Feedstocks Of Ti6Al4V Alloy For 3D Printing By Fused Filament|Granules Fabrication (FFF|FGF)

Keyword(s) :
Titanium Alloys; Fused Filament Fabrication; Colloidal Processing; Oscillatory Rheology

Abstract :
3D printing technology is the solution to the free-mold fabrication challenge of light parts of Ti alloys with complex geometries, and Fused Filament Fabrication (FFF) the most competitive technology for titanium processing. Main advantages of FFF is the design flexibility to produce complex geometries and light internal structures without supports. Biomass thermoplastics use turns printing eco-efficient, limiting debinding to a thermal step. Moreover, colloidal procedure allows the use of low particle size powders (D5010 μm), achieving feedstocks with high-quality particles dispersion to enhance sintering and Ti-parts performance, and lowering the diameter of the printing nozzle (0.4 mm) to improve surface finishing.In this study, printable PLA-based filaments of Ti6Al4V alloy (76-72 wt.%) were produced following the colloidal process patented by COLFEED4Print company. Oscillatory melting rheology were analyzed varying temperature, deformation rate and frequency parameters, to adjust the printing window and control flowability of melt. Printed and sintered samples were analyzed.

Innovative Aspect(s) :
This work proposes the development of sinterable Ti64 filaments for FFF 3D printing using a biomass thermoplastic PLA-based matrix. Additionally, it aims to develop an in-process quality control protocol for Ti64 filaments based on oscillatory rheology behaviour in order to obtain a proper assessment of the filaments that can be used in an FFF 3D printer.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235766295

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** Other Consolidation Technologies

Author : Mr Aguilar José Luis (Carlos III University, Spain)

Co-author(s) : Prof Dr Jimenez-Morales Antonia (Carlos III University, Spain), Prof Dr Ruiz-Navas Elisa M. (Carlos III University, Spain), ,

Title : Improving The Densification Of Aluminium-based Feedstock Produced By Additive Manufacturing

Keyword(s) :
Sintering Process; Aluminium Alloy; Composite Extrusion Modeling (CEM); Powder Injection Moulding (PIM); Sustainable Feedstock

Abstract :
This work studies the sintering process of the 2024 aluminium alloy after 3D printing from sustainable pellet feedstocks (CEM), as an alternative route to process aluminium alloys. For the design of the sustainable feedstock of aluminium, powders were combined with water-soluble and low CO2 emissions polymers, PEG and CAB respectively. The powder injection moulding (PIM) technique was used as a first approach to produce good quality samples, thanks to previous studies by the research group. The sintering process was carried out by adding different percentages or traces of alloying elements in the aluminium-based feedstock to improve the sinterability of the material and designing an optimal experimental setup for this critical final stage. A microstructural characterisation and thermogravimetric analysis of the parts trough the different stages of the processing was carried out in order to obtain the optimum sintering parameters for this aluminium alloy after printing.

Innovative Aspect(s) :
In this work, samples of aluminium alloys were obtained by Composite Extrusion Modeling (CEM). In order to do this, sustainable aluminium-based feedstock pellets were produced that combined a water-soluble polymer (PEG) and a low CO2 emitting polymer (CAB). In the same way, the sintering stage was optimized to obtain good quality samples with the highest possible densification.

Reviewer's name : ....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : ....

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765074

Requested presentation type : Oral Presentation

Topic : Consolidation Technologies **Subtopic :** Other Consolidation Technologies

Author : Prof Dr Elkady Omayma (Central Metallurgical Research & Development Institute (CMRDI), Egypt)

Co-author(s) : Dr Abu-Oqail Ahmed (Faculty of Technology and Education, Beni-Suef University, Egypt)

Title : Comparison Between The In- Situ WC Formation In W-20Cu Dual Matrix Reinforced With Bi- Modal Nano Al2O3 And GNPs Prepared By PSM & Hot Coining Techniques

Keyword(s) :
Press Sintering Technique; Hot Coining Consolidation; In-situ WC Formation; Microstructure; Hardness; Wear Resistance

Abstract :
Dual W-20Cu matrix is reinforced with Bi- modal particles of Al_2O_3 & GNPs prepared by PSM & Hot Coining techniques. Al_2O_3 and GNPs are coated with 10wt.% nano Ag by electroless deposition. 10 wt% Al_2O_3 was added while GNPs by 0.2, 0.4, 0.6, 0.8 &1 wt.%. XRD revealed that for the PSM method at 0.6 wt.% GNPs sharp peaks of WC were recorded due to In-Situ reaction between W & GNPs. But for the higher percentages of GNPs, both WC & Carbon peaks are recorded. So, some GNPs are consumed in the In-Situ formation of WC and the others remains as GNPs. While no WC peaks were recorded for the Hot Coining samples. The effect of In-Situ WC, GNPs & nano Al_2O_3 on the properties were investigated. By increasing the ratio of GNPs, hardness and wear resistance are improved up to 0.8 GNPs then decreased.

Innovative Aspect(s) :
Comparison between using the PSM & Hot Coining techniques for the In-Situ WC formation in the W-Cu nano composite reinforced with a bi- modal particles of alumina & GNPs. In which for the PSM method, WC is In- Situ formed at 0.6 wt % GNPs, and no peaks corresponding to C were recorded which indicated that all GNPs are consumed in the formation of WC. But for the 0.8 & 1 wt. % the XRD revelead the presence of both WC & C peaks which indicated that only some of the GNPs are converted to WC and the others (More than the stoichiometric ratio) remains in the form of GNPs. While for the Hot coining consolidation method samples, no WC peaks were recorded. The In- Situe formation of WC have a great positive effect on the microstructure, hardness & wear resistance of W-20Cu- 10 Al_2O_3- x GNPs nano composites.

Reviewer's name : ....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : ....

Notes to author : ....

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765449

Requested presentation type : Poster Presentation

Topic : Consolidation Technologies **Subtopic :** Other Consolidation Technologies

Author : Dr Kamalakshi Hemachandran Thulasi Raman (Socieity for Innovation and Development , IISc, India)

Co-author(s) :

Title : Free Standing Metal Membranes Using Rapid Electron Beam Sintering Process

Keyword(s) :
Rapid Electron Beam Sintering; Free Standing Metal Membranes; Thick Films

Abstract :
Rapid electron beam(EB) powder sintering of thin layers of ceramic and metal powders would be versatile technology to make advanced energy devices such as solid-state batteries and other solid-state thin and thick film devices. With the state of EB technology, EB can be manipulated for heating the materials at higher heating rates. In this work, 150 µm thick free-standing metal membranes were prepared using electron beam sintering. The free-standing membrane area is 100X100 mm and membrane pore diameter and density could be varied by EB power and the sintering time. The sintering time of the membrane as low as 10 s could be achieved with 10,000 m|s beam speeds. The sintering temperature of the process varied between 500o-750oC and produces copper membrane density from 6.2-7.9 g|Cm3. The pore size of membrane could be varied by changing the powder particle size distribution (PSD) and 45-100 µm PSD was used.

Innovative Aspect(s) :
Free standing metal membrane preparation using selective electron beam sintering process. In this process, we can produce continuous roll to roll membranes with different pore density and thickness. In this process, one can prepare metal membranes width up to 150mm.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

Technical Programme Committee
15th February 2023

APPLICATIONS

EPMA european powder metallurgy association

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Technical Programme Committee
15th February 2023

APPLICATIONS

AEROSPACE

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european powder metallurgy association

EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235762322

Requested presentation type : Oral Presentation

Topic : Applications **Subtopic :** Aerospace

Author : Mr Aytar Umit (Turkish Aerospace, Turkey)

Co-author(s) : Mr Bayar Abdülcelil (Turkish Aerospace, Turkey), Prof Özerinç Sezer (METU, Turkey)

Title : Ti6Al4V Additive Manufacturing Powder Qualification And Reuse Methodology For Aerospace Application

Keyword(s) :
Additive Manufacturing; Ti6Al4V; Powder Reuse; Mechanical Properties; Selective Laser Melting; LPBF

Abstract :
This project aims to determine the reusability limits of the powders for L-PBF process through a series of productions and tests. In the project, 2 different powder sizes (15&45 and 20&63) were supplied.Each build will consist of 18 cylindrical bars with a diameter of 15 mm build in vertical orientation. The bar height will be 325 mm in the first run and will gradually decrease. Due to the nature of the reuse study, each cycle of production should be made on the exact same machine without interruption. That is, no other production should take place in the machine during the duration of this work. At the end of the project, powder qualification studies will be supported and limits will be determined for the alloy with reusability limits.

Innovative Aspect(s) :
The different powder sizes used and the relationship between reusability and fatigue life will be examined.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235762437

Requested presentation type : Oral Presentation

Topic : Applications **Subtopic :** Aerospace

Author : Dr Liu Yan (Simtec Soft Sweden AB, Sweden)

Co-author(s) : Dr Adolfsson Erik (Research Institutes of Sweden AB (RISE AB), Sweden), Dr Hosseini Seyed B. (Research Institutes of Sweden AB (RISE AB), Sweden), Mr Christoffersson Örjan (TurnTime Technologies AB, Sweden, Sweden), Dr Yan Zhenghua (Simtec Soft Sweden AB, Sweden)

Title : Simulation And Additive Manufacturing Of Complexly Designed Aircraft Component

Keyword(s) :
Cargo Handling Systems of Aircraft; Metal Binder Jetting; Sintering; CFD Simulation; Validation

Abstract :
An innovative component used for the cargo handling systems of Boeing 737 aircraft is developed to improve loaders' working conditions and protect cargo spaces, passenger luggage, and goods from damage. The design of the component makes it difficult to manufacture using conventional techniques, therefore metal binder jetting (MBJ), an additive manufacturing technique both faster and more cost-effective compared to the conventional laser|electron beam techniques is used.However, there is a risk of thermally induced distortion in connection with the post-process, specifically the sintering step. To address this, a 3D computational fluid dynamics (CFD) simulation model is developed and simulations are made to identify where and when unwanted distortions may occur during the sintering process. In the simulation, the sintering process follows an about 15 hours full sintering cycle with all the heating, holding, and cooling stages. The simulations are compared with experimental results to validate the simulations.

Innovative Aspect(s) :
Full-scale 3D CFD simulations of a full complete MBJ specimen sintering with all the heating, holding, and cooling stages will be presented.
To obtain a better understanding of the details of thermal gradients and gas flow during the sintering process.
This method allows 3D calculation of all the important processes including thermal gradients, gas flowing, thermal radiation, heat transfer, and conjugate heat conduction in solids so that the sintering processes of MBJ specimen can be well simulated, which can be used to optimize the sintering.
A complexly designed aircraft component can be manufactured through MBJ.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765437

Requested presentation type : Oral Presentation

Topic : Applications **Subtopic :** Aerospace

Author : Dipl-Ing Mosler Susanne (Rolls-Royce Deutschland Ltd & Co KG, Germany)

Co-author(s) :

Title : Development Of 3D Screen Printing Technology For Oxidation Resistant High Temperature Alloy Sealing In Jet Engines

Keyword(s) :
3D Screen Printing; Sintering; Sealing; Aerospace; High Temperature Alloy

Abstract :
The aerospace industry has been relying on a limited range of options for air system sealing solutions and is now exploring improvement opportunities by using the 3D screen printing technology. As a sinter based metal powder process screen printing allows freedom in material choice as well as seal structure design. To achieve high sealing performance stringent requirements on uniformity and repeatability of component features have to be fulfilled. The influence of screen printing process parameters and sinter process parameters on material properties are investigated.

Innovative Aspect(s) :
3D screen printing technology is used for the first time to optimise an air sealing system in a jet engine. The screen printing process enables us to manufacture an alternative material with a specific porosity while also optimising the feature design of the seal. These options are not available for conventional honeycombs.

Reviewer's name : ....

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EURO PM2023 CONGRESS & EXHIBITION

Technical Programme Committee
15th February 2023

APPLICATIONS

AUTOMOTIVE

EPMA european powder metallurgy association

EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764215

Requested presentation type : Oral Presentation

Topic : Applications **Subtopic :** Automotive

Author : Dipl-Ing Walther Gunnar (Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM, Branch Lab Dresden, Germany)

Co-author(s) : Dr Ing Trapp Johannes (Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM, Branch Lab Dresden, Germany), Prof Dr Weißgärber Thomas (Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM, Branch Lab Dresden & Technische Universität Dresden, Faculty of Mechanical Engineering, Institute of Materials Science, Germany)

Title : Environmentally Friendly Sintered Friction Materials For Clutch And Brake Systems

Keyword(s) :
Aluminum Brake Disk; Sintered Brake Pads; Copper Free; Tribology; Iron-Based Friction Material

Abstract :
Sintered friction materials are used in particular for high performance applications due to their excellent temperature stability. Increasingly, new regulations regarding sustainability and environmental compatibility require innovative materials. In the USA, only brake pads with less than 0.5 percent may be sold by 2025 due to toxic abrasion. In addition, the new Euro 7 standard also imposes stricter limitations on non-exhaust particulate emissions.In this paper, material solutions for iron-based sintered linings for motorcycle brakes and synchronizer rings are discussed as an example of how to replace copper-based systems without losses in performance. Furthermore, the development of an aluminum composite brake disc is presented. These new brake discs use a particle-reinforced aluminum friction ring, which ensures an almost complete avoidance of the abrasion and, therefore, particle emission. Besides, the aluminum-based brake discs allow for lighter and more sustainable cars, e.g. by a 50 % reduction of the brake system's weight.

Innovative Aspect(s) :
Environmentally friendly materials
Cost efficient materials
Economical production process

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Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

Technical Programme Committee
15th February 2023

APPLICATIONS

BIOMEDICAL

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EURO PM2023 CONGRESS & EXHIBITION
01-04 October 2023

Paper Number : EP235735526

Requested presentation type : Oral Presentation

Topic : Applications **Subtopic :** Biomedical

Author : Dr Rossi Mariana (Federal University of São Carlos, Brazil)

Co-author(s) : Dr Kuroda Pedro, Prof Dr Afonso Conrado (Federal University of São Carlos, Brazil), Prof Dr Amigó Vicente (Universitat Politècnica de València, Spain)

Title : Difference On Organization And Geometry Parameters Of TiO2 Nanotubes In Different Beta Ti Alloys

Keyword(s) :
Beta Ti alloy; Surface modification; Anodization; Biocompatibility

Abstract :
Surface treatment of metallic materials can respond in different ways, based on it is chemical composition, phases and microstructure. In this work, four titanium alloys were coated by anodization process, to create a nanotube (Nt) layer to improve their corrosion and biological functions. The alloys presented different characteristics, being them: commercial pure Ti (c.p Ti), typical a phase; Ti-15Nb, a-prime + ß phases; Ti-34Nb-6Sn (ß metastable phase at room temperature); Ti-40Nb (ß stable at room temperature). The main difference among these alloys are the microstructure (grain size), chemical composition and phases. In this sense the characteristics of the Nts as well as the surface properties (roughness, contact angle, surface energy) will be investigated.

Innovative Aspect(s) :
This work can guarantee a greater success of these materials in the long term, by leading to adequate and faster osseointegration (in orthopedic field). In addition to these modifications, in the case of formation of NTs, they may be good candidates to carry key substances for tissue regeneration. It is noteworthy that there are few works reported in the literature on the formation of Nts on Ti-Nb(Zr,Sn) alloys and the correlation of the NTs properties and surface parameters.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235753753

Requested presentation type : Oral Presentation

Topic : Applications **Subtopic :** Biomedical

Author : Dr Ing Günther Anne (Fraunhofer IKTS, Germany)

Co-author(s) : Dipl-Ing Stelzer Sebastian, Ms Dudeck Anna (Fraunhofer IWU, Germany), Dipl-Ing Mannschatz Anne (Fraunhofer IKTS, Germany)

Title : Material And Process Hybridisation For Implant Materials - Laser Powder Bed Fusion (LPBF) Of Titanium Powders On In-mould Labelled Metallic Nonwovens In Injection Moulded Zirconia (CIM) Substrates

Keyword(s) :
Implantology, Medical Application; Titanium; LBPF; Zirconia; Injection Molding; Nonwoven; Steel; Composite; Interface; Damage-Tolerant; In-Mold Labelling

Abstract :
The research aims not only at the hybridisation of metal and ceramic structures via an innovative textile interface, but also at the hybridisation of conventional and additive powder technologies. In this way, multifunctional components with a geometric complexity are producible. One focus is on powder injection moulding in combination with in-mould labeling and LPBF. Composite components are bonded to each other by means of a metallic textile nonwoven. Due to the inherent properties of the nonwoven, like non-directional struture of the thin fibres and isotropic compressibility, it can partially embedded in the ceramic substrate and sintered without damaging the composite due to the different coefficents of thermal expansion (CTE) and shrinkage behaviour of ceramics and metals. For applications in implantology, in this case zirconia is bonded with titanium via LPBF by using a steel nonwoven to create the bond between the two materials and at the same time act damage-tolerant.

Innovative Aspect(s) :
The combination of different materials and processes is of great advantage for most areas of application in order to further optimize existing component properties and to be able to guarantee the increasingly complex requirements. In medical technology and especially in implantology, the materials zirconia and titanium are often used, as their biocompatible and mechanical properties are best suited for use in the human body. After titanium was successfully thoughened on alumina zirconia (ATZ) in the "Agent-3D" project cluster, the next goal was to minimize cracking in the ceramic during LPBF and to generate a damage-tolerant interface between the two materials. Industry-related projects have shown that a metallic nonwoven can withstand both, ceramic heat treatment and shrinkage and also energy input during LPBF, while protecting the composite from brittle fracture. In further work, one goal will be to replace the steel fibers with titanium to get better bonding effects.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235763609

Requested presentation type : Oral Presentation

Topic : Applications **Subtopic :** Biomedical

Author : Dipl-Ing Wolff Martin (Helmholtz-Zentrum Hereon, Germany)

Co-author(s) : Dr Nidadavolu Eshwara, Dipl-Ing Limberg Wolfgang, Dr Ebel Thomas, Prof Dr Willumeit-Roemer Regine (Helmholtz-Zentrum Hereon, Germany)

Title : Comparison Between MIM- And FGF-processed (3D-printing) Biodegradable Binary Mg-6.3Gd-Alloy

Keyword(s) :
MgGd; Biomaterial; Biodegradable; 3D-Printing; MIM; FGF

Abstract :
Recent research attests MgGd-alloys high suitability as biodegradable biomaterial due to its good strength, low stiffness and excellent biocompatibility. Moreover, novel investigations have proven that Mg-alloys can be successfully processed by binder based sintering technologies like MIM and Fused Granular Fabrication (FGF). While MIM intends to near net shape mass production, the latter one applies mainly to prototyping and production of individual patient specific implants; even with a scaffold-like strut structure inside of a dense shell.This study compares mechanical properties and microstructures of the binary alloy Mg-6.3Gd, processed by MIM and by FGF, respectively. It is shown that today's FGF technique achieves mechanical properties up to 215 MPa ultimate tensile strength (UTS) at 10% elongation at fracture, comparable to the MIM processed reference material. Both processes, MIM and FGF lead to the almost the same microstructure. Hence, novel FGF technique could overcome current challenges in 3D-printing of Mg-alloys.

Innovative Aspect(s) :
Recently, binder based 3D-printing technologies suffer from printing defects and delamination.Nowadays, this study pointed out that using Fused Granular Fabrication (FGF), the same mechanical properties and simular microstructure of biodegradable magnesium alloy Mg-6.3Gd were achieved than using Metal Injectiuon Molding (MIM).Worlwide first investigation about approching mechanical properties of biomedical material Mg-6.3Gd in comparison to the properties of MIM processed parts. The FGF technology enables fabrication of sophisticated shaped parts, obtaining inner hollow structure (eg. scaffold strut structure) and outside dense.Hence, patient adapted individual implants, obtaining material properties as MIM-produced, can be produced by binder based 3D-printing technology (FGF).

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765805

Requested presentation type : Oral Presentation

Topic : Applications **Subtopic :** Biomedical

Author : Mr Tripathi Gaurav (Indian Institute of Technology Delhi, India)

Co-author(s) : Mr Tripathi Gaurav, Prof Pandey Pulak Mohan (Indian Institute of Technology Delhi, India)

Title : A Novel Route For Fabrication Of Iron--hydroxyapatite Biodegradable Implants Using Powder Metallurgy And Pressureless Microwave Sintering

Keyword(s) :
Bio-Implant; Bio-Degradable; CIP; Rapid Tooling; Additive Manufacturing

Abstract :
This work is intended to fabricate a biodegradable iron-hydroxyapatite (Fe-HAp) composite using rapid tooling and pressureless microwave sintering. Carbonyl iron particles (CIPs) and hydroxyapatite powder were mixed in a planetary ball mill to get a uniform mixture which was filled (under ultrasonic action) in molds made of a phosphate-based investment material. Many intricated and customized shapes can be produced using this rapid tooling process. Patterns for preparation of molds were made using stereolithography (SLA), which were later burnt out to get the cavity of same shape in which powder was filled and sintered successfully. Response surface methodology (RSM) was used to evaluate the effect of various sintering process parameters. Multi objective optimization of process parameters was done utilizing the approach of GA (genetic algorithm).

Innovative Aspect(s) :

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

Technical Programme Committee
15th February 2023

APPLICATIONS

ENERGY

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235783264

Requested presentation type : Oral Presentation

Topic : Applications **Subtopic :** Energy

Author : Ms Monterde Gascón Mari Carmen (AMES PM Tech)

Co-author(s) : Dr Bernadet Lucile, Dr Torrell Faro Marc (IREC, Spain), Dr Calero Martinez Jose Antonio (AMES PM Tech, Spain), Dr Jimenez-Piqué Emilio (Universitat Politecnica de Catalunya - EEBE, Spain)

Title : Roll Painting Deposition Of $MnCo_2O_4$ Coating On SUS445 Interconnects Manufactured By Powder Metallurgy:electrochemical Test In SOFC Mode And Degradation Test After 800h In SOEC Mode

Keyword(s) :
Solid Oxide Cell System; Interconnects; Barrier Layer; Coating; Manganese Cobalt Oxide Spinel; Ferritic Stainless Steel

Abstract :
Manganese cobalt oxide spinel ink applied by roll painting on SUS445 steel interconnects are promising protective coating materials as a barrier layer for volatile chromium species. To achieve high density, these coatings are often sintered in two stages, involving heat treatment in reducing and oxidizing atmospheres. This work shows the design, development and optimization of a functional metal interconnect fabricated by conventional powder metallurgy for solid oxide systems. The efficiency of the obtained coated interconnect is evaluated by single repeat unit electrochemical tests and post-mortem analysis. The polarization curve obtained in solid oxide cell mode at 800°C shows a current density around 0.9 A|cm2. The degradation results below 1%|Kh after 800h at 800°C under 10A working in solid oxide electrolysis mode show an efficient barrier layer coating to volatile chromium species. The obtained results show the efficiency of the coating process and the functionality of the designed interconnector.

Innovative Aspect(s) :
The obtained results indicated that ferritic stainless steel interconnect manufactured by powder metallurgy with simply mix of powder and with a lower content in chromium are a potential alternative to be considered in solid oxide systems. Effectiveness and efficiency of $MnCo_2O_4$ coating apliyed by roll painting like a barrier layer for volatile chromium species at 800°C in SOFC and SOEC mode. Development, design, construction and validation of a demonstrator for the measurement of high temperature solid oxide electrolyzer systems.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235762125

Requested presentation type : Oral Presentation

Topic : Applications **Subtopic :** Energy

Author : Dr Sun Jinhua (Chalmers University of Technology, Sweden)

Co-author(s) : Dr Sun Jinhua, Dr Sun Jinhua (Chalmers University of Technology, Sweden)

Title : Coating Different Graphene Derivatives On Cathode Powders For Lithium-ion Battery With Improved Performance

Keyword(s) :
Graphene; Coating; Cathode; Powder; Lithium Ion Battery

Abstract :
Efficient strategy to increase the electrical conductivity of cathode is highly desirable for achieving high-performance lithium-ion battery (LIB). Here, we developed a universal method to controllably coat different graphene derivatives (e.g., graphene oxide (GO), reduced graphene oxide (RGO), and graphite nanoplatelet) on both commercial lithium iron phosphate and Lithium nickel manganese cobalt oxides-based powders and investigate the corresponding electrochemical performance for LIB. Benefiting from such industrial adaptable strategy, the graphene derivatives are uniformly coated on cathode materials (loading up to 8 wt%) in large scale without aggregation. The effect of three different graphene derivatives on the performance of cathode was systematically investigated, and the most favorable graphene derivatives was selected and recommended for the industrial partner with the consideration of balancing the performance, cost, availability, and processability. This study provided a fundamental understanding of different graphene derivatives as conformally coated conductive materials on the performance of LIBs.

Innovative Aspect(s) :

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235763996

Requested presentation type : Oral Presentation

Topic : Applications **Subtopic :** Energy

Author : Mr Lindroos Tomi (VTT, Finland)

Co-author(s) : Dr Pippuri-Mäkeläinen Jenni, Ms Manninen Aino, Dipl-Ing Riipinen Tuomas, Dr Metsä-Kortelainen Sini, Mr Antikainen Atte, Mr Kinos Timo (VTT, Finland)

Title : Additive Manufacturing Of Permanent Magnet Assisted Electric Motor Components

Keyword(s) :
Soft Magnetic; Additive Manufacturing; Powder; Electrification; Electric Motor

Abstract :
Green electrification is vital for the society's decarbonisation. This sets a strong pressure on manufacturers of electrical machines to produce items of higher efficiency and, simultaneously, prepare oneself for forecasted supply risks of raw materials. Additive Manufacturing is seen as enabler to produce components for novel electrical machine architectures with performance and designs unattainable with conventional manufacturing. In this study, a permanent magnet (PM) assisted synchronous reluctance motor based on laser powder bed fusion (L-PBF) is introduced. Production of soft magnetic powder tailored for L-PBF and optimization of process parameters and further post treatments to achieve goods magnetic properties are shown. Characterized magnetic properties are used as input values for motor design where both performance and possibilities of L-PBF are used as design criteria. Permanent Magnet electric motor of the e-scooter is used as reference. The results show that optimized architectures provide high performance with lower PM content.

Innovative Aspect(s) :
Tailored soft magnetic powder for L-PBF introducedDesign and manufacturing route for permanent magnet assisted synchronous reluctance motor is introduced. Results are compared against commercial permanent magnet electric motor of e-scooter. By utilization freedom of design provided by AM high performance motor with remarkably lower permanent magnet content can be realized.

Reviewer's name : ....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : ....

Notes to author : ....

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765639

Requested presentation type : Oral Presentation

Topic : Applications **Subtopic :** Energy

Author : Dr Ing Andersen Olaf (Fraunhofer IFAM Dresden, Germany)

Co-author(s) :

Title : Development Of 316L Sinter Paper For Application As Gas Diffusion Layer In PEM Fuel Cells

Keyword(s) :
Sinter Paper; 316L; PEM Fuel Cell; GDL; Porous Metal

Abstract :
Using processes derived from paper technology, organic fibers, fillers and additives can be mixed with metal powder to produce a flat product. In a subsequent heat treatment, the organic components are removed, leaving a purely metallic porous material, the so-called sinter paper. This approach is used for the development of an innovative Gas Diffusion Layer (GDL) for mobile fuel cells. GDLs are arranged between the bipolar plate and the electrode in fuel cell stacks. They ensure optimal gas distribution as well as the removal of water, heat and electricity.So far, metallic sinter paper that meets the materials specification of stainless steel 316L could be made. The thickness of the paper was reduced down to 200 µm, and the porosity of the base material reaches values around 60 %. A thorough morphological characterization was carried out based on high-resolution µCT scans and their analysis via the software package GeoDict.

Innovative Aspect(s) :
Standard material is currently based on graphite.Novel performance properties are expected.A new sintered product with mass production capability.

Reviewer's name : ……………………………………………………………………………………………….

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : ……………………………………………………………………………….

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EURO PM2023 CONGRESS & EXHIBITION

Technical Programme Committee
15th February 2023

APPLICATIONS

OTHER APPLICATIONS OF PM

EPMA
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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764058

Requested presentation type : Oral Presentation

Topic : Applications **Subtopic :** Other Applications of PM

Author : Dr Ing Leitz Karl-Heinz (Plansee SE, Austria)

Co-author(s) : Dr Ing Valentini Bernhard (PlanseeSE, Austria)

Title : Energy Efficient Thermo-fluid Dynamically Optimized High Temperature Vacuum Furnaces For Heat Treatment

Keyword(s) :
Energy Efficiency; High Temperature Vacuum Furnace; Fast Cooling; Refractory Metals; Simulation

Abstract :
High temperature vacuum furnaces for heat treatment typically have operation powers of several hundred kilowatts. They are generally equipped with a fast cooling system that has to assure that cooling rates, required for certain heat treatment processes, are uniformly met in the whole load. In this contribution thermo-fluid dynamic models of a high temperature vacuum furnace with a refractory metal hotzone are applied to show potentials for energy savings without losing cooling efficiency. The simulation results are validated by experimental data. The results show that an optimization of the gas system in combination with new design concepts allows significant energy savings.

Innovative Aspect(s) :

Reviewer's name : ……………………………………………………………………………………………….

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764202

Requested presentation type : Oral Presentation

Topic : Applications **Subtopic :** Other Applications of PM

Author : Mr Resendes Tomás (CEMMPRE - University of Coimbra, Portugal)

Co-author(s) : Prof Dr Vieira Teresa, Dr Rodrigues Patrícia (CEMMPRE - University of Coimbra, Portugal)

Title : Shape Memory Alloy Strain Sensor Integrated In Structural 3D Object During Additive Manufacturing

Keyword(s) :

Abstract :

The additive manufacturing process lets freedom to explore new ways to make several complex geometries of 3D objects. However, these can be critical to the mechanical behavior during the structural application. Maintaining the stress field inside the component within the safe values previously evaluated from the design is essential to prevent its premature failure. This study aims to promote a precise measurement of the deformation through a strain sensor integrated into the 3D object close to critical zones. The NiTi shape memory alloy could promote high-precision measurements of sensors. The superelasticity of this alloy enables a linear relationship between the deformation and the resistivity. Therefore, this solution allows taking advantage of superelasticity to evaluate close to the critical zones deformation of 3D objects with high precision during their lifetime. The present study highlights the role of inside strain sensors embedded during AM and compares them with conventional measurements.

Innovative Aspect(s) :

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION
01-04 October 2023

Paper Number : EP235765498

Requested presentation type : Oral Presentation

Topic : Applications **Subtopic :** Other Applications of PM

Author : Mr Ozates Cem (Sentes-BIR R&D Center, Turkey)

Co-author(s) : Dr Ertugrul Onur (Izmir Katip Celebi University, Turkey), Mr Genc Bulent (Sentes-BIR R&D Center, Turkey)

Title : Influence Of Powder Oxygen Level And Particle Size On The Properties Of Copper Binder Jetting Parts

Keyword(s) :
Additive Manufacturing; Binder Jetting; Copper; Particle Size

Abstract :
Binder jetting has advantages such as multiple production and low processing costs. In this study, effects of particle size distribution (15-45 and 10-63 µm) and oxygen content of the copper powders on the density and mechanical properties of the final part are investigated. In addition, sintering optimization with various sintering regime and atmosphere is studied. As a result, it is seen that 1070°C and 100% H_2 are required for sintering. Also, the best results of tensile tests are obtained with low oxygen (LO) content of 15–45 µm particle size copper powders. According to Archimedes tests, lower oxygen content 10-63 powder resulted in higher density compared to LO 15-45 powder. However, according to the image analysis, 15–45 µm particle size has better densification, and the internal porosities were much smaller in the structure. The surface roughness differs among the two powders as 10-63 particle size results.

Innovative Aspect(s) :
Copper is among the most conductive metallic materials. Its electrical and thermal conductivity is second only to silver. For most metals, 3D printing is mostly done by laser or electron beam powder bed fusion processes. Due to copper's high reflectivity and very good thermal and electrical conductivity, it becomes very difficult to print 3D parts with powder bed fusion methods. Binder jetting has a high potential for use in order to eliminate these problems of copper.

Reviewer's name : ....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

Technical Programme Committee
15th February 2023

APPLICATIONS

TOOLING

european powder metallurgy association

EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235763604

Requested presentation type : Oral Presentation

Topic : Applications **Subtopic :** Tooling

Author : Dr Ing Schmid Dominik (Kennametal Shared Services GmbH, Germany)

Co-author(s) : Dr Prichard Paul (Kennametal Inc., USA)

Title : Challenges And Solutions In The Additive Manufacturing Of Metal Cutting Tools

Keyword(s) :
Cemented Tungsten Carbide; Hot Work Tool Steel; Binder Jet Printing; Laser Powder Bed Fusion; Metal Cutting

Abstract :
Additive manufacturing provides new opportunities for cutting tools to provide geometric freedom to enhance functionality and performance. The challenge in realizing the full potential is multifarious: the additive processes need to match the material quality of existing processes while creating these complex geometries. At the same time the engineered tool designs have to make use of the geometric freedom to exceed the capabilities of conventional tools. This work will highlight some challenges and solutions in processing cemented tungsten carbide as well as hot work tool steel. The presentation will also discuss opportunities with respect to tool design and show examples of innovative structures.

Innovative Aspect(s) :
Processing of cemented carbide by additive manufacturing (binder jet printing).
Additive manufacturing of hot work tool steel (laser powder bed fusion).
Innovative approches in metal cutting tool design-Industrialized applications.

Reviewer's name : ....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764696

Requested presentation type : Oral Presentation

Topic : Applications **Subtopic :** Tooling

Author : Dr Bezuidenhout Martin (Stellenbosch University, South Africa)

Co-author(s) : Dr Wartbichler Reinhold, Dr Tarragó José, Ms Beltz de Arancibia Christa, Dr Moseley Steven (Hilti AG, Liechtenstein), Prof Sacks Natasha (Stellenbosch University, South Africa)

Title : Wear Observations Of Cemented Carbide Tips In Reciprocating Sawing Of Structural Steel

Keyword(s) :
Reciprocating Sawing; Cemented Carbide; Wear; Construction

Abstract :
The performance of different hardmetal cutting tip grades were investigated in this study for handheld powered reciprocating sawing of structural steel. Variants consisted of fine-grained WC with 12 wt% Co binder and medium-grained WC with 8 wt% Co binder content. The latter was tested with and without a PVD AlTiN-based coating. Microscopy techniques were applied to analyse the wear according to the performance indicators of an industry relevant application case. Early fractures were dominant on all blades with uncoated tips. Contextually, this was not considered as traditional catastrophic failure since blades remained operational until tips were near to or completely removed. Fractures were delayed on coated tips with fatigue indicators observed in the microstructure. Based on the main tool life limiting wear observations, critical areas are discussed which, when addressed during cutting tip manufacturing, would be expected to enhance the on-site performance of the tools.

Innovative Aspect(s) :

Reviewer's name : ……………………………………………………………………………………………………….

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765264

Requested presentation type : Oral Presentation

Topic : Applications **Subtopic :** Tooling

Author : Dr Ing Deirmina Faraz (Sandvik Additive Manufacturing, Sweden)

Co-author(s) : Mr Quarzago Lorenzo, Prof Pellizzari Massimo (University of Trento, Italy), Dr Ing Bettini Eleonora (Sandvik Additive Manufacturing, Sweden), Ing Ritche Matthew, Ing Butcher Daniel, Prof Mehraban Shahin, Prof Lavery Nicholas (Swansea University, United Kingdom)

Title : Hot Work Tool Steel Tailored For The Laser Powder Bed Fusion Processing

Keyword(s) :
Hot Work Tool Steel; Alloy Design; Tempering; Thermal Fatigue; Additive Manufacturing

Abstract :
Hot work tool steels with medium C contents are known to be difficult to process by laser powder bed fusion (L-PBF). Cold and, to a lesser extent, hot cracking occur in these alloys. Cold cracks are attributed to the low ductility and large residual stresses due to the complex thermal profiles. These can be avoided by platform preheating, which may introduce additional costs and side-effects on microstructure and properties. Therefore, the market trend is to develop new steel grades with improved 3D-printabilty. In this work, a prototype alloy with a leaner C content is proposed. To compensate for the negative effect of reduced C, computational thermodynamics was used to define chemistries with an optimized balance of carbide forming elements, and Si. The prototype tool steel shows enhanced L-PBF processability, and properties meeting and|or exceeding those of wrought AISI H13 in terms of hot strength, tempering and thermal fatigue resistance.

Innovative Aspect(s) :
By the aid of cost efficient computational thermodynamics a novel hot work tool steel has been designed to meet both requirements for laser powder bed fusion processability and service application performance.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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Paper Number : EP235765795

Requested presentation type : Oral Presentation

Topic : Applications **Subtopic :** Tooling

Author : Mr Arya Shitanshu (Indian Institute of Technology Delhi, India)

Co-author(s) : Prof Pandey Pulak Mohan (Indian Institute of Technology Delhi, India)

Title : Parametric Optimization Of Sintering Parameters For Fabrication Of Tool For Electrical Discharge Machining

Keyword(s) :
Rapid Tooling; Microwave Sintering; Genetic Algorithm

Abstract :
The present work focuses on fabricating a complex shape copper tool for electric discharge machining application through a novel route that employs rapid tooling and pressureless microwave sintering. The combination of experiments was obtained using central composite design (CCD) technique for three different process parameters namely sintering temperature, holding time and heating rate associated with the sintering machine used. The response in the form of sintered density, shrinkage and electrical conductivity was studied. To obtain the optimal parameters for maximum electrical conductivity of the tool, multi-objective optimization was done using genetic algorithm. Further addition of graphene was done successfully to improve the electrical conductivity of tool which resulted in better performance of tool.

Innovative Aspect(s) :

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Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

Technical Programme Committee
15th February 2023

TOOLS FOR IMPROVING PM

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EURO PM2023 CONGRESS & EXHIBITION

Technical Programme Committee
15th February 2023

TOOLS FOR IMPROVING PM

TEST AND EVALUATION

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235755779

Requested presentation type : Oral Presentation

Topic : Tools for improving PM **Subtopic :** Test and Evaluation

Author : Prof Dr Danninger Herbert (Technische Universität Wien, Austria)

Co-author(s) : Dr Marschnigg Stefan, Dr Herzig Christopher, Prof Dr Gierl-Mayer Christian, Prof Dr Limbeck Andreas (Technische Universität Wien, Austria), Dr Weirather Thomas (CERATIZIT Austria GmbH, Austria), Dipl-Ing Granzer Thomas (Plansee Composite Materials GmbH, Germany)

Title : Analysis Of The Binder Element Content In The W Phase Of Tungsten Heavy Alloys

Keyword(s) :
Tungsten Heavy Alloys; Tungsten Phase; Solubility; Nickel; Iron; Laser Ablation ICP-MS

Abstract :
Tungsten heavy alloys are liquid phase sintered two-phase materials in which tungsten grains are embedded in an austenitic base matrix. While the solubility of W in the binder phase is high both at sintering temperature, when the binder phase is liquid, and also after cooling, the solubility of the binder elements in the W phase is very low. However, the exact content has been a matter of discussion for a long time. In the present study, laser ablation induction coupled plasma mass spectrometry (LA-ICP-MS) has been employed for analyzing the Ni and Fe content in the W phase of W-Ni-Fe heavy alloys, using specifically prepared low-binder specimens for calibration. It showed that the binder element content is in fact significantly lower than presented in the literature, LA-ICP-MS yielding contents of approx. 340 µg|g for Fe and 60 µg|g for Ni.

Innovative Aspect(s) :
The high ductility of W heavy alloys depends in part on the ductility of the W grains in the microstructure which in turn depends on the purity of the W, in particular on the content of binder elements. Published data for this content are scarce and questionable. In the present work, an innovative analytical method was employed that enables analysis also in the ppm range.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION
01-04 October 2023

Paper Number : EP235761326

Requested presentation type : Oral Presentation

Topic : Tools for improving PM **Subtopic :** Test and Evaluation

Author : Mr Pruesse Philipp (Dimensionics Density GmbH, Germany)

Co-author(s) : Dr Ing Krueger Hendrik, Dipl-Ing Kostbade Robert, Mr Evers Mathias (Dimensionics GmbH, Germany), Dipl-Ing Walcher Hartmut (ARBURG GmbH + Co KG, Germany)

Title : Automated Archimedes Density Measurement Of Green And Sintered Parts For Process Parameter Improvement In MIM And CIM Production

Keyword(s) :
Density; Injection Molding Process; CIM; MIM; Green Density; Green Body; Process Automation; Process Parameter Improvement; Cost-Efficiency; Saving Resources

Abstract :
In powder injection molding processes, every new batch of feedstock or tool change, especially when starting production with a new tool, requires an iterative adaption process of machine parameters to find the proper setup to yield parts with the correct green density. The decisive factor for the quality of injection molding components is the constant density distribution over the whole green part. Uneven distribution causes uneven shrinkage behavior, which leads to warped dimensionally unstable pieces.The study is a cooperation of Dimensionis Density GmbH and ARBURG. Through very accurate green density measurements provided by the platform for automated density measurement of Dimensioinics, the green density of injection molding parts can be analyzed in much more detail. The study shows how the material behaves after being injected into the mold under different conditions and casts a new light on the influence of varying process parameters on the green density of parts.

Innovative Aspect(s) :
The new machine platform allows automated density measurements independent of the part condition (green or sintered part). This innovative process was developed by Dimensionics Density and marks a milestone in the advancement of density measurement for solids.The study's findings made a new understanding of the distribution of density across the part within the mold possible. The results imply that measuring the green density of injection molding parts as part of the process holds a new level of process knowledge and control. Thanks to the highly accurate density measurements, the shrinkage of green parts in the sinter ovens can be predicted very precisely. This allows an early intervention before a part enters the energy-intensive sintering oven.Finally, new ways of computer-aided quality assurance and further process automation are enabled, which helps companies to reduce scrap and defective parts and improve process reliability.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235763648

Requested presentation type : Oral Presentation

Topic : Tools for improving PM **Subtopic :** Test and Evaluation

Author : Dr Ing Ciuffini Andrea Francesco (ESRF, France)

Co-author(s) :

Title : Latest Advances In Powder Metallurgy Characterization At European Synchrotron Radiation Facility (ESRF)

Keyword(s) :
Additive Manufacturing; Synchrotron XRD; Synchrotron X-ray Tomography; Residual Stresses; Morphological Characterization; Alloy Design; Solidification

Abstract :
In 2021 was completed the upgrade of the European Synchrotron Radiation Facility ESRF – EBS (Extremely Brilliant Source), becoming the first new generation of high-energy synchrotron, increasing brilliance and coherence of X-ray beams by a factor of 100 compared to present-day light sources. The highlights of the research activities in powder metallurgy made in these 2 years would be presented:The stress relief given by heat treatment on the residual stresses of an additive manufactured 316L stainless steel arch structure (part of EU-funded EASI-STRESS project);Synchrotron μ-tomographic morphological description of additively manufactured open porous structures made by Laser-based Powder Bed Fusion (L-PBF), to characterize attached spherical particles on the surface of functional structures;Study of the solidification of a new Al-4Mn-3Ni-2Cu-1Zr alloy, designed for L-PBF, developing a new strategy for alloy design in high-strength aluminum alloys for powder metallurgy.

Innovative Aspect(s) :
The use of synchrotron light source for measurements is yet an innovative aspect since it provides X-rays much brighter than the X-rays used in common instrumentation. This may be exploited in may useful way for powder metallurgy applications.In stress measurements, achieving higher precision and measurements depth.In morphological measurements, synchrotron-based µCT is drastically reducing scan times and at the same time improving image quality as compared to laboratory-based µCT tools. This is because of the high photon flux and the high coherence of X-rays generated by synchrotrons.In microstructure measurements, X-ray synchrotron nano-tomography allowing to finely characterize the microstructure in 3D, revealing crucial information on the microstructure inherited by fabrication path.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764060

Requested presentation type : Oral Presentation

Topic : Tools for improving PM **Subtopic :** Test and Evaluation

Author : Dr Gatões Daniel (University of Coimbra, Portugal)

Co-author(s) : Mr Cacho Luís, Dr Vieira Teresa (University of Coimbra, Portugal)

Title : MCT Non-destructive Testing Of Additively Manufactured 3Dobjects As Support For True Sustainability

Keyword(s) :

Abstract :
Additive Manufacturing is an essential process for novel geometries. However, complex parts demand a new perspective in defect control and support to the modelling of mechanical behaviour in order to assess the applicability of the 3Dobject to the service conditions. Therefore, non-destructive testing is essential for the evaluation of the role of stochastic defects (size, shape and homogeneity distribution) on the mechanical properties of AM objects. In this study, a wide evaluation of µCT (micro-computed tomography) for two metallic additive manufacturing processes – powder bed fusion (direct) and material extrusion (indirect) – is performed. The results are analysed in terms of the physical changes that occur in additive manufacturing per defect origin type. Comparison of mechanical properties with the results of modelling, having in mind the defect characteristics, led to conclude that µCT is a powerful tool for AM parameter optimisation and for the improvement of process sustainability.

Innovative Aspect(s) :

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764573

Requested presentation type : Oral Presentation

Topic : Tools for improving PM **Subtopic :** Test and Evaluation

Author : Dipl-Ing Parareda Sergi (Eurecat, Spain)

Co-author(s) : Dr Casellas Daniel, Dipl-Ing Bemani Milad (Eurecat, Spain), Dr Mateo Antonio (UPC, Spain), Dr Molotnikov Andrey, Dr Das Raj (RMIT, Australia)

Title : A Fast Method To Evaluate The Fatigue Resistance Of Additive Manufacturing Metal Specimens

Keyword(s) :
Fatigue Resistance

Abstract :
The evaluation of fatigue resistance requires expensive and time-consuming tests, which often limits the generation of data for different material and processing conditions. This is especially relevant when characterising specimens built by additive manufacturing (AM), because the fatigue resistance is influenced by many processing parameter and the inherent anisotropic behavior of many AM techniques. So, accelerated or more straightforward testing procedures would help to further progress in microstructural development of fatigue optimised AM parts.This work shows the application of a method based on damage mechanics to the evaluation of the fatigue resistance of a Ti6Al4V alloy manufactured by SLM. The obtained fatigue limit shows a good agreement with the results from a conventional fatigue method, i.e., the stair-case. Then, the method allows to quickly evaluate the effect of process parameters on fatigue strength and would permit to optimize the design of fatigue dimensioned parts produced by AM.

Innovative Aspect(s) :
Some methods have been developed to reduce the testing time, by accelerating the application of the cyclic loads or by measuring the evaluation of material properties through thermography or following damage mechanics. Recently, the method based on damage mechanics has been successfully applied to obtain the fatigue limit in a wide range of steel and aluminium alloys. It gives a good estimation of the fatigue limit in less than one day using a conventional universal testing machine and digital image correlation techniques, which is much faster than conventional fatigue testing methods. This work shows the application of such method to the evaluation of the fatigue resistance of a Ti6Al4V alloy manufactured by SLM. The presented the method allows to quickly evaluate the effect of process parameters on fatigue strength and would permit to optimize the design of fatigue dimensioned parts produced by AM.

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Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765014

Requested presentation type : Oral Presentation

Topic : Tools for improving PM **Subtopic :** Test and Evaluation

Author : Dr Duffy Violeta (Malvern Panalytical, Netherlands)

Co-author(s) : Dr Duffy John (Malvern Panalytical, United Kingdom)

Title : Detecting Contaminants In Metal Powders Using X-ray Fluorescence

Keyword(s) :

Abstract :
Contamination of metal powders used for additive manufacturing provides a significant risk to product quality and safety. That's because the presence of contaminant particles with different melting characteristics or mechanical properties than the bulk powder can lead to localized stress points in the printed part. This could lead to premature or catastrophic failure and is especially important in risk adverse sectors such as aerospace, medical, and oil and gas. Contamination can originate at various stages in the value chain, including powder production, powder handling, and powder recycling at the AM facility. Identifying contamination can be difficult though as we are often dealing with ppm levels of contaminant, and in the case of cross-contamination with other AM powders they can look visibly similar. In this talk we show the potential of X-ray fluorescence as a tool for identifying inorganic and metallic contaminants in metal powders down to ppm level.

Innovative Aspect(s) :
As far as we are aware noboby has come up with a prefered for solution for detecting contaminants in metal powders for AM and nobody has explored the potential of XRF in this regard. We will show how can be a quick aand easy method for detecting certain inorganic contaminants.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765170

Requested presentation type : Poster Presentation

Topic : Tools for improving PM **Subtopic :** Test and Evaluation

Author : Mr Just Marvin (CERATIZIT Luxembourg S.à r.l., Luxembourg)

Co-author(s) : Dr Useldinger Ralph (CERATIZIT Luxembourg S.à r.l., Luxembourg), Dr Baller Jörg, Mr Medina Peschiutta Alexander (University of Luxembourg, Luxembourg)

Title : Maximum In Mass Flow Rates Of Hard Metal Granules Through Circular Orifices In Relation To The Angle Of Repose

Keyword(s) :
Mass Flow Rate; Beverloo Law; Granular Material; Angle of Repose

Abstract :
The mass flow of granular matter through orifices can be described by the well-known Beverloo law. It depends on particle and orifice sizes, interparticle and particle|container interaction forces, particles' surfaces - to name a few influences on the mass flow rate. We present an experimental study of the flow of a set of ready-to-press (RTP) hard metal powders through orifices of varying diameter. The obtained parameters of the Beverloo law are compared with angle of repose measurements. The interplay between attractive interparticle forces and gravitational forces are discussed for both types of experimental measurements and related to the difference between particle and orifice size.

Innovative Aspect(s) :
The presented study systematically relates angle of repose measurements to mass flow rates through orifices for ready-to-press hard metal powders. It contributes to the knowledge of the flow behaviour of this class of materials.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

Technical Programme Committee
15th February 2023

TOOLS FOR IMPROVING PM

SECONDARY OPERATIONS

EPMA
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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235755706

Requested presentation type : Oral Presentation

Topic : Tools for improving PM **Subtopic :** Secondary Operations

Author : Dr Vattur Sundaram Maheswaran (Höganäs AB, Sweden)

Co-author(s) : Dr Andersson Michael (Höganäs AB, Sweden)

Title : Tailored PM Steel Materials For Heat Treatment Using A Simulation Tool To Predict The Hardenability

Keyword(s) :
Heat Treatment; Simulations; Hardenability; PM Steels

Abstract :
The performance of PM steels is directly related to the material properties which is a consequence of the input alloying addition and processes involved. However, it is of significance to understand the hardenability requirements, specific to the component size|dimensions and the selected material for the specific heat treatment (HT) processes where gas and oil are used for quenching. Processes such as sinter-hardening, case-hardening, and through-hardening are commonly performed to enhance the performances. In this work, quenching simulations were performed and a tool for hardenability calculation is developed with respect to the materials, components size, and different quenching mediums. For the given component dimensions, this tool predicts the suitable material and the cooling rate required to transform the microstructure into fully martensitic using FEM. Eventually, this allows for the minimising the number of trials required for optimising the HT process for PM steels.

Innovative Aspect(s) :
In order to optimise a heat treatment for the PM steels, practically it requires several heat treamtent trials for each and individual material and components, which results in the longer process development time and additional resources.For the given PM steel component with the specific size and the dimensions, using FEM the hardenability can be predicated at the different regions, allowing for tailored material and the process selection.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235762567

Requested presentation type : Oral Presentation

Topic : Tools for improving PM **Subtopic :** Secondary Operations

Author : Mr Iss Valérian (IWM RWTH Aachen, Germany)

Co-author(s) : Mr Ulferts Alexander (Inductoheat Europe, Germany), Mr Rajaei Ali, Prof Dr Broeckmann Christoph (IWM RWTH Aachen, Germany)

Title : Development Of A Robust And Reliable Induction Surface Hardening Process For Sintered Steel Components

Keyword(s) :
Heat-Treatment; Induction Hardening; Sintered Gears

Abstract :
Induction hardening enables to control the properties of the surface layer of components through suitable process parameters. This heat-treatment is characterized by short process times, low energy costs, high reproducibility and low distortion levels. With sintered steels, however, the risk of cracking in induction hardened components is high due to low thermal conductivity, reduced ductility and high residual stresses. Large scale deployment of induction hardening for sintered steel components requires deeper understanding of the relationships between material and process parameters. In this work, the relevant material data, such as the phase transformation behavior of different alloys, is determined. Induction hardening tests on components made of sintered steels are carried out with systematic variation of both material properties (carbon concentration, porosity) and process conditions (heating, quenching and tempering parameters), in order to link these interacting parameters with the resulting microstructure, hardness, residual stresses and susceptibility to cracking.

Innovative Aspect(s) :
A systematic investigation of the influencing parameters of induction hardening heat-treatment of components made of sintered steels had not been conducted so far. The results may deliver enhanced knowledge about the relationships between the material and process conditions and the metallographic and mechanical properties of inductive surface-hardened parts. This represents a major step towards optimized induction heat-treatment processes for sintered steels.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION
01-04 October 2023

Paper Number : EP235764667

Requested presentation type : Oral Presentation

Topic : Tools for improving PM **Subtopic :** Secondary Operations

Author : Dr Colaneri Alessandro (RINA Consulting Centro Sviluppo Materiali Spa, Italy)

Co-author(s) : Dr El Sayed Yasin Mohamed, Dr Fransesini Leonardo, Dr Lionetti Stefano (RINA Consulting Centro Sviluppo Materiali Spa, Italy), Dr Romeo Paolo, Dr Pispola Giulio, Dr Burattini Claudia (Umbragroup Spa, Italy)

Title : Surface Roughness Modification Methods For AM Heat Exchangers Applications

Keyword(s) :
Additive Manufacturing; Surface Finishing; Post Treatments

Abstract :
The effect of surface roughness on heat transfer capacity is still an active research area in the sector of heat exchanger manufacturing because AM allows to design complex and articulated geometries directly with cooling channels. Management of roughness is important because on one hand it has been demonstrated that a rough surface can increase the heat exchange, when this value is comparable to the height of the laminar layer, and on the other hand increasing surface roughness increase pressure drop which can reduce the performance of the heat exchanger. The possibility to apply surface treatment methods to internal cooling channels of different dimensions in AlSi7Mg components obtained through SLM technology is studied. The application of tumbling and electropolishing is evaluated through an experimental campaign. Different tumbling and electropolishing conditions are applied with the aim of evaluating the penetration effect of the treatment into the channels of the component.

Innovative Aspect(s) :
The paper presents results of the experimental test on laboratory scale of cheap and fast technique to control surface roughness.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION
01-04 October 2023

Paper Number : EP235765571

Requested presentation type : Oral Presentation

Topic : Tools for improving PM **Subtopic :** Secondary Operations

Author : Dr Mellin Pelle (Swerim AB, Sweden)

Co-author(s) : Dr Heino Stefan (Swerim AB, Sweden), Mr Shipley James, Mr Magnusson Anders (Quintus Technologies AB, Sweden), Dr Forsberg Fredrik (Luleå University of Technology, Sweden), Mr Forsgren Björn, Mr Waernqvist Per (Ringhals AB, Sweden)

Title : XCT-Tracking Pore Size Development, In L-PBF Built 316L, During HIP And Subsequent Heat Treatments

Keyword(s) :
L-PBF; Porosity; Regrowth; HIP; 316L

Abstract :
Understanding the shrinking and regrowing porosity in 316L is the purpose of this work. Pores always shrink during Hot Isostatic Pressing (HIP), which is a technique for defect-healing of materials after L-PBF, sintering, casting etc. X-ray computer tomography (XCT) is here used to track the size of individual pores, as they shrink during HIP, and regrow at high temperature. The pores regrow since they are Ar-filled and pressurized, as result of L-PBF (under Ar) and HIP. However, in light of the obtained results, the regrowth is predictable and largely a function of original pore volume and temperature which the material is exposed to. These two parameters determines the internal pressure of the pore, which must be suffciently high for expansion to occur. A post-weld heat treatment at 680 °C, resulted in no regrowth regardless of size. Only heat treatments at high temperature resulted in regrowth of the largest pores.

Innovative Aspect(s) :
This work tracks individual pores and gives a solid understanding of the link between original pore size, internal pressure (depending on temperature) and regrowth.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765766

Requested presentation type : Oral Presentation

Topic : Tools for improving PM **Subtopic :** Secondary Operations

Author : Mr Beamer Chad (Quintus Technologies LLC, USA)

Co-author(s) :

Title : Development Of Clean Hot Isostatic Pressing (HIP) Processing

Keyword(s) :
HIP; Surface Oxidation; Heat Treatment; Getters

Abstract :
HIP has often been coupled with oxidation of part surfaces. Oxygen originating from several different individual sources, all which must be controlled to avoid surface oxidation and various forms of contamination. This has led to the need to wrap components with different types of metal foils gettering the contaminants before these can react with the part surfaces. The need for getters of course consumes resources placing a demand to develop a viable solution to this challenge.Quintus Technologies has now developed a new toolbox under the High-Pressure Heat Treatment umbrella called Quintus Purus®, a combination of best practices in way of working with the HIP system, new equipment capabilities and fit for purpose oxygen getter cassettes. This concept promises the opportunity to reduce oxygen species in the HIP process by over 95%. The result is a path for significantly less part surface oxidation and contamination.

Innovative Aspect(s) :
Quintus Technologies has developed a new capability for HIP|High Pressure Heat Treatment equipment with the purpose to make it possible to avoid extensive surface oxidation of high oxygen affinity materials when densified and heat treated in Compact HIP equipment and in the new generation of furnaces. An added benefit is that the heater materials degrade at a lower rate, increasing system total lifetime and cost of operation.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

Technical Programme Committee
15th February 2023

TOOLS FOR IMPROVING PM

DIGITIZATION

EPMA
european powder metallurgy association

EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235762920

Requested presentation type : Oral Presentation

Topic : Tools for improving PM **Subtopic :** Digitization

Author : Dr Hein Sebastian Boris (Fraunhofer IFAM, Germany)

Co-author(s) : Mr Sandmann Malte, Mr Gerken Felix, Mr Cogotti Andrea, Miss Reineke Lea (Fraunhofer IFAM, Germany)

Title : Integration Of In Situ Measurements To Monitor The Print Process In MBJ

Keyword(s) :
Metal Binder Jetting; In Situ Measurement; Powder Spreading; Powder Bed Temperature; Powder Binder Interaction; Green Part Density; Green Part Strength

Abstract :
Metal Binder Jetting (MBJ) gains increasing industrial attention due to its serial production potential. In order to tap the full potential of MBJ, a deep process understanding is crucial. The aim of this work is to gain a deeper insight of the influence of process parameters on the powder spreading and powder bed heating by using in situ measurements, as a way to create a basis for real-time process control and optimization. This is achieved by generating images of the powder build-up in front of the spreading roller and thermal imaging of the powder bed for each layer. An automated image processing was developed to examine the powder build-up, and the green part properties were evaluated with different powder heating settings respectively. A proper control of the powder spreading and powder bed temperature positively influences powder binder interaction and green part properties, while minimizing the scrap rate.

Innovative Aspect(s) :
The innovation of this work is the development of in situ measurement methods to quantify the impact of equipment settings regarding powder spreading and drying.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

Technical Programme Committee
15th February 2023

TOOLS FOR IMPROVING PM

OTHER TOOLS FOR IMPROVING PM

EPMA
european powder metallurgy association

EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235762617

Requested presentation type : Oral Presentation

Topic : Tools for improving PM **Subtopic :** Other tools for improving PM

Author : Dr Momeni Mohammad (European Patent Office, Netherlands)

Co-author(s) : Dr Gimeno-Fabra Lluis (European Patent Office, Netherlands), Prof Danninger Herbert (Technische Universität Wien, Austria)

Title : Ferrous Powders & Sintered Steels; An Overview Of Granted Patents At The European Patent Office From 2015 To 2020

Keyword(s) :
Intellectual Properties; Patents; European Patent Office; Ferrous Powders; Sintered Steels

Abstract :
Patents provide a solid legal framework for inventors to fairly benefit from their contribution to technology. The social deal around patents, requires a clear and sufficient disclosure of novel and inventive subject-matter. This means that patents contain precious information on the most advanced state of innovation worldwide. Consequently, providing an overview of the granted patents seems to be crucial to know the industrial trends. In this presentation, the public data is decoded and presented in granted patents at European Patent Office (EPO) from 2015 to 2020 to sketch this evolution and show the major industrial trends, wherein their opposition periods have expired. The scope of the presentation is revealing the latest industrial developments and growing technology developments in manufacturing of ferrous powders & sintered steels.

Innovative Aspect(s) :
Providing an overview of the granted patents at European Patent Office (EPO) from 2015 to 2020 to know the industrial trend in manufacturing of ferrous powders & sintered steels.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764023

Requested presentation type : Oral Presentation

Topic : Tools for improving PM **Subtopic :** Other tools for improving PM

Author : Ing Berger Aaron (Ruhr-University Bochum, Germany)

Co-author(s) : Ing Ziesing Ulf, Dr Ing Benito Santiago, Prof Dr Weber Sebastian (Ruhr-University Bochum, Germany)

Title : A New Experimental Investigation Of The High-Temperature Thermophysical Properties Of Metallic Powders

Keyword(s) :
Thermophysical Properties; Thermal Conductivity; Thermal Diffusivity; Characterization of Powder; Additive Manufacturing

Abstract :
PBF-LB|M is the most suitable process for the additive manufacturing with metallic powders when it comes to complex parts with geometrical accuracy. Nevertheless, some unknown variables are present in the process. Especially the thermal conductivity adds high degrees of uncertainty, due to the significant influence of the heat flux from the part to the powder batch on the resulting properties of the part. A lack of experimental data addressing the thermophysical properties of powder and a deep understanding of the influences amplifies this problem. This work presents the thermophysical properties of different steels powders which are commonly used in the PBF-LB|M process using a newly developed powder container. In a quantitative comparative analysis with the corresponding solid materials, it could be shown that chemical composition and microstructure play a subordinate role in the resulting heat conductivity. It is rather powder size distribution the key parameter defining the emerging behaviour.

Innovative Aspect(s) :
The here presented work shows the thermophysical properties of different steel powders and assesses a deep understanding on the influences on these properties like it has never been done bevore. In this work, a newly developed powder capsule has been used to determine the powder's thermal diffusivity directly, enabling a closer look at this significant part of the thermal conductivity. By the comparison of the powder properties with the corresponding solid materials, the influence of the microstructure and chemical composition can be analysed. Furthermore, by the comparison of different particle sizes, the influences on the thermophysical properties can be pointed out in detail, enabling a novel and deep understanding of the addressed properties.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764669

Requested presentation type : Oral Presentation

Topic : Tools for improving PM **Subtopic :** Other tools for improving PM

Author : Mr Medina Peschiutta Alexander (University of Luxembourg | Ceratizit Luxembourg SARL|, Luxembourg)

Co-author(s) : Dr Useldinger Ralph (Ceratizit Luxembourg SARL, Luxembourg), Dr Baller Jörg (University of Luxembourg, Luxembourg), Mr Just Marvin (University of Luxembourg & Ceratizit Luxembourg SARL, Luxembourg)

Title : Comparative Study On The Methods To Determine The Critical Particle Volume Content Of Hard Metal Paste

Keyword(s) :

Abstract :

We present a comparative study on determining the critical particle volume content (CPVC) of a hard metal paste using the following techniques: theoretical calculation, density method, oil titration, binder titration, and Reddy's model. The theoretical calculation involves density measurements to discern the metallic powder-free volume. The density method lies in the principle of void formation in the paste as the solid fraction is increased. The titration methods consist of a stepwise increase of the organic content while the mixer torque is recorded. In contrast, Reddy's model requires the preparation of several feedstocks at varying solid loadings, which are tested in a capillary rheometer to obtain the CPVC. The paste consists of tungsten carbide-cobalt (metallic phase) and a macromolecular multiphase system (organic phase). An optimal solid loading range for a proprietary binder system is nominated.

Innovative Aspect(s) :

The research's comparative aspect illustrates how the different methods affect the value of the critical particle volume content. Applying these techniques to a tungsten carbide with fine grain size is another innovative area of the study.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765515

Requested presentation type : Oral Presentation

Topic : Tools for improving PM **Subtopic :** Other tools for improving PM

Author : Dr Ing Nasiri Aida (Ionics SA, Belgium)

Co-author(s) :

Title : Powder Functionalization By Low Temperature Low Pressure PVD, PECVD And Ion Implantation Technologies

Keyword(s) :
PVD; PECVD; Ion Implantation; Alloys; Core-Shells; Functionalization; Coatings; Surface Layers; Additive Manufacturing; Sintering

Abstract :
Coating and functionalization of powders by low pressure surface treatment technologies has proven to be very efficient to enhance manufacturing processes and final product performances. Though the theoretical advantages are being explored in academic institutes, the challenges to have a fine-tuned and homogenous product with cost effective process at industrial scale were not currently addressed. Ionics Surface Technologies has industrialized Physical Vapor Deposition (PVD), Plasma-Enhanced Chemical Vapor Deposition (PECVD) and ion implantattion (IBI) coating system adapted to any types of powders. Metal and ceramics could be deposited on various powders in the form of dots, layers, or core-shells . Some of the potential applications among the numerous possibilities include: surface activation, protective or active layers deposition, fine-tuned new alloys development, surface structuration, multilayers architecture and so on. Examples of surface modification of different powders by the three aforementioned technologies and some industrial applications are presented in this manuscript.

Innovative Aspect(s) :
Modification of powders surface with low pressure technologies to develop new alloys, enhanced manufacturing processes efficiency and produced parts with increased performances or new properties.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

Technical Programme Committee
15th February 2023

TOOLS FOR IMPROVING PM

DESIGN AND MODELLING

EPMA
european powder metallurgy association

EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235751775

Requested presentation type : Oral Presentation

Topic : Tools for improving PM **Subtopic :** Design and Modelling

Author : Mr Mamykin Petr (Université de Bourgogne, France)

Co-author(s) : Prof Chateau-Cornu Jean-Philippe, Prof Bernard Frederic (Université de Bourgogne, France)

Title : Modelling The First Compaction Stages Of A Metallic Powder During Load-assisted Sintering: Using DEM Simulations To Homogenise The Behaviour Of A Powder ERV

Keyword(s) :
HIP; Sintering; Simulation; Model; Cam-Clay; Leblond-Perrin-Suquet; LPS; DEM

Abstract :
The work goal is to develop a model simulating powder compaction at the beginning and during hot isostatic pressing. Such a model would increase the precision of finding the initial shape of a hip container for net-shape HIP manufacture while maintaining low computation times.To simulate the powder compaction a set of equations (constitutive laws) will be used : Cam-Clay model and the Levi-Mises. In addition, at higher temperature, the Leblond-Perrin-Suquet (LPS) model is used, as well as a number of other equations describing the thermal expansion, the creep, and change in thermal conductivity.Reference data for model development obtained experimentally from uniaxial compression tests as well as from interrupted HIP tests on a spherically shaped container. Data for characterization of shear behaviour and thermal conductivity of powder is found using discrete element method (DEM) simulations.

Innovative Aspect(s) :
Finding out powder characteristics for DEM simulations by Uniaxial compression tests, using SPS equipment.
Usage of DEM simulations in order to refine constutive law simulation model.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235752342

Requested presentation type : Oral Presentation

Topic : Tools for improving PM **Subtopic :** Design and Modelling

Author : Mr Hellenbrand Gerrit (Werkzeugmaschinenlabor (WZL) der RWTH-Aachen University, Germany)

Co-author(s) : Dr Ing Mevissen Dieter, Dr Ing Brimmers Jens, Prof Dr Brecher Christian (Werkzeugmaschinenlabor (WZL) der RWTH-Aachen University, Germany)

Title : Tooth Contact Analyses Of Powder Metal Gears Under Consideration Of Local Material Properties

Keyword(s) :
Gear Calculation; Powder Metallurgy; PM-Gears; Densification

Abstract :
An efficient gear design requires minimal safety margins to realise a full material utilization in terms of the load carrying capacity. This leads to a necessity of increasingly accurate calculation methods for the load carrying capacity of gears. In this paper, a method for the stress calculation in the tooth contact of surface densified powder metal gears considering local material properties is presented. The approach to integrate the densification profile is realized, based on an image-processing tool that analyses metallographic microsections. These profiles serve as an input for an FE-based tooth contact analysis with consideration of the local material properties. Parallel, the fully densified surface area is calculated with an analytical approach and the results are compared to the results of the numerical calculation to build up a calculation method, with a combined approach for the resulting stress depth profile.

Innovative Aspect(s) :
The presented calculation approach takes the porosity profile of pm-gears into account for a tooth contact analysis. Within this tooth contact analysis, a combined method of numerical (FEM) and analytical calculation is processed in order to gain knowledge on the prevailing stresses in loaded powder metal gears.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235754938

Requested presentation type : Oral Presentation

Topic : Tools for improving PM **Subtopic :** Design and Modelling

Author : Dr Abburi Venkata Kiranmayi (Hexagon | Simufact Engineering GmbH, Germany)

Co-author(s) : Dr Ing Gao Siwen (Hexagon | Simufact Engineering GmbH, Germany)

Title : Sintering Simulation Framework As A Virtual Design And Process Optimisation Tool For Sustainable Sinter-based Additive Manufacturing

Keyword(s) :
Metal Binder Jetting; Sintering Simulation; Live Setters; Pre-Compensation

Abstract :
Sinter-based additive manufacturing (AM), especially Metal Binder Jetting (MBJ) is emerging as an economical AM technology for cheaper metal parts production. Although sinter-based manufacturing has been around for over half a century, the design freedom and specific process characteristics of MBJ necessitate reliable sintering simulation. A validated simulation tool provides greater understanding of the underlying material behaviour necessary for design optimisation, process control and standardisation. Using Simufact Additive MBJ module, the macroscopic shrinkage and deformation behaviour of the material during MBJ sintering are predicted accurately. The simulation predictions are used to automatically generate pre-compensated part geometry such that the part tolerances are within quality specification after sintering. Other quality control strategies such as live setters|supports can also be assessed to identify the best strategy for a given geometry, material and process parameter combination. The simulation framework as a virtual design tool is validated on industry relevant geometries with experimental investigation.

Innovative Aspect(s) :
The automatic pre-compensation of part geometries based on sintering deformation|shrinkage as a quality control tool. Considering live setters|supports in sintering simulation in addition to part geometries. The simulation tool is agnostic as it is valid for any metallic material and process combination, independent of hardware. Validation of the simulation framework on several industry relevant geometries through experimental investigations. Automatic generation of material data required for simulation with greater accuracy.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235755250

Requested presentation type : Oral Presentation

Topic : Tools for improving PM **Subtopic :** Design and Modelling

Author : Prof Barrière Thierry (Univ. Bourgogne Franche-Comté, FEMTO-ST Institute, CNRS|UFC|ENSMM|UTBM, Department of Applied Mechanics, France)

Co-author(s) : Dr Cheng Gang (INSA Centre Val de Loire, France), Dr Xiao Fangnao (Université Bourgogne Franche-Comté, FEMTO-ST Institute, France)

Title : Influence Of Particle Characteristics On The Mechanical Properties Of Particle Reinforced Tungsten Alloys In Compression Tests

Keyword(s) :
Particle Reinforced Alloys, Tungsten, Mechanical, Compression Tests, Numerical Simulation

Abstract :
The manufacturing processing and the mechanical properties of particle reinforced metal matrix composites are strongly dependent on their microstructural characteristics. In this research, 2D and 3D models in microscale of tungsten alloys reinforced by Zr(Y)O2 particles (W-Zr(Y)O2) were established to investigate their uniaxial compression deformation behaviours. The effects of particles contents, size and their distribution on the compressive properties of W-Zr(Y)O2 alloy were discussed. The mechanical behaviours of the reinforced W alloys were improved by increasing the content of Zr(Y)O2 particles. With the same particles content, the strength of the reinforced alloys increased with smaller size particles. With the same particle size and content, the stress concentration was reduced with more homogeneous distribution of the reinforced particles. The predicted strengths with 2D and 3D models are compared with the experiment data, and the 3D simulation exhibits higher prediction accuracy.

Innovative Aspect(s) :
Elaboration of particle reinforced W alloy by innovative technologies.
Numerical simulation of compression tests with the high-performance W alloys.
Effect of particle amount, size and distribution on the mechanical properties of W alloys.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO
PM2023
CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235755820

Requested presentation type : Oral Presentation

Topic : Tools for improving PM **Subtopic :** Design and Modelling

Author : Mr Schuppener Jannik (Chair of Materials Technologgy, Germany)

Co-author(s) : Dr Ing Benito Santiago, Prof Dr Weber Sebastian (Chair of Materials Technologgy, Germany)

Title : Optimization And Live Adaptation Of The Heat Treatment In An Industrial Heat Treatment To Different Initial States Of A PM Tool Steel And Energy-efficient Process Optimization With Requested Product Properties

Keyword(s) :
Simulation, Tool Steel, Optimization, Heat Treatment

Abstract :
Hot isostatic pressing of powder metallurgy tool steels results in high performance tools with outstanding properties. However, the successively deployed conventional heat treatments are not tailored for this manufacturing route, generating room for improvement. This work presents a simulation workflow targeting a twofold optimization of the heat treatment after the consolidation process. These two goals are (i) the determination of the most efficient treatment to guarantee a minimum hardening depth; and (ii) the improvement of the process stability regarding hardness and chemical variations resulting from the as-delivered condition. The workflow includes calculation of metastable states using MatCalc®, finite element analysis using AbaqusFEA®, and optimization routines written in Python and MATLAB®. To validate the models, a PMX153CrMoV12 ingot was treated in a laboratory furnace, with supporting dilatometry and hardness testing completing the experimental setup. The models and measurements showed great agreement, proving the suitability of the workflow for industrial deployment

Innovative Aspect(s) :
This work is the first to use the previously developed simulation model to calculate the local microstructure and mechanical properties of a complex component in different initial states depending on batch-specific and manufacturing routes. To enable this complete simulation, different models were combined with each other. For the heat transfer from the heat treatment furnace into the component as well as the distribution in the component, an Abaqus FEM simulation was combined with a MatLab optimization model to obtain the heat transfer coefficient, the microstructural changes were simulated by exact time-temperature curves for each FEM node using the software MatCalc and the resulting mechanical properties were calculated by an optimized sum function, which was developed from an extensive data set. The combination of these models and their application is a new approach.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235760991

Requested presentation type : *Oral Presentation*

Topic : Tools for improving PM **Subtopic :** Design and Modelling

Author : Dr Ing Schneider Markus (GKN Powder Metallurgy, Germany)

Co-author(s) : Ing Radis Christos, Ing Wawoczny Dennis, Dipl-Ing Maassen Robert (GKN Powder Metallurgy, Germany),

Title : The Role Of Apparent Hardness On The Critical Defect Size Derived From Kitagawa-Takahashi Diagrams

Keyword(s) :
Da|dN-ΔK Curves; Kitagawa-Takahashi Diagram; Critical Defect Size; Sintered Steels

Abstract :
The critical defect size a0 is that defect size a which can be tolerated by the material without a loss of strength. Its magnitude is of relevance for all non-destructive testing methods because it defines the needed resolution limit. The critical defect size a0 depends on materials ductility (apparent hardness H) and on the loading ratio R. Four different sintered steels with a wide apparent hardness H range were chosen for the internal fatigue crack propagation campaign: AS 1000BMn + 2 % Cu + 0.6 % C, FD 4600A + 0.5 % C, FLD-49DH + 0.65 % C and AS 150 HP + 0.5 % C. Moreover, the sintered density ? was varied between ?=6.8 g|cm³ and ?=7.2 g|cm³. Derived da|dN-?K curves were combined with existing s-N lines (“Woehler lines”) and the effect of the apparent hardness H on the critical defect size a0 was investigated.

Innovative Aspect(s) :
The derivation of critical defect sizes a0 for sintered steels is rather new and the dependency on the apparent hardness H is unknown.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235762579

Requested presentation type : Oral Presentation

Topic : Tools for improving PM **Subtopic :** Design and Modelling

Author : Dr Lancelot Carl-Magnus (Thermo-Calc Software AB, Sweden)

Co-author(s) : Ing Markström Andreas, Dr Malik Amer, Dr Do-Quang Minh, Dr Jeppsson Johan (Thermo-Calc Software AB, Sweden)

Title : A New CALPHAD-based Finite Element Tool For Additive Manufacturing Simulation

Keyword(s) :
Thermo-Calc; CALPHAD; Additive Manufacturing (AM); Powder Bed Fusion ; Multiphysics Simulation; Finite Element Method (FEM); Solidification; Scheil Calculation; Melt Pool; Thermophysical Properties; Laser Melting

Abstract :
Thermo-Calc has spent the last few years developing new models to predict thermophysical material properties to incorporate with CALPHAD-based materials descriptions. This foundation is currently used to extract CALPHAD-based materials data for use in dedicated Finite Element simulation codes, which usually treat material properties in a highly simplified manner.This development has laid the foundation for a completely integrated simulation tool, using the CALPHAD-based descriptions of phase equilibria and physical properties, to simulate the Additive Manufacturing (AM) process.The Additive Manufacturing Module in the Thermo-Calc software was released this summer, and it gives a unique possibility to address the problem of solidification during AM, where we obtain a unified treatment of both process parameters and chemistry-dependent thermophysical properties when solving the multiphysics problem of a moving heat source that melts and solidifies metal powder.Examples are shown of the Additive Manufacturing module applied to different material classes.

Innovative Aspect(s) :
This is a FEM tool for multiphysics simulation of laser melting of additive powders with CALPHAD-based materials descriptions at the foundation, where traditionally either handbook data is incorporated, or a user needs to extract calphad data separately for processing and input. This also enables direct pairing of Scheil-Gulliver simulation of rapid solidification with the FEM tool.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235762889

Requested presentation type : Oral Presentation

Topic : Tools for improving PM **Subtopic :** Design and Modelling

Author : Dr Aminnia Navid (University of Luxembourg, Luxembourg)

Co-author(s) : Dr Estupinan Donoso Alvaro, Prof Peters Bernhard (University of Luxembourg, Luxembourg)

Title : Modeling Of Marangoni-induced Flow In Selective Laser Melting Using Coupled CFD-DEM Approach

Keyword(s) :
Computational Fluid Dynamics; Discrete Element Method; Powder Bed Fusion; Melt Pool; Multiphase Flow; CFD-DEM

Abstract :
Computational models play a role in the optimization of metal additive manufacturing parts and in evaluating component quality. However, obtaining reliable models of this process remains a challenge due to the complex, interrelated phenomena involved. A key component of such models will be the detailed simulation of flow and heat transfer in and around the melt pool that is formed when the powder bed is melted. A Marangoni force arises at the gas-liquid interface due to the gradient in temperature, which drives high-temperature liquid to flow toward the low-temperature region. In this study, a CFD solver is coupled with an in-house developed DEM code known as eXtended Discrete Element Method (XDEM) to model the dynamics and thermodynamics of the particles. This numerical framework will help to determine how powder size distribution, laser velocity and power, among other factors, will affect the characteristics.

Innovative Aspect(s) :
Coupling of CFD-DEM where DEM also solves for the thermodynamics of the powder particles, including laser radiation and powder melting.The heat conduction between the particles is calculated explicitly based on the Vargas-Mccarthy model.The heat convection between the particles and the melt or the ambient gas is calculated explicitly for each powder particle.The particles are discretized in the radial direction, thus facilitating better capture of partial melting of the powder particles.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235763767

Requested presentation type : Oral Presentation

Topic : Tools for improving PM **Subtopic :** Design and Modelling

Author : Mr Schenk Oliver (RWTH Aachen University, Germany)

Co-author(s) : Mr Deng Yuanbin, Dr Ing Kaletsch Anke, Prof Dr Broeckmann Christoph (RWTH Aachen University, Germany)

Title : Constitutive Modelling Of The Densification Of Astaloy 85Mo Sintered Steel During Cold Working

Keyword(s) :
Gurson Model; Densification; Rastagaev; Plasticity; Sizing; Astaloy 85Mo

Abstract :
The powder metallurgical (PM) process chain stands out by its ability to produce precise components at low cost. However, the inherent porosity of PM components, which has a particular impact on fatigue behaviour, is crucial for components such as gears. Hence, cold rolling is commonly applied to densify the surface of sintered components. This induced densification can be modelled by a constitutive law introduced by Gurson, Tvergaard and Needleman. In this work, a modified GTN model was derived to simulate the densification behaviour of Astaloy 85Mo sintered steel. The stress-strain-behaviour of sintered samples with different densities was deduced from compression tests according to Rastagaev. A synthesized description of the plasticity of the dense material was then combined with the densification behaviour during compression to obtain a density-dependent GTN model. The model was validated by comparison with experimental data on the densification during sizing and cold isostatic pressing of sintered samples.

Innovative Aspect(s) :
The set up of process steps such as sizing or cold rolling, that involve the plastic deformation of a component, often rely on empirical data or experience. A profound understanding of plastic deformation and related densification of sintered steels offers the potential to optimize these processes as well as to predict the shape and density distribution of the final component. This understanding can be gained by the presented approach that enables the precise derivation of a novel numerical model.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235763805

Requested presentation type : Oral Presentation

Topic : Tools for improving PM **Subtopic :** Design and Modelling

Author : Mr Schenk Oliver (RWTH Aachen University, Germany)

Co-author(s) : Mr Deng Yuanbin, Dr Ing Kaletsch Anke, Prof Dr Broeckmann Christoph (RWTH Aachen University, Germany), Dr Ing Şelte Aydin (Uddeholms AB, Sweden)

Title : Multiscale Modelling Of Powder Compaction Of Astaloy 85Mo

Keyword(s) :
Drucker Prager Model; Powder Compaction; Friction; Tool Steel; Machine Learning; Multiscale; Astaloy 85Mo

Abstract :
Powder compaction is an essential part of the powder metallurgical (PM) process chain, being mainly responsible for the shape and distribution of the inherent pores of a sintered component. While the significant effects of the porosity and the pore morphology on the fatigue behaviour of PM components have been widely investigated, their numerical prediction during PM processing has rarely been performed. In this work, a multiscale model of powder compaction of Astaloy 85Mo is presented, which provides information on both density distribution and pore morphology. A modified Drucker-Prager model and a friction model were experimentally derived to simulate the compaction process for different tool steels on macroscale, providing information on the density distribution. Using machine learning, artificial microstructural images of the powder compact were generated depending on local density. Both models were combined and applied to the compaction of a gear, which delivered promising results that agree well with experiments.

Innovative Aspect(s) :
The simulation of powder compaction on the macroscale has been widely studied. However, those investigations were often limited to two dimensional simulations and commonly applied to simple geometries. Methods to predict the microstructure after compaction have rarely been proposed. The presented models and their combination offer a novel multiscale model, that provides information on both the macro- and the mesoscale of complex shaped geometries.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764034

Requested presentation type : Oral Presentation

Topic : Tools for improving PM **Subtopic :** Design and Modelling

Author : Dr Ivannikov Vladimir (Helmholtz-Zentrum Hereon, Germany)

Co-author(s) : Mr Munch Peter, Prof Dr Kronbichler Martin (University of Augsburg, Germany), Dr Ebel Thomas (Helmholtz-Zentrum Hereon, Germany)

Title : Large-scale Phase-field Simulations Of Solid State Sintering Of Metallic Powders

Keyword(s) :
Phase-Field; Sintering; FEM; Deal.II; HPC

Abstract :
In order to perform plausible predictive numerical simulations of solid-state sintering, it is essential to capture accurately both shrinkage and microstructure evolutions of a given material. Moreover, for the results to be meaningful and statistically relevant, one has to analyze packings containing hundreds and thousands of particles. In the current work we present a highly efficient phase-field based numerical model that is able to handle large-scale three-dimensional cases at the early and later stages of sintering. The approach is based on the classical phase-field model of Wang. Multiple novel algorithms are developed for its efficient numerical FEM implementation: fully distributed tracking of individual grains, graph colorization for minimization of the number of order parameters, problem specific preconditioners and order parameters cut-off. The microstructures obtained in the benchmark tests performed for a real material (titanium) were compared with those obtained in experiments.

Innovative Aspect(s) :
The majority of the existing phase-field approaches has been applied in the context of sintering modeling to small scale problems working thus with a few dozens of particles. The proposed model relies on the state-of-the-art techniques from the deal.II library for its numerical implementation in order to maximize the performance and robustness. Particularly, we extensively use the modern matrix-free approach, vectorization and fully distributed algorithms. This made it possible to analyze the earlier and later stages of sintering of large particles assemblies within a few hours of real time with the aid of midsize HPC clusters. Special attention was given to the efficient computation of the microstructure metrics (porosity and grain sizes distributions) for simpler and more natural comparison of the numerical results with experimental data.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765038

Requested presentation type : Oral Presentation

Topic : Tools for improving PM **Subtopic :** Design and Modelling

Author : Dr Lindroos Matti (VTT Research Centre of Finland, Finland)

Co-author(s) : Mr Andersson Tom, Dr Biswas Abhishek, Dr Ren Sicong, Mr Suhonen Tomi, Mr Lagerbom Juha, Mr Lindroos Tomi, Prof Dr Laukkanen Anssi (VTT Research Centre of Finland, Finland), Dr Rey Rodriquez Pilar (AIMEN, Spain)

Title : Performance Driven Design And Modeling Of Compositionally Complex AM AlCoNiFe Alloys

Keyword(s) :
Alloy Design; Micromechanics; Crystal Plasticity; Complex Alloys; Superalloy; Fatigue

Abstract :
Virtual of design of additively manufactured AlCoNiFe alloys enables optimization of material performance required at elevated operational temperatures. Compositional tailoring of the material leads to complex mixture of stable and metastable phase structures, which affect the engineering material properties. This focuses on the micromechanical modeling of AlCoNiFe alloy microstructures with crystal plasticity by utilizing preceding material design steps with Calphad analysis for the alloys suggested by neural network decision making. We evaluate key aspects of the material behavior such as strength|strain hardening, fatigue and creep responses.

Innovative Aspect(s) :
The work focuses on understanding the effect of different microstructures to desired material performance criteria such as strength|fatigue|creep, especially at elevated temperatures. Design of complex alloys enables achieve superior properties. However, calphad|ML design of the material phase structures does not guarantee good material behavior as it largely depends on the heterogeneous elasto-plastic-damage relationships at the microstructural scale; thus the work focuses on delivering a view to evaluate|rank different material options with respect to their microstructure using crystal plasticity approach. As a noteworthy remark, the materials are manufacture with additive manufacturing from the tailored powders. Some of the alloys are considered as superalloys, which introduces special needs for the used crystal plasticity models.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765090

Requested presentation type : Oral Presentation

Topic : Tools for improving PM **Subtopic :** Design and Modelling

Author : Mr Rajaei Ali (Institute for materials applications in mechanical engineering - RWTH Aachen University, Germany)

Co-author(s) : Prof Dr Broeckmann Christoph (Institute for materials applications in mechanical engineering - RWTH Aachen University, Germany)

Title : A Computational Approach To Determine The Load Bearing Capacity Of High Strength Sintered Gears

Keyword(s) :
Finite Element Modelling; Sintered Gears; Surface Densification; Case Hardening; Phase Transformations; Residual Stresses; Local Fatigue Strength; Multiaxial Fatigue Limit; Load Bearing Capacity

Abstract :
The performance of PM gears must be increased towards the level of the conventional high strength gears for a reliable application in automotive transmission. To this end, the potentials of the PM production of gears must be fully utilized. Surface densification and hardening of sintered gears are examples of economically plausible measures to increase the strength of these components. However, a comprehensive consideration of the strength-relevant parameters - such as geometry, porosity, hardness and residuals stresses - is required to define an optimized choice of particular material and process chain for higher gear strength. In this work, a computational approach is developed, which integrates the numerical modelling of the case hardening and the tooth loading, and the calculation of the load bearing capacity using different fatigue limit criteria. The results of the simulation are evaluated by comparing with available experimental findings.

Innovative Aspect(s) :
The innovation is provided due to the holistic nature of the calculation method. By predicting the hardness and residual stress profiles and taking the density profile into account, the influence of the variations in the surface sealing and heat treatment can be directly investigated numerically on the load-bearing capacity.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765189

Requested presentation type : Oral Presentation

Topic : Tools for improving PM **Subtopic :** Design and Modelling

Author : Prof Dr Cristofolini Ilaria (University of Trento, Italy)

Co-author(s) : Dr Zago Marco, Ing Uçak Onur Utku (University of Trento, Italy), Dr Vicenzi Bruno (EPMA, France), Dr Dougan Mark J. (AMES PM Tech Center SAU, Spain), Dr Schneider Markus (GKN Sinter Metals Engineering GmbH, Germany), Ing Pedersen Preben Hedegard (Sintex a|s, Denmark), Dr Voglhuber Juergen (MIBA Sinter Austria GmbH, Austria)

Title : Design For Sintering 2 Club Project - Anisotropy Of Dimensional Changes In The Compaction Plane As Affected By Compaction Strategy

Keyword(s) :
Anisotropic Dimensional Changes; Design For Sintering; Compaction Strategy

Abstract :
Design for Sintering 2 is an EPMA Club Project aimed at improving the previously developed design procedure accounting for anisotropic dimensional changes on sintering. Goal of the project is both enlarging the reference database through the fruitful cooperation of the industrial partners and investigating in depth the mechanisms responsible for anisotropic dimensional changes. This work is focused on the second part of the project, aimed at studying the influence of compaction parameters. Axi-symmetric parts characterized by different materials and geometrical parameters were produced at different green densities with different compaction strategies. Focusing the attention on the anisotropy in the compaction plane, dimensional changes were measured and evaluated, also relating them to the attainable dimensional tolerances. The influence of compaction strategy was analysed in depth, and for the different materials and geometries the more robust process conditions for dimensional precision were highlighted.

Innovative Aspect(s) :
Anisotropic dimensional changes in axial direction and in compaction direction are well known phenomenon in P&S, but anisotropy in dimensional changes in the compaction plane was scarcely investigated so far. The effect of anisotropy in the compaction plane is instead significantly affecting the precision of sintered parts, and it has to be considered in the design step.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765208

Requested presentation type : Oral Presentation

Topic : Tools for improving PM **Subtopic :** Design and Modelling

Author : Dr Ing Piotter Volker (Karlsruhe Institute of Technology (KIT), Germany)

Co-author(s) : Ing Klein Alexander, Miss Nguyen Thi Tra My, Ing Plewa Klaus, Mr Walter Heinz (Karlsruhe Institute of Technology (KIT), Germany)

Title : Particularities Of PIM Feedstock Properties Measurements

Keyword(s) :
PIM Simulation; Feedstock Flow Behavior; PIM Rheology; Simulation Verification

Abstract :
Precise and reliable simulation of Powder Injection Molding (PIM) process steps requires particular determination of material parameters. Compared to pure or low-filled polymers, however, feedstocks often show significantly different flow behavior.In this respect, recent investigations at KIT targeted the impact of Bagley pressure correction on simulation accuracy. Calculations were performed using corrected and non-corrected data followed by real injection molding experiments including pressure measurements during mold filling. As expected, precise simulation results could only be achieved if corrected pressure values were applied. In case of PIM feedstocks (50 Vol% filling of zirconia powder), however, simulation were correlated well to experimental results irrespectively whether the pressure data had been corrected or not. Conclusions on flow conditions during viscosity measurements, especially powder-binder segregation effects, will be proposed.

Innovative Aspect(s) :
Specialities of PIM feedstock flow behavior compared to pure or low-filled polymers. Simulation of PIM mold filling, differences to conventional plastics, all verified by real experimental results. In particular: Impact of Bagley correction on simulation accuracy depending on powder loading. Inferences on special feedstock flow behavior at rheologic characterization. Conclusions for improved PIM modelling.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765332

Requested presentation type : Oral Presentation

Topic : Tools for improving PM **Subtopic :** Design and Modelling

Author : Dipl-Ing Gaisina Vladilena (KTH Royal Institute of Technology, Sweden)

Co-author(s) :

Title : Modelling Shrinkage And Neck Evolution In Sintered Astaloy™ 85 Mo

Keyword(s) :

Abstract :
Porosity and interparticle neck size are microstructural parameters that play an important role for pressed and sintered materials. To understand the effect of sintering parameters such as time and temperature on the microstructure of a pre-alloyed sintered steel (Astaloy™ 85 Mo), a mean-field modelling approach tracking the neck size and density evolution during sintering is developed in combination with experimental studies of microstructure and the use of thermodynamic databases. Building upon a mathematical framework describing the geometrical changes in equisized particles with multiple contacts, due to the diffusion mechanisms active during solid-state sintering, the influence of sintering conditions on various aspects of particle and neck geometry is investigated. To calibrate the model, experimentally evaluated shrinkage and observed microstructures of Astaloy™ 85 Mo are also studied.

Innovative Aspect(s) :
Incorporating diffusion data from thermodynamic database (Thermo-Calc) in a sinter model with exact spherical geometry to study the evolution of sinter necks and particles that could in theory be applied to a range of compositions.Calibrating model against real commercial material and comparing the monosized model applicability for different particle size distributions.Discussion of how a literature model for the sintering of loosely compacted powder can be adapted to pressed materials with pre-existing flat contacts sintered at higher densities by considering the impact of interparticle contact on diffusion.

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EURO PM2023 CONGRESS & EXHIBITION
01-04 October 2023

Paper Number : EP235765361

Requested presentation type : Oral Presentation

Topic : Tools for improving PM **Subtopic :** Design and Modelling

Author : Mr Deng Yuanbin (RWTH Aachen University, IWM, Germany)

Co-author(s) : Dr Ing Kaletsch Anke, Prof Dr Broeckmann Christoph (RWTH Aachen University, IWM, Germany)

Title : Digital Twin Of The Binder Jetting Manufacturing Route From Powder To Component

Keyword(s) :
Binder Jetting; Discrete Element Method; Finite Element Method; Simulation; Digital Twin

Abstract :
Binder jetting is ideally suited to produce individual components, as it offers the possibility to directly achieve highly complex geometries. To assure the direct production of net-shape components with optimized process parameters, numerical models across scales were developed in this study to model and simulate each manufacturing step on the entire process chain. Using discrete element and finite element methods, the powder spreading process and the subsequent sintering process were simulated. By considering the influences of the density distribution on green bodies, the gravity, and the friction between the sintering substrate and the sintering parts, the sintering shrinkage and the final geometry could be precisely predicted. The simulation models were validated by comparison with the experimental data. With the help of the inverse optimization, the geometry of the green parts was optimized iteratively, which allows the net-shape components with the desired geometries being manufactured despite sintering distortion.

Innovative Aspect(s) :
The digital twin of the binder jetting process was applied in the product development. It allows the manufacturer to prototype a product virtually before real production. The simulation of each manufacturing step helps to achieve net-shape components with desired geometries and microstructure at the same time to save time and resources.

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EURO PM2023 CONGRESS & EXHIBITION

Technical Programme Committee
15th February 2023

TOOLS FOR IMPROVING PM

HEALTH & SAFETY

EPMA
european powder metallurgy association

EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765510

Requested presentation type : Oral Presentation

Topic : Tools for improving PM **Subtopic :** Health & Safety

Author : Dr Mellin Pelle (Swerim AB, Sweden)

Co-author(s) : Ms Nilsson Åhman Hanna, Dr Götelid Sareh (Swerim AB, Sweden), Mrs Danielsson Ulrika (Siemens Energy AB, Sweden), Mr Lidman Henrik (Befesa Scandust AB, Sweden)

Title : Microscopy Of Airborne Powder And Dust Particles, Captured Using A Bio-Pump Plus

Keyword(s) :
Airborne Metal Powder; Health; Safety; Microscopy

Abstract :
In this work a Zefon Bio-Pump Plus, from Cole-Parmer, was used to capture airborne metal powder and dust particles on a sticky surface. The sticky surface coats a glass slide, which is enclosed in a cheap premade cassette called Air-O-Cell. The method is optimized for capturing fungal spores, but herein we show that metal powder particles can be captured as well. SEM-EDS enable identification of the alloy that constitutes the captured particles. SEM-EDS first requires heat treatment of the Air-O-Cell cassettes; we found that 30 minutes in vacuum, at 80 °C, works well. Using the method, we found airborne powder particles in the range of 1-10 µm, in a workshop handling large quantities of L-PBF powder (15-45 µm). Such 1-10 µm particles are present in L-PBF powder despite the label. We also successully identified the correct nickel-base alloy using EDS.

Innovative Aspect(s) :
This is completely new research on an untested method, which could be useful for EHS improvements at metal powder producers and users of metal powder.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

Technical Programme Committee
15th February 2023

TOOLS FOR IMPROVING PM

SUSTAINABILITY & LIFE CYCLE ANALYSIS

EPMA european powder metallurgy association

EURO PM2023 CONGRESS & EXHIBITION
01-04 October 2023

Paper Number : EP235761105

Requested presentation type : Oral Presentation

Topic : Tools for improving PM **Subtopic :** Sustainability & Life Cycle Analysis

Author : Dipl-Ing Reijonen Joni (VTT Technical Research Centre of Finland Ltd, Finland)

Co-author(s) : Mr Silva Juan, Mr Puukko Pasi, Dr Metsä-Kortelainen Sini (VTT Technical Research Centre of Finland Ltd, Finland), Mr Pulli Oskar, Mr Hahtonen Kasper, Mr Ulkuniemi Jari, Mr Niskanen Jari (University of Oulu, Finland)

Title : Comparative Life Cycle Inventory Of PBF Additive Manufacturing And CNC Machining

Keyword(s) :
Powder Bed Fusion; CNC-Machining; LCI; Sustainablity

Abstract :
Additive manufacturing is often referred to as resource-efficient or even sustainable manufacturing with very little reliable scientific data to support the claims. Here we have made a comparative life cycle inventory of the energy and raw material flows during PBF AM and CNC machining of three components having different geometrical features and functionalities: gear, impeller and manifold. The scope of this study was on the manufacturing phase of the components (from gate-to-gate). The energy and material consumptions were measured, with emphasis on providing accurate, transparent and reliable data of the most important input flows through direct measurement. For all the three studied components, PBF consumed more energy, but required less material, than CNC machining. Geometry of the component had the most significant impact on the energy and material consumption in these processes. Optimizing part geometry and process parameters in PBF to minimize resource consumption showed much potential for improvement.

Innovative Aspect(s) :
In this study we have conducted accurate, transparent and reliable collection of data for the most important input flows (energy, gas and raw material consumption) for the manufacturing processes through direct measurement. This is valuable for conducting reliable life-cycle analyses for components made with PBF or CNC machining. We have studied the effect of the part geometry on the input flows and show, that the geometry is the most important factor influencing the result. The functional unit of comparison should be therefore a geometry that fulfills the intended functionality of the component - not kg of part produced as often used in previous studies. In PBF, the layer thickness, part nesting and orientation was found to have significant impact on the consumption of resources. Furthermore, we have studied the effect of post processing (EDM, CNC) on the total input consumption during PBF manufacture, which is often neglected by previous studies.

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EURO PM2023 CONGRESS & EXHIBITION

Technical Programme Committee
15th February 2023

POWDER PRODUCTION

EPMA european powder metallurgy association

EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235742148

Requested presentation type : Oral Presentation

Topic : Powder Production **Subtopic :** Powder Production

Author : Ing Meyer Philipp (Neue Materialien Bayreuth GmbH, Germany)

Co-author(s) : Dr Ing Daoud Haneen (Neue Materialien Bayreuth GmbH, Germany), Dr Ing Schwarte Stefan (Jäkel GmbH & Co. KG, Germany), Ing Riehle Daniel (K.U.L.T. Kress Umweltschonende Landtechnik GmbH, Germany), Prof Dr Glatzel Uwe (University of Bayreuth – Chair of Metals and Alloys, Germany)

Title : Manufacturing Of WC-based Metal Matrix Composites By Wire Arc Thermal Spray

Keyword(s) :
Tungsten Carbide; Powder Atomization; Spherical Powder; Wear Resistance

Abstract :
Metal matrix composites (MMC) promote high wear and temperature resistance for various applications. The desired tribological, mechanical or thermal properties of MMC components can be specifically adjusted by an optimal combination of metallic matrix and reinforcement particles. Tungsten carbide (WC) reinforced powders for additive manufacturing are produced by premixing of both reinforced particles and matrix particles. However, due to the density differences of the two phases and the dissolution effect of WC-particles under high temperature, manufacturing of homogenous MMC-components is still challenging. In this study, a new approach to produce homogeneous, with high wear resistance WC-M powder is proposed. Therefore, cored WC-wires are atomized by newly developed wire arc thermal spray atomization method. The powders were characterized to surface morphology, particle size distribution and dissolution behavior of WC particles. The influence of atomization parameters and the use of different metal matrix materials will be discussed.

Innovative Aspect(s) :
Development of tungsten carbide reinforced metal powder for homogneous coatings with high wear resistance.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235749638

Requested presentation type : Oral Presentation

Topic : Powder Production **Subtopic :** Powder Production

Author : Dr Ing Qaddah Baraa (IRT M2P, France)

Co-author(s) : Dr Chapelle Pierre, Prof Bellot Jean Pierre, Ing Jourdan Julien (Institue Jean Lamour, France), Prof Rimbert Nicolas (LEMTA, France), Ing Deborde Agathe, Ing Hammes Raphael (IRT M2P, France)

Title : Primary And Secondary Breakup Of Molten TA6V In An EIGA Atomizer For Metal Powder Production

Keyword(s) :
Free-Fall Atomizer; Swirling Supersonic Gas Flow; Metal Powder; Primary Fragmentation; Secondary Fragmentation; High-Speed Camera

Abstract :
Gas atomization is the predominant method of Powder Production for metal additive manufacturing. The EIGA atomizer (Electrode Induction melting Gas Atomization) is a free-fall process used to produce spherical powders, particularly for refractory and high-purity metals such as the titanium alloy Ti-6Al-4V (TA6V). In this process, a swirling supersonic gas jet hits a molten metal stream atomizing it into small droplets through various fragmentation mechanisms.To identify the different mechanisms of molten TA6V fragmentation within the process, a visualization of the metal atomization by a high-speed camera is performed in an EIGA tower. The role of the atomization gas pressure, the pressure in the melting chamber and the slit size at the nozzle outlet on the fragmentation mechanisms and on the final particle size distribution are determined. The mechanisms observed are fiber breakup, bag breakup and Rayleigh breakup for primary fragmentation and bag breakup and shear breakup for secondary fragmentation.

Innovative Aspect(s) :
Identify the different fragmentation mechanisms of molten TA6V within the EIGA atomizer using high-speed camera. Determine the role of the atomization gas on the fragmentation mechanisms and on the final particle size distribution.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235750577

Requested presentation type : Oral Presentation

Topic : Powder Production **Subtopic :** Powder Production

Author : Mr Sista Kameswara Srikar (TATA STEEL LTD, India)

Co-author(s) : Mr Pirjade Bilal Murtuza, Dr Moon Abhijeet Premkumar, Dr Dwarapudi Srinivas (TATA STEEL LTD, India)

Title : Comparative Study Of Iron Powders Synthesis From Steel Industry By-product Through Conventional And Microwave Reduction

Keyword(s) :
By-product; Iron Powder; Hydrogen; Reduction; Microwave

Abstract :
Iron powders are one of the widely used metal powders for powder metallurgy applications. Among various synthesis techniques, iron powders from chemical reduction route holds an advantage of yielding sponge like iron powders with versatile down streaming attributes. In the present work, temperature (600-900 0C) and time (30-180 min) optimization for synthesis of iron powder from iron bearing by-product of steel industry through hydrogen reduction is explored. Powders obtained are characterized for chemical, physical and morphological attributes using wet chemical analysis, X-Ray Diffraction, PT-X powder tester, BET surface area and Scanning electron microscopy. A comparative study on variation in synthesis parameters and output powder characteristics through conventional hydrogen reduction and microwave hydrogen reduction is presented. Microwave route of synthesis attracts faster and effective powder synthesis. This work paves path to modern, green and efficient methods for pure iron powder synthesis from a steel industry by-product.

Innovative Aspect(s) :
Present work brings out an important and novel comparative study of convetional hydrogen reduction vs microwave hydrogen reduction. This work elucidates the property changes of product outputs from both the processes which stands unique. It also paves path to novel, green and efficient way to iron powder synthesis from a steel industry by-product.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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EURO PM2023 CONGRESS & EXHIBITION
01-04 October 2023

Paper Number : EP235755976

Requested presentation type : Oral Presentation

Topic : Powder Production **Subtopic :** Powder Production

Author : Dipl-Ing Choma Tomasz (Warsaw University of Technology | AMAZEMET, Poland)

Co-author(s) :

Title : Novel Approach To Manufacture Powders With Tailored Chemical Composition For Additive Manufacturing

Keyword(s) :
3D Printing; Additive Manufacturing; Metallic Powders; Materials Development

Abstract :
The technology of ultrasonic atomization itself is quite old, but due to technological and material limitations available in the 1950s-80s, it has been almost completely supplanted by gas and plasma atomization technologies. Nevertheless, these commonly used methods, despite obtaining spherical powders of high purity and appropriate granulation, require the use of a large amount of material. In industrial settings, this is an advantage in high-volume production, but unit manufacturing processes dedicated to specific implementations, or prototyping currently carried out with 3D printing technologies, require much smaller amounts of powder, which is provided by ultrasonic atomizers. This technique also has another significant advantage and other methods of manufacturing alloy powders. A small amount of batch materials allows, under laboratory conditions, rapid validation of the chemical composition, phase structure and mechanical properties of newly designed alloys with specific, strictly dedicated performance properties.

Innovative Aspect(s) :
A state of the art device has been build based on ultrasonic atomization technology that allows to highly accelerate the development of new materials. It speed up the research and highly reduce the time of testing new alloys with tailored chemical composition that are not available commercialy.

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Paper Number : EP235756925

Requested presentation type : Oral Presentation

Topic : Powder Production **Subtopic :** Powder Production

Author : Prof Dr Hryha Eduard (CAM2|Chalmers University of Technology, Sweden)

Co-author(s) : Dr Riabov Dmitri (Höganäs AB, Sweden), Dr Raza Ahmad (CAM2|Chalmers University of Technology, Sweden)

Title : Powder For Metal Additive Manufacturing: Production, Reuse And Degradation And Its Effect On Material Properties

Keyword(s) :
Metal Additive Manufacturing; Powder for AM; Powder Manufacturing; Surface Chemistry of Powder; Powder Degradation; Powder Reuse

Abstract :
Metal powder is the feedstock for most of the metal additive manufacturing (AM) technologies, including powder bed fusion – laser beam (PBF-LB) and electron beam (PBF-EB), binder jetting (BJT) and powder blown directed energy deposition (DED). However, even if nearly the same alloys systems are used, requirements to the powder feedstock are rather different. Processing conditions during powder-based metal AM differ significantly, depending on technology, hardware solution and process parameters employed. This results in changes in powder properties during manufacturing cycle and especially during its reuse, also having significant impact on the final component properties. This work summarizes recent experimental observations and thermodynamic simulations of the changes in powder properties during the whole life-cycle of metal powder: from its manufacturing through powder handling and AM processing by variety of powder-based metal AM technologies. Generic model of the powder degradation in dependance on alloy composition and AM technology, is elaborated.

Innovative Aspect(s) :
Paper provide the most recent overview of powder for AM, its properties and degradation in dependance on alloy composition, powder properties and AM technology, powder reuse and its impact on material properties, as a result of the 5-year work in the CAM2 centre - Centre for Additive Manufactruing - Metal.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235761079

Requested presentation type : Oral Presentation

Topic : Powder Production **Subtopic :** Powder Production

Author : Dipl-Ing Aderhold Dirk (Atomising Systems Ltd, United Kingdom)

Co-author(s) : Dr Dunkley John, Mr Williamson Tom, Mr Mellor Adam, Mr Westnedge Joe (Atomising Systems Ltd, United Kingdom)

Title : The Reporting Of Research On Gas Atomisation

Keyword(s) :
Gas Atomisation; Performance; Operating Parameters; Powder Testing

Abstract :
The ever-increasing interest in additive manufacturing (both binder jetting and LPBF) has led to a renewed interest in gas atomising research across the globe. As this is being done by workers with different atomising equipment, the opportunity arises to test both theoretical and empirical correlations on a variety of designs. This paper reviews some relevant literature and sets out some basic equations and the relevant parameters that should ideally figure in all reports on gas atomisation tests. A methodology is proposed to standardise reporting of date, e.g. mass-median, standard deviation, graphical methods and operating parameters to allow some benchmarking by gas atomiser operators and allow improvements to be clearly identified. Remaining unanswered questions on gas atomisation will be discussed, which would surely benefit from more comprehensive publication, in particular the question of the importance of gas pressure in determining "efficiency" of atomisation, and how "efficiency" might be assessed and compared.

Innovative Aspect(s) :
While there are lots of data presented individually, each author tends to report operating and resulting powder parameters in different ways, frequently omitting important parameters. This means that, very often, the actual "performance" of the atomising nozzle used is not readily assessed or compared with other authors' work. This paper will set out the important parameters that should, ideally, be reported, and also outline how to assess the "efficiency" of the nozzle in terms of fineness, distribution width (and hence narrow-cut yields) and Gas-Metal Ratio (GMR) which massively affects costs of operation. Reference examples will be cited. The vexed question of the role of gas pressure, as distinct from GMR, would particularly benefit from better reporting, as each system is typically only operated in a relatively narrow pressure range, but different systems operate anywhere from 10 bars to 100bars pressure.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235761175

Requested presentation type : Oral Presentation

Topic : Powder Production **Subtopic :** Powder Production

Author : Mr Wilkens Yannik (SMS group GmbH, Germany)

Co-author(s) :

Title : Influence Of Particle Size Variations And Nanoparticle Coating On Flow Behavior Of 316l Stainless Steel Powder And Mechanical Properties In Powder-based Additive Manufacturing

Keyword(s) :

Abstract :
In powder-bed-based additive manufacturing (AM) processes, the flowability of the powder is decisive for the quality of the manufactured part. Since fine particle fractions worsen the flowability, in the laser powder bed fusion (LPBF) process the lower limit of the powder fraction is usually 15 µm. Nanoparticle coatings can reduce the attractive forces between particles. It has been investigated how these fumed silica (SiO2) nanoparticle dry-coating affect the initial flow behavior of standard gas-atomized (15-45 µm) 316l powder and powders with increased content of fines (0-45 µm). It was shown that flowability and bulk density increased as a result of the coating. Relative density and mechanical properties of the LPBF specimen showed similar results compared to the un-coated powder with significantly increased tensile strength. The economic potential of coated powder for AM was demonstrated by the successful LPBF processing of fractions 0-45 µm and 0-63 µm with increased utilization.

Innovative Aspect(s) :

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235762594

Requested presentation type : Oral Presentation

Topic : Powder Production **Subtopic :** Powder Production

Author : Dr Davies Paul (Sandvik Additive Manufacturing, United Kingdom)

Co-author(s) :

Title : Sustainable Production Of Inert Gas Atomised Metal Powders For Metal Injection Moulding & Additive Manufacturing

Keyword(s) :
Sustainability; Powder Metallurgy; Metal Injection Moulding; Additive Manufacturing

Abstract :
The sustainability of inert gas atomised metal Powder Production is a key factor in supporting the important message that Powder Metallurgy is a green technology. Especially, when applied as a raw material to the advanced manufacturing technologies of Metal Injection Moulding (MIM) & Additive Manufacturing (AM), which can be compared with conventional manufacturing technologies. The principle process steps of inert gas atomised metal Powder Production are analysed, in terms of energy consumption and carbon foot print, while factoring efficiencies, to provide a sustainable low-impact production process. A Powder Production process that ideally utilises renewable energy sources and incorporates recycled raw materials, generates low levels of waste, with efficient use of resources & logistics modes that ultimately create efficient supply chains. The principle of science based targets are embraced and environmental claims, especially for recycled content, are validated against recognised standards. The life cycle of metal powders are reviewed, from

Innovative Aspect(s) :
Setting the example of a responcible corporation by measuring and recording energy & resource consumption to ultimately reduce the enviromental impact of production of material for the powder metallurgy industry.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235762802

Requested presentation type : Oral Presentation

Topic : Powder Production **Subtopic :** Powder Production

Author : Dr Altenberend Jochen (Tekna, France)

Co-author(s) : Mrs Bailly Ophélie, Dr Dolbec Richard (Tekna, Canada), Dr Vert Romain, Mr Van Wijk Pierre (Tekna, France)

Title : Recycling Of Additive Manufacturing Powders By RF Plasma Treatment

Keyword(s) :
Recycling; Sustainability; RF Plasma; Spheroidization

Abstract :
In most additive manufacturing (AM) processes, a significant fraction of the non-consolidated powder can be reintroduced into the process . However, after several cycles, altered flowability and|or oxygen pick up make such powders unsuitable for their reuse so that they become waste material. Radio Frequency (RF) plasma treatment can increase the flowability of these powders and for some materials it can even reduce oxygen content. As a result, powders initially considered as waste can now be transformed into high quality powders. In this study, examples from the literature together with original results are presented to show how RF plasma treatment can make additive manufacturing even more sustainable.

Innovative Aspect(s) :
While currently large amounts of powder are discarded as waste material the recent results show that many of these powders can be recycled.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235779996

Requested presentation type : Oral Presentation

Topic : Powder Production **Subtopic :** Powder Production

Author : Dr Ing Urionabarrenetxea Ernesto (CEIT, Spain)

Co-author(s) : Dr Ing Avello Alejo, Dr Ing Martín José Manuel (CEIT, Spain)

Title : Advances In The Numerical Modelling Of The Close-coupled Gas Atomisation Process: Optimal Coupling Between Primary And Secondary Atomisation Stages

Keyword(s) :
Close-Coupled Gas Atomisation; Gas Atomiser; Computational Fluid Dynamics (CFD); Particle Size Distribution (PSD)

Abstract :
Efficient simulation of close-coupled gas atomisation can nowadays be used to improve machine designs and to gain understanding on the complex phenomena taking place in the atomisation process. Two-stage multiphase models can predict particle size distributions by using an Eulerian approach for the primary atomisation and a Lagrangian particle tracking for the secondary atomisation. Previous numerical results confirm that these models correctly predict trends of median particle size for varying gas-to-melt mass flow rate ratios, although significant differences between predicted and measured particle size distribution spreads indicate that models need to be improved. In this work, different coupling hypotheses between the primary and secondary atomisation stages are addressed to optimize the model's capacity to predict the entire particle size distribution. By comparing experimental results with simulations obtained with varying surfaces of particle injections and corresponding boundary conditions, an improved model with better predictive capacity has been obtained.

Innovative Aspect(s) :
The simulation of metal powder gas atomisation is extremely challenging due to huge differences in geometric and temporal scales, supersonic gas velocities, high temperature gradients, high heat transfer speeds and solidification. Although accurate modeling of all these phenomena is beyond current calculation capabilities, efficient simplified methods can be used as an effective tool to gain insight and quantify the impact of operating conditions on the particle size distributions. The main innovation of this work is the optimal coupling between primary and secondary atomization stages varying the way of injecting the particles and the imposed boundary conditions. Comparisons between simulations and experimental atomisations prove that the method correctly predicts the particle size distributions of the metal powders.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235762851

Requested presentation type : Oral Presentation

Topic : Powder Production **Subtopic :** Powder Production

Author : Mr Sanchez-Valverde Andoni (Outokumpu, Germany)

Co-author(s) :

Title : Outokumpu Meets Powder

Keyword(s) :
Powder Metallurgy; Recyclability; Sustainability; Novel Materials; Laser Powder Bed Fusion (PBF-LB)

Abstract :
Outokumpu, the first and biggest stainless-steel producer in Europe, started producing spherical metal powder in a Vacuum Induced Gas Atomization (VIGA) plant in Krefeld Germany at the beginning of 2023. Using flat scrap arising from its own processes as raw material the company can produce high-quality metal powders, focusing on recyclability and sustainability. The produced metal powders are high-quality, customizable, and sustainable raw materials for production in various Powder Metallurgy (PM) technologies. Level up your manufacturing capabilities while strengthening the circular economy with Outokumpu's metal powders.

Innovative Aspect(s) :
Present Outokumpu metal powder business concept with our vision and added values to the powder metallurgy industry with a special focus on sustainability.
Introduce examples of novel stainless steel powder materials barely used nowadays in the powder industry. To be presented in the conference, elevated temperature (253MA, 1.4835) or high corrosion (904L,1.4539) grades.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235763134

Requested presentation type : Oral Presentation

Topic : Powder Production **Subtopic :** Powder Production

Author : Mr Vanzetti Matteo (Politecnico di Torino, Italy)

Co-author(s) : Mr Pavel Michael, Dr Perez Andrade Lorena, Dr Weaver Mark, Prof Dr Brewer Luke (University of Alabama, USA), Dr Padovano Elisa, Dr Aversa Alberta, Prof Dr Bondioli Federica (Politecnico di Torino, Italy)

Title : Gas Atomized AlSi10Mg+Cu Powders For Metal Additive Manufacturing

Keyword(s) :
Powders; Additive Manufacturing; Aluminum Alloy; Copper; Rapid Solidification

Abstract :
Metallic powders are one of the most common feedstock material for metal additive manufacturing (MAM). Nowadays, only few alloys can be processed by these technologies and most of them are casting alloys. This work is focused on the characterization of a novel aluminum alloy produced by a close coupled gas atomizer (CCGA) with composition AlSi10Mg + x Cu (x= 4, 8, 20 wt%). These compositions are very attractive because copper is a well-known strengthener for aluminum alloys.The produced powders have been characterized in terms of morphology, flowability, particle size distribution (PSD) and density. Furthermore, the powders microstructures have been analyzed to evaluate the composition and the morphology of the phases generated by the rapid solidification that characterized the gas-atomization process.

Innovative Aspect(s) :
A new processable alloy for Metal Additive Manufacturing and in particular for Laser Powder Bed Fusion technology.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235763265

Requested presentation type : Oral Presentation

Topic : Powder Production **Subtopic :** Powder Production

Author : Dr Abid Aamir (Retech Systems LLC, USA)

Co-author(s) : Mr Stone Matthew, Mr Dusky Goeffery, Mr D'Alba Bryce (Retech Systems LLC, USA)

Title : Plasma Gas Atomization For Reactive And Refractory Metal Alloys

Keyword(s) :
Powder Production Equipment; Plasma Gas Atomization; Refractory and Reactive Alloys; Additive Manufacturing

Abstract :
A barrier to the broader adoption of refractory and reactive metal powders (like Titanium and its alloys) is the high cost of AM-suitable powders. Additionally, though companies are producing AM powders using a range of technologies, production rates are slow compared to steel and nickel Powder Production rates. There is also a limit to the available alloys as conventional processes require the production of high-cost bar or wire feedstock. To address the above-mentioned challenges, Retech has developed an atomization system that would provide a larger production capacity for a range of metal and alloy powders utilizing Plasma Arc Melting (PAM) in combination with gas atomization. Plasma melting allows for the introduction of a broad range of feed materials including revert without incurring the additional cost of processing feed to wire or bar forms. With this flexibility of feed materials, recycling high-value materials become an economically viable option.

Innovative Aspect(s) :
Novel Plasma Gas Atomization equipment for AM Powder Production
Ability to use low cost feedstock (scrap, revert, and other forms)*Ability to use broad range of feedstock forms (does not necessarily require wire or rod)
Capable to melt and atomize at very high rates (similar to rates for Ni and Steel hot-wall systems)

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235763600

Requested presentation type : Oral Presentation

Topic : Powder Production **Subtopic :** Powder Production

Author : Dr Samokhin Andrey (Institute of Metallurgy and Materials Science, Russia)

Co-author(s) : Dr Alexeev Nikolay, Mr Fadeev Andrey, Mr Sinaisky Mikhail, Mr Dorofeev Aleksey, Mr Zavertyaev Ilya (Institute of Metallurgy and Materials Science, Russia), Dr Gryaznov Mikhail (National Research Lobachevsky State University of Nizhny Novgorod, Russia)

Title : Processing Of Tungsten Powders In DC-arc Thermal Plasma System

Keyword(s) :
Tungsten; Nanopowder; Synthesis; Granulation; Micropowder; DC-Arc Thermal Plasma; Heat Treatment; Additive Technology; LPBF

Abstract :
The paper presents the results of R&D of plasma-chemical synthesis of tungsten nanopowders, as well as their granulation and subsequent plasma treatment of produced granules for spherical tungsten micropowders production for modern 3D printing technologies. Plasma-chemical synthesis of tungsten nanopowder is based on the reduction of tungsten oxide compounds powders in the flow of hydrogen-containing low-temperature thermal plasma generated in an electric arc plasma torch. Granulation of tungsten nanopowder was carried out by spray drying using an ultrasonic nozzle. Heat treatment of nanopowder granules was realized in a low-temperature thermal DC arc plasma in both sintering and melting modes. The influence of LPBF process parameters on the structure and properties of samples obtained at a 3D printer by using produced spherical tungsten micropowders was investigated. The results of the development of DC arc plasma systems for tungsten micropowders spheroidization are presented.

Innovative Aspect(s) :
The development of technology for the production of high-quality spherical tungsten micro-powders with a submicron grain size will provide the possibility of their use in modern highly efficient additive technologies for the manufacture of complex shape parts with high performance characteristics, primarily for experimental thermonuclear installations.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764227

Requested presentation type : Oral Presentation

Topic : Powder Production **Subtopic :** Powder Production

Author : Dr Emadinia Omid (INEGI - Institute of Science and Innovation in Mechanical and Industrial Engineering, Portugal)

Co-author(s) : Mr Silva Pedro (INEGI - Institute of Science and Innovation in Mechanical and Industrial Engineering, Portugal), Prof Dr Reis Ana, Prof Dr Vieira Manuel, Mr Zafar Fahad (Faculty of Engineering University of Porto, Portugal)

Title : Upcycling Aluminium Chips To Powder Feedstocks For Powder Metallurgy Applications

Keyword(s) :
Aluminium; Ball Milling Parmeters; Powder Characteristics; Densification; Energy; Properties

Abstract :
The aluminium scrap, either from industry or end-of-life consumer products is recycled. This approach can still consume up to one-third of the energy needed to produce primary aluminium since it also requires the addition of the pure metal apart from other processing. Aluminium metal swarf, a waste from subtractive manufacturing processes can be upcycled to produce metal powders. Conventionally, aluminium powders are produced using atomization processes with considerable energy and inert gas consumption. Thus, it is worth evaluating approaches like mechanical milling to explore the potential of energy savings as well as reducing the carbon footprint. Identifying and controlling the key milling parameters is paramount to achieving desired characteristics in the milled powders. This study explores the feasibility of the production of AlSi10Mg alloy powder by mechanical milling of waste metal swarf for sintering and additive manufacturing purposes. Material characterization, mechanical testing results and energy calculations will be presented.

Innovative Aspect(s) :
In addition to the transformation of aluminium swarf to powder feedstocks, that is an adding value to these metal residues, this study aims at optimizing milling conditions to reduce the Powder Production time and to enhance the productivity. Densification analysis for sintered materials, and the feasibility of printing classified powders through selective laser melting or even direct energy deposition by laser will be evaluated. In the meantime, the energy consumption and cost will be assessed to provide a base for comparing conventional atomization with the milling approach. Although sintering or printing are influenced by particle shape, optimization of processing conditions is opted for achieving best results.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764483

Requested presentation type : Oral Presentation

Topic : Powder Production **Subtopic :** Powder Production

Author : Prof Fang Zhigang Zak (University of Utah, USA)

Co-author(s) : Prof Fang Zhigang Zak (University of Utah, USA)

Title : A Novel Sustainable Low-Cost Process For Making Spherical Ti Alloy Powders for Additive Manufacturing

Keyword(s) :
Titanium; Powder Production; Deoxygenation; Additive Manufacturing; Sustainability

Abstract :
In the most recent decade, with the advent of additive manufacturing (AM) technologies, the manufacturing of Ti components using a laser (LPBF) or electron beam (EBM) emerged as one of the most important areas of additive manufacturing of metals. The cost of high-quality Ti and Ti alloy powder has become a glaring technical challenge. Therefore, developing a truly low-cost process for making high-quality Ti alloy powders will profoundly impact the adoption of Ti by additive manufacturing and other manufacturing processes. This presentation describes a novel method, the granulation-sintering-deoxygenation (GSD) process, that can produce spherical Ti and Ti alloy powders at a fraction of the cost of equivalent powders. Ti and Ti alloy powders produced with the GSD process have low oxygen content. GSD process can be used to upcycle high-oxygen scrap Ti alloy powder or bulk Ti alloy scraps, making the process the most sustainable Ti Powder Production process to date.

Innovative Aspect(s) :
The process that will be presented in this paper differs from the state-of-the-art processes for making spherical Ti alloy powders. The SOA process is costly. Instead of using conventional atomizing techniques, the new process is a thermochemical process that enables the deoxygenation of Ti alloy powder with high oxygen content. The new process is novel, low-cost, and sustainable.

Reviewer's name : ....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : ....

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764662

Requested presentation type : Oral Presentation

Topic : Powder Production **Subtopic :** Powder Production

Author : Dr Ing Gobber Federico Simone (Polythecnic of Turin, Italy)

Co-author(s) : Ing Monti Chiara, Ing Turani Matteo (inspire AG, Switzerland), Prof Dr Bambach Markus (ETH Zurich, Switzerland), Prof Dr Actis Grande Marco (Polythecnic of Turin, Italy)

Title : Innovative Al-based Powders Through Ultrasonic Vibration And Gas Atomizing

Keyword(s) :
Gas-Atomization; Ultrasonic-Vibration Atomization; AlCuTiFeCr; Powder Characterization

Abstract :
The need for spherical powders with enhanced flowability and tailored compositions has brought on new atomization techniques particularly suited for the lab-scale and highly competitive R&D activities. Among metal atomization techniques suitable for lab-scale development, those assisted by ultrasonic vibration are experiencing a notable diffusion at the R&D level. Gas-atomization is, however, the primary technique for producing spherical powders when larger batches are needed for production or R&D purposes. The present study analyzes the characteristics of an innovative Al-Cu-Ti-Fe-Cr alloy obtained by the two Powder Production techniques. At first, the two atomization processes are compared in terms of yield in specific PSD ranges, a peculiarity of the AM technologies. Then, the main body of the study presents the characterization and comparison of the powders in terms of morphology, composition, rheology, density and microstructure in different size fractions.

Innovative Aspect(s) :
Few studies in literature deal with the production and related characterization of Al-based atomized powders despite their overall employment, particularly as AM regards. This paper's innovative aspects lie in the characterization of a new Al-alloy composition, starting from a thorough description of the two atomization routes studied with related process information. Furthermore, the crossed characterization of ultrasonic-vibration atomized and gas-atomized powders, apart from the interesting scientific aspects, allows for debating the scalability from small-scale R&D to larger production batches.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764680

Requested presentation type : Oral Presentation

Topic : Powder Production **Subtopic :** Powder Production

Author : Mr Rahimi Ehsan (Materials Processing Institute, United Kingdom)

Co-author(s) : Mr Rahimi Ehsan, Mrs Fennell Catherine, Dr Birley Richard (Materials Processing Institute, United Kingdom)

Title : A New Measure To Predict Maximum Reusability Of Virgin Powder In Powder Bed AM

Keyword(s) :
Powder Characterisation; Morphology; Flowability; Laser Powder Bed Fusion; Powder Reusability

Abstract :
The reuse of metal powder is an essential step to make the powder bed fusion (PBF) process cost-effective; therefore, understanding the capability of virgin powder is of high importance. Not all the powder is used to make parts in a PBF process. A significant proportion of the un-used powder is collected during de-powdering of the final part. This proportion and a small proportion in the waste chamber can be sieved for reuse. In this research, powder samples were reused until their flowability was below the acceptable level for re-coating. Before every process, morphology, size and flowability were evaluated using the index that was developed in the previous research presented at WorldPM2022. The index was modified based on the alloy type and reusability aspects and it has been proposed to predict the maximum reusability of virgin powder on the condition that acceptable flowability, morphological distributions and mechanical properties are maintained.

Innovative Aspect(s) :
At the Materials Processing Institute, circular economy and sustainability are at the core of the research. The Institute aims to introduce versatile methodologies to measure the quality and processability of metal powder for recycling and reuse. In one of the recent Innovate UK grant-funded projects, PRISM, a new platform was created to evaluate and classify the powder based on its reusability. This platform improves the decision-making ability of the part and powder manufacturers. In the L-PBF process, the proportion of un-used (coated and waste) powder is significantly high. The un-used powder can be sieved for reuse; however, the quality reduces every time. To ensure the powder processability, flowability performance should be re-evaluated. Therefore, a measurement methodology that can predict and grade reusability of the virgin powder before the process is a step change in materials management. This work is a continuation of the previous research presented at WorldPM2022.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765086

Requested presentation type : Oral Presentation

Topic : Powder Production **Subtopic :** Powder Production

Author : Ing Pennacchio Antonio (Polytechnic University of Turin, Italy)

Co-author(s) : Dr Ing Gobber Federico Simone, Prof Dr Actis Grande Marco (Polytechnic University of Turin, Italy)

Title : Effect Of Process Gas Composition On The Characteristics Of Atomized UNS S32760 Duplex Stainless Steels Powders

Keyword(s) :
Gas Atomization; UNS S32760 (AISI F55) Powders

Abstract :
Super duplex stainless steels combine the advantages of ferritic and austenitic steels and reach an excellent combination of mechanical and corrosion properties. High chromium, molybdenum, and intermediate nitrogen concentrations confer high pitting resistance. Optimal gas process parameters are necessary to obtain UNS S32760 powders with suitable chemical composition, especially in terms of nitrogen content, for subsequent process techniques (L-PBF, 3D printing, MIM,…) to get the best pitting resistance and a good balance in the a ferrite|austenite phase. One of the main goals of the research activity is to evaluate the variation in nitrogen concentration for powders produced by Vacuum Inert Gas Atomization under two different melt chamber atmospheres, Ar or N2. After sieving, the effect of different process gases on the characteristics of the final powder, in terms of granulometry, morphology, microstructure, chemical composition (considering light elements as N, O, H, C, and S) and rheology, was investigated.

Innovative Aspect(s) :
The paper follows and extends the work presented by the authors at the WORLDPM2022. The new aspects are related to using different combinations of gases in the melting and atomization zones, comparing the different powders' chemistries, physical and morphological properties.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765094

Requested presentation type : Oral Presentation

Topic : Powder Production **Subtopic :** Powder Production

Author : Dr Ing Trapp Johannes (Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM, Branch Lab Dresden, Germany)

Co-author(s) : Mr Walther Gunnar, Dr Ing Fries Manfred (Fraunhofer Institute for Ceramic Technologies and Systems IKTS, Germany), Prof Dr Weißgärber Thomas (Fraunhofer IFAM & Technische Universität Dresden, Germany), Mr Hoffmann Mathias (Ostec GmbH, Germany), Mr Böhme Sven (PolyMIM GmbH, Germany)

Title : Iron Powders For Additive Manufacturing And Metal Injection Molding Produced By An Environmentally Friendly Route From Steel-production Sourced Ore Wastes

Keyword(s) :
Iron Powder; Additive Manuacturing; Metal Injection Moulding; Circular Economy

Abstract :
The demand for small, spherical powders increases, for examply due to the growing additive manufacturing market. For particles = 10 µm, mainly two production routes exist: atomization and the carbonyl process. The production of such powders is costly, so alternatives are needed.We present developments in a novel solid state processing route using iron ore from the steel steeping process that otherwise might end up as waste. The ore is first granulated by wet spraying. To scale up the production to hundreds of kilograms per day, the granules are reduced and sintered in a rotary kiln to form porous but stable agglomerates and post treated in a NARA hybridizer mill to form dense particles.Pure iron particles with < 0.2 m% oxygen, an apparent density of ˜ 3 g|cm³, and a purity of > 98 % are obtained at a competitive prize of < 3 €|kg. The suitability for MIM is verified with test geometries.

Innovative Aspect(s) :
The Powder Production process is not only supposed to produce cheaper powder within Europe, but also significantly reduces the CO2 emissions due to the hydrogen based proceesing route. Finally, the starting material is waste from steel-making and contributes to an approach of a circular economy.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765259

Requested presentation type : Oral Presentation

Topic : Powder Production **Subtopic :** Powder Production

Author : Dr Sanchez Angela (IRT M2P, France)

Co-author(s) : Dipl-Ing Deborde Agathe (IRT M2P, France), Dr Cornu Jérôme, Dr Vassa Alexandre, Dr Chebab Béchir, Dr Piaget Alexandre (C-TEC, France)

Title : Effect Of Atomization Process Parameters On Properties Of Aluminium Alloy Powder For Additive Manufacturing

Keyword(s) :
Gas Atomization; Aluminium Powder; Additive Manufacturing

Abstract :
Constellium Technology Center (C-TEC) has developed new high performance aluminium alloy powders specifically designed for laser powder bed additive manufacturing processes. Rapid solidification metallurgy is used to bring properties which would not be achievable with conventional alloys. The alloys require higher melting temperatures than conventional aluminium systems.The specific optimization of the atomizing process is carried out on the new VIGA atomizer installed by IRT M2P. Effects of different process parameters on yield and process continuity were investigated: melt superheat, delivery tube diameter, gas pressure and oxygen content in the atomizing gas. Powder characterizations were then performed (PSD, morphology, oxygen content, flowability, density…). Finally, the powders were tested by Laser Powder Bed Fusion (LPBF) and the performance of the printed parts were evaluated by metallography and mechanical testing.

Innovative Aspect(s) :
High performance aluminium alloy powders.
Effect of atomization parameters on yield and process continuity.
Link between atomization parameters, powder properties and LPBF parts performance.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765262

Requested presentation type : Oral Presentation

Topic : Powder Production **Subtopic :** Powder Production

Author : Dr Pijuan Jordi (Eurecat, Centre Tecnològic de Catalunya, Spain)

Co-author(s) : Miss Cegarra Sasha (Eurecat, Centre Tecnològic de Catalunya, Spain), Dr Riera Maria Dolores (Universitat Politècnica de Catalunya, Spain)

Title : Cooling Rate Evaluation Of Al-4%Cu Alloy Powders During Centrifugal Atomization

Keyword(s) :
Powder Production; Centrifugal Atomization; Cooling Rate

Abstract :
Centrifugal atomization technique to produce metal powder offers many advantages in terms of spherical morphology of the powders, high production yield and narrow particle size distribution. Centrifugal atomization is also considered a rapid solidification technique. The final microstructure of the atomized particles is closely linked with the thermal history and cooling rates experienced during the atomization process. In this work, Al-4% Cu alloy was atomized via centrifugal atomization under different atomization conditions. Gas composition and melt superheat temperature were investigated as processing parameters that influence in the cooling history of the atomized droplets. Colling rate was experimentally evaluated by means of Secondary Dendrite Arm Spacing (SDAS) technique using several methods found in the literature, and a numerical model was implemented to study the heat transfer between the droplets and the surrounding once the particles have been expelled from the disk, to identify the correlation between theoretical and experimental results.

Innovative Aspect(s) :
Although there is numerous research in evaluate cooling rate in other atomization methods such as gas atomization, and several theoretical models adjusted for this technology, there is few information about cooling rate evaluation in centrifugal atomization. This study is the first step of investigating the correlation between theoretical models, and experimental methods based on metallography analysis, to evaluate the cooling rate using this atomization technique.

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765330

Requested presentation type : Oral Presentation

Topic : Powder Production **Subtopic :** Powder Production

Author : Prof Colombini Elena (University of Modena and Reggio Emilia, Italy)

Co-author(s) : Prof Veronesi Paolo, Dr Lassinantti Gualtieria Magdalena (University of Modena and Reggio Emilia, Italy)

Title : Recycling Of Spent Powders From Laser Powder Bed Fusion Processing Of Inconel 625 For The Mechanical Synthesis Of CoCrFeNiMoxNb0.4x (x=0-0.1) Multi-Principal Element Alloys (MPEAs)

Keyword(s) :
Multi-Principal Element Alloys; Recycling; LPBF

Abstract :
Laser powder bed fusion processing (L-PBF) is an emerging additive manufacturing (AM) technique particularly suitable for the production of parts with complex shapes made of materials with low machinability, such as Ni-based superalloys. Although most of the excess powder following each building cycle can be recycled in successive ones, some solid scrap consisting of large particle aggregates are sieved out from the recycled powder stream and disposed of as hazardous waste. An interesting alternative is recycling for the synthesis of products with high added value such as Multi-Principal Element Alloys (MPEAs). This was explored here for the mechanical synthesis of equimolar CoCrFeNi fcc-structured MPEA strengthened by 4d transition metals (CoCrFeNiMoxNb0.4x with x=0-0.1) originating from spent powders of Inconel 625. Results from extensive microstructural characterizations and nanoindentation analyses of the powders highlight the feasibility of using spent powders for the mechanical synthesis of fcc MPEAs with enhanced solid solution strengthening.

Innovative Aspect(s) :

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765429

Requested presentation type : Oral Presentation

Topic : Powder Production **Subtopic :** Powder Production

Author : Mr Sandoval Neyder A. (Universidad Carlos III de Madrid, Spain)

Co-author(s) : Dr Sánchez-Delgadob Sergio, Dr Serrano Daniel, Dr Tsipas Sophia (Universidad Carlos III de Madrid, Spain)

Title : Surface Modification Of An Aluminium Alloy Powder (Al2024) With SiC Nanoparticles For Application In Additive Manufacturing

Keyword(s) :
Additive Manufacturing; Surface Functionalization; Fluidied Bed

Abstract :
Additive manufacturing (AM) is booming at an industrial level due to the possibility of producing components of complex geometry, while reducing use of raw materials, cost and time. However, in many processes there is still a lack of understanding of the composition-processing-microstructure relationship and a limited range of raw material compositions, as well as reproducibility problems. In search of improving these problems, surface modification of an aluminium alloy powder (Al2024) for its use in AM is proposed. A fluidized bed reactor was designed and built for the surface functionalization with SiC nanoparticles. SiC nanoparticles were produced by milling and dispersed in colloidal suspensions. Homogeneity, stability and rheology of the suspensions was studied. A homogeneous deposition of the nanoparticles on the host particles in the fluidized bed was obtained. The properties of samples produced with the modified powders were evaluated in comparison with samples produced with unmodified powders.

Innovative Aspect(s) :
Design and optimization of a fluidized bed reactor for surface functionalization of Al powders for AM. This study demonstrated that surface modification processes of powders can be stable at the industrial level, thus increasing versatility in the commercial raw material currently available for AM. The modified powders where used in Composite Extrusion Modelling (CEM) and LBPF processes. The properties of AM samples produced with modified powders were compared with the properties of samples produced with unmodified powders

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765563

Requested presentation type : Oral Presentation

Topic : Powder Production **Subtopic :** Powder Production

Author : Dr Ing Cordova Laura (Chalmers University of Technology, Sweden)

Co-author(s) : Dr Ing Raza Ahmad, Prof Dr Hryha Eduard (Chalmers University of Technology, Sweden)

Title : Analysis Of Processability And Reusability Of Ti6Al4V Powders For PBF-EB

Keyword(s) :
Powder Reuse; Powder Quality; PBF-EB; Electron Beam Melting

Abstract :
Processability in Powder Bed Fusion Electron Beam (PBF-EB) depends on the interaction of the electron beam with the metal powder. For a good, consolidated part to be processed, the powder must be smoothly applied on the powder bed and the beam transmits the electrons throughout the powder layers. Only with powder of specific characteristics, this is possible (narrow PSD, smooth and spherical morphology, high chemical purity). In this study two different TI6Al4V powder batches are analyzed, one batch presented challenges with processability even in virgin state. For both powders, an assessment of the morphology, particle size, rheology, and chemistry will determine the feasibility to achieve optimal processability and the possibility to reuse in consecutive cycles.

Innovative Aspect(s) :
This work explores the potential to use different qualities of the Ti64 powder and feasibility to reuse it. Even when the quality is not optimal. It is important to maintain the cost-effectiveness and sustainability of the process.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235766354

Requested presentation type : Oral Presentation

Topic : Powder Production **Subtopic :** Powder Production

Author : Dr Ing Molavi Kakhki Amin (Rio Tinto Metal Powder, Canada)

Co-author(s) : Dr Sander Jan (Brose Group, Germany), Mr Fischer Maximilian (Brose Group, Germany), Mrs Labrecque Chantal (Rio Tinto Metal Powder, Canada),

Title : Industrial Additive Manufacturing Using Water Atomized Steel Powder For Low To Medium Series Production

Keyword(s) :
Low Carbon Steel Powder; Water Atomized; Laser Powder Bed Fusion; Serial Production; Heat Treatment

Abstract :
Industrial application of Additive Manufacturing (AM) is recently getting more attention, as the printing technologies are evolving towards a faster printing speed and eventually lower manufacturing cost. Choosing the right part and application and an optimum set of printing parameters along a wise selection of low-cost feed material will help to extend the real industrial use of AM. In this work, ATOMET 1025, a water atomized low carbon steel powder, produced by Rio Tinto Metal Powder was evaluated as the feed material for low to medium series production of industrial parts via a high-speed Laser Powder Bed Fusion (LPBF) method, developed by Brose Group. A series of different types of heat treatment was studied on the printed samples to achieve the target mechanical properties. The results confirmed that this combination of material, printing process and post processing can lead to the properties equivalent or better than the conventional counterparts.

Innovative Aspect(s) :
Innovative way of using water atomized powder to additively manufacture cost competitve parts for low to medium series production.
Heat treatment of low carbon steel parts to target special mechanical properties.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235768771

Requested presentation type : Oral Presentation

Topic : Powder Production **Subtopic :** Powder Production

Author : Mr Henrichs Julian (Linde GmbH & Technical University of Munich, Germany)

Co-author(s) : Mr Hilbert Jimmy, Dr Ing Giglmaier Marcus, Prof Dr Adams Nikolaus A. (Technical University of Munich; TUM School of Engineering and Design, Germany), Mr Rosenberg Ronald, Mr Forêt Pierre (Linde GmbH, Germany)

Title : Experimental Investigation And Visualization Of The Transonic Gas Flow In An Industrial Scale Test Bench For Metal Powder Atomization

Keyword(s) :
Additive Manufacturing; Gas Atomization; Metal Powder Production; Schlieren Imaging; Gas Dynamics; Primary Atomization; Secondary Atomization

Abstract :
One of the current major barriers to the industrialization of metal additive manufacturing (AM) is the cost-effective production of a high-quality metal powder, usually in the range of 1-63 µm, making investigations of the atomization process essential. Numerical investigations usually reach their limits due to the massive multiscale problem, whereas experimental investigations are either performed on a laboratory scale with limited transferability or on industrial equipment with limited accessibility for measurement techniques. To face this challenge a new atomization test bench is developed which was tailored for detailed experimental investigation on the fundamentals of atomization in an industrial scale set-up. All input parameters can be set individually and are measured continuously and precisely. At the same time, the good optical accessibility allows a temporally and spatially highly resolved visualization of the gas flow as well as a detailed investigation of the mechanisms of decomposition during primary and secondary atomization.

Innovative Aspect(s) :
Atomization test bench specifically developed for investigating gas dynamics as well as primary and secondary droplet breakup phenomena present during gas atomization in a 1:1 scale test setup (nozzle and gas flow) Setup is optimized for visualization of all ongoing phenomena, this includes a high speed schlieren and shadowgraph imaging solutions which can be used over the entire length of the test chamber All process parameters like pressure, temperature and composition are easily adjustable in a broad range. Roadmap: After the test bench's commissioning, investigation of the gas structures, followed by research on liquid break up using model fluids will be conducted. In the end, results will be validated on an industrial atomizer Using this test bench in addition to traditional methods allows acceleration of R&D The new set up allows fast, cheap and resource-saving R&D, while maintaining best possible comparability and transferability to industrial atomizers.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235766782

Requested presentation type : Oral Presentation

Topic : Powder Production **Subtopic :** Powder Production

Author : Prof Bengtsson Sven (Höganäs AB, Sweden)

Co-author(s) : Mr Gherekhloo Human (Höganäs AB, Germany), Ms Larsson Anna (Höganäs AB, Sweden), ,

Title : Qualification Of A New Powder Production Process For Laser Powder Bed Fusion Application

Keyword(s) :
Vacuum Melting; Inert Gas Atomization

Abstract :
The introduction of additive manufacturing in the production of advanced parts for aerospace and similar high-end applications have increased the demands on the powder. For a LPBF process not only the chemistry, but also the physical properties of the powder are critical to performance. In this report the some of the consequences of replacing an older atomizing line by a more modern equipment are outlined. The new system is easier to operate which should translate into less downtime. It also has an integrated anti-satellite system that should provide less variation in physical properties of the powder. Physical and chemical properties of several powder lots were systematically measured and compared to the older equipment. Furthermore, a number of prints using the LPBF process were performed and the mechanical properties of the printed and heat treated parts were compared.

Innovative Aspect(s) :
The Powder Production equipment and sequence of process steps is outlined.
The resulting consequences for powder quaality and printed part are is described.

Reviewer's name : ....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235762509

Requested presentation type : Poster Presentation

Topic : Powder Production **Subtopic :** Powder Production

Author : Mr Han Chulwoong (KITECH, Korea, Republic of)

Co-author(s) : Miss Kim Song-Yi, Mr Park Sung Cheol (KITECH, Republic of Korea)

Title : Nickel Nano-particle Synthesis By RF Thermal Plasma Process

Keyword(s) :
Nickel Nano-Particle; RF Thermal Plasma; Vaporization; Condensation

Abstract :
Conductive metallic nano-particles are extensively used for electrical|thermal management of electronic components in the printable electronic industries. Nickel nano-particle is a representative conductive metal for base metal multi-layered ceramic capacitor fabrication. Ni nano-particle size has been reduced in accordance with the miniaturization trend. In this study, Ni metallic nano-particle was synthesized by feeding nickel hydroxide micro-powder into argon-hydrogen thermal plasma at different mass feeding rate. Phase, morphology, and size were investigated for as-synthesized particles. Through the results, it could be proven that nickel hydroxide feedstock particle underwent a vaporization, reduction, and condensation pathway. In addition, mean particle size was increased with feedstock mass feeding rate increasing. Higher mass feed-rate increased vapor pressure of Ni when most of feedstock powder was vaporized within the scope of this study. Accordingly, increased Ni vapor pressure raised critical condensation temperature and collision and coalescence probability between particles at relatively high temperature.

Innovative Aspect(s) :

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765726

Requested presentation type : Poster Presentation

Topic : Powder Production **Subtopic :** Powder Production

Author : Mr Costa Marques Anderson (Universidade Federal Do Rio Grande Do Norte-UFRN, Brazil)

Co-author(s) : Miss Samara Vieira Pâmala, Miss Queiroz e Silva Thalita, Prof Dr Mashhadikarimi Meysam (Universidade Federal Do Rio Grande Do Norte-UFRN, Brazil)

Title : Hardening Of Copper Powder With Tungsten Carbide By High Energy Grinding

Keyword(s) :
High energy milling; Cu-WC composites; Copper powder hardening; Powder microhardness.

Abstract :
The composites produced with a copper matrix and reinforced with a ceramic material and refractory are of great importance, due to its various applications in electrical conductors and heat sinks. In this sense, the work aimed to investigate the hardening of copper powder with the addition of tungsten carbide (WC) through high energy milling in order to evaluate the influence of WC percentage and grinding time on copper powder properties. The milling of the powders was performed for 1, 2, 5, 10 and 20 hours. The results obtained showed that the milling method used in this work proved to be efficient for obtaining Cu-WC. Besides that, it was found that the milling time was an important factor to obtain a greater dispersion and homogenization of the powder particles. Finally, it is noted that the Vickers microhardness value is directly related to the amount of WC and with the grinding.

Innovative Aspect(s) :
The innovative aspect of this work is to obtain composite powders of Cu-WC, with concentrations of 5, 10, 15 and 20% (% by mass) of tungsten carbide, via high energy milling, using milling times of 1, 2, 5, 10 and 20 h, in order to verify the effect of composition (%WC) and processing (milling time) variables on morphology and crystalline structure. Moreover, another innovative characteristic of the research is the performance of Vickers Microhardness on the Cu-WC powders, aiming to analyze the effect of WC content and milling time on the hardness of the material. And with this, to obtain composites with good mechanical, electrical and thermal properties, to be applied in electrical conductors and heat sinks.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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Notes to author : ....

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235765286

Requested presentation type : Poster Presentation

Topic : Powder Production **Subtopic :** Powder Production

Author : Dipl-Ing Planta Xavier (Eurecat,Centre Tecnològic de Catalunya, Spain)

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Title : Microwave-induced Plasma To Recondition Scrap Particles For Additive Manufacturing

Keyword(s) :
Plasma; Powder Conditioning; WC; Scrap

Abstract :
Metal scrap from additive manufacturing (AM) can be reused as bars for further melting and casting. Metal powder for AM and PM is usually gas-atomized from cast bars with a high energy consumption, long production times and can generate waste, as some particles cannot be used for AM or PM.The Microwave Induced Plasma (MIP) technology allows producing spherical particles from scrap or irregular shape particles. MIP can be done on-site, saving energy by 30% and reducing costs by more than 75%. MIP is oriented to the reconditioning of scrap (chips, fibres, particles) adapted to the processes and reconditioned, in the form of spherical particles, increasing its final utility and added value, being a clear demonstration of the circular economy concept. This work shows the application of MIP to some metallic (Al alloys, copper alloys, 20MnCr5 steel) and ceramic (WC) particles reconditioning to be use as a feedstock for AM

Innovative Aspect(s) :
There are several systems to produce|recover metallic powders, such as water atomization, gas atomization, centrifugal atomization, ultrasonic atomization and inductively coupled plasma atomization. Due to their cost efficiency and easy availability, water and gas atomization are popular and commercially used processes.MIP is an attractive alternative to these systems because consumes less energy and produces particles with better quality. Some of its differential characteristics are: Easy flame ignition. Laminar and supersonic flow is not necessary nor is it necessary a strong magnetic field Efficient and sustainable process. MIP consumes 5-7 KWh|kg and Inductive Coupled Plasma 17-22 KWh|kg, which is between 29-35%, means less consumption. MIP can use different types of gases at atmospheric pressure to produce plasma suitable for whatever it need Microwave-induced plasma does not use electrodes and thus there is no waste associated.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235764653

Requested presentation type : Poster Presentation

Topic : Powder Production **Subtopic :** Powder Production

Author : Mr Lee Yongkwan (Korea Institute of Industrial Technology, Korea, Republic of)

Co-author(s) : Mr Sim Jaejin, Mr Heo Sunggue, Dr Oh Soong ju, Ms Lee Mi hye, Dr Shin Jae Hong, Dr Seo Seok jun, Dr Park Kyoung Tae (Korea Institute of Industrial Technology, Republic of Korea)

Title : Effect Of Reducing Agent And Carbon Content On Particle Properties Of Tungsten Carbide Powder Manufactured Through The SHS Process

Keyword(s) :
Tungsten Carbide; Self-Propagating High-Temperature Synthesis; Tungsten Oxide; Particle Size; Carbon

Abstract :
Tungsten carbide (WC) is the main raw material of cemented carbide (WC-Co) and is mainly used for cutting tools, wear-resistant tools, and impact-resistant tools because of its excellent high-temperature hardness and high strength. The properties of cemented carbide are greatly affected by the particle size of the tungsten carbide powder, and the development of particle size control technology of the tungsten carbide powder is being actively developed to improve the performance of the tool material. This study evaluated the characteristics according to the amount of reducing agent and carbon input to control the particle size of tungsten carbide powder. The phase composition and morphology evolution of synthesized powders has been examined by X-ray diffraction, scanning electron microscope, and particle size analyzer. As a result, WC powder with a particle size of about 0.9 nm was manufactured under optimized experimental conditions through the control of the reducing agent and carbon content.

Innovative Aspect(s) :

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Paper Number : EP235765398

Requested presentation type : Poster Presentation

Topic : Powder Production **Subtopic :** Powder Production

Author : Dr Gomes Uílame (Universidade Federal Do Rio Grande Do Norte, Brazil)

Co-author(s) : Miss Galvão Kívia Fabiana, Mr Lourenço Cleber, Dr Raimundo Rafael, Mr Souza Vitor Manoel (Universidade Federal Do Rio Grande Do Norte, Brazil), Dr Lima Maria José (UFRN, Brazil)

Title : Study Of The Influence Of Milling Time On The Synthesis Temperature Of Monoclinic And Orthorhombic Nanostructured CuNb2O6 Via High-energy Milling

Keyword(s) :
CuNb2O6; Synthesis; High Energy Milling

Abstract :
Copper niobate (CuNb2O6) has been studied for technological and environmental applications, such as in solar cells and photocatalysts, for example. And to make the application of CuNb2O6 even more feasible, in this study, therefore, high-energy milling was applied in its synthesis process with variation in the milling time, from the precursor powders Nb2O5 and CuO. The calcination occurred in a muffle with temperatures in the range of 500 °C to 1000 °C, for 3 h and heating rate of 5 °|min. Then, the powders were characterized by XRD, SEM, EDS and Raman. The powders showed crystallite sizes smaller than 80 nm, good homogeneity and high purity. The particle morphologies and the raman spectrum are coherent with the literature. It was also verified that the increase in milling time reduced the initial formation temperature of the monoclinic phase and the calcination time for the complete formation of the orthorhombic phase.

Innovative Aspect(s) :
The innovation of this work consists in the study of a little explored material, both in terms of its application and its acquisition. However, CuNb2O6 has a high potential and importance for science due to the following factors: The great abundance of its precursors (Niobium and Copper), the range of properties due to its polymorphism, highlighting the good conduction and catalytic activity present in both phases that allows it to be used in important applications such as CO2 photoreduction, photocatalysts, sensors, catalysts, lithium ion batteries, capacitors and solar cells, for example. Thus, studies on obtaining and characterizing its particles are essential to define and structure the processing steps, since the properties can be altered by the way of synthesis and by the phase obtained. In addition, there is always a constant search for the ideal synthesis parameters, which benefit the product, costs and methodology.

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Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2023 CONGRESS & EXHIBITION

01-04 October 2023

Paper Number : EP235762517

Requested presentation type : Poster Presentation

Topic : Powder Production **Subtopic :** Powder Production

Author : Mr Han Chulwoong (KITECH, Korea, Republic of)

Co-author(s) : Miss Kim Song-Yi (KITECH, Republic of Korea)

Title : A Combined Process For Fine And Spherical Cu-Zr Alloy Particle Preparation

Keyword(s) :
Cu-Zr Alloy; RF Thermal Plasma; Spheroidization; Vaporization

Abstract :
Powder metallurgy has been a fundamental manufacturing technology and the performances of PM components depend on the feedstock particle properties. Fine and spherical metallic particles are required to meet the industrial needs such as down-sizing and good sinterability. A combined process for fine and spherical particle preparation was designed and suggested in this study. The process consisted of particle comminution and thermal plasma spherodization. Cu-Zr alloy was cast and then mechanically pulverized. After that, the broken particles were spheroidized by RF thermal plasma process. Feasibility of the process was evaluated in view of size, morphology, and chemical composition. The combined process showed high selectivity on both size and morphology. However, there was a critical limitation in the reliability of chemical composition. Vaporization of copper in the in-flight particle resulted in the deviation of chemical composition from starting feedstock particle. With the feedstock particle size decreasing, vaporization was much more

Innovative Aspect(s) :

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01-04 October 2023

Paper Number : EP235762518

Requested presentation type : Poster Presentation

Topic : Powder Production **Subtopic :** Powder Production

Author : Mr Han Chulwoong (KITECH, Republic of Korea)

Co-author(s) : Miss Kim Song-Yi (KITECH, Republic of Korea)

Title : Nanoparticle Dispersed Micro-granule As A Bridge Material For Penetration Of Nanoparticle To Powder Metallurgy

Keyword(s) :
Mixture of Nanoparticle and Micro-Powder; Homogeneous Mixture; Heterogeneous Mixture; Compaction; Sintering

Abstract :
Nanoparticles dispersed micro-granules in which nanoparticles are dispersed on the surface of micro-powder are designed as a bridge powder to manipulate processing abilities of powder in the powder metallurgy technology. In the suggested nanoparticle dispersed micro-granule, spiky micro-powder was chosen as supporting constituent and RF thermal plasma synthesized nanoparticles were used as compaction and sintering activating agents. Size difference makes nanoparticles fill the pockets on the spiky micro-powder surface and micro-powder is spheroidized by nanoparticle attachment through facile 3-D turbulent mixing. Compaction behaviors of micro-granule are compared to nanoparticle and micro-powder according to weight fraction of nanoparticle in micro-granule. Besides, it is proven that nanoparticles which are located at the particle interfaces enhance sintering by the presence of double-step shrinkage in the dilatometry. Micro-granule belongs to blended elemental powder in the conventional powder metallurgy and it can be divided into homogeneous micro-granule and heterogeneous one according to chemical composition.

Innovative Aspect(s) :

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