EURO PM2023
CONGRESS & EXHIBITION

Technical Programme Committee
15th February 2023

ABSTRACTS BOOK – GROUP 6

CONSOLIDATION TECHNOLOGIES

EPMA
european powder metallurgy association

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 Y2O3 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.

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 : 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.

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 : 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.

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 : 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.

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 : 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.

Reviewer's name : .....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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Withdraw ☐ Reason : .....

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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.

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 : 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.

Reviewer's name : .....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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Notes to author : .....

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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.

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 : 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.

Reviewer's name : .....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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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) :

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 : 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) :

Reviewer's name : .....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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EURO PM2 23
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.

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 : 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 (N2:H2: 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.

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 : 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.

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

CONSOLIDATION TECHNOLOGIES

FIELD ASSISTED SINTERING TECHNOLOGIES

EPMA
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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.

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 : 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.

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 : 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.

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 : 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.

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 : 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.

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 : 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

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 : 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.

Reviewer's name : .....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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Notes to author : .....

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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.

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 : 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) :

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 : 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.

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 : 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.

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

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.

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 : 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) :

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 : 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.

Reviewer's name : .....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

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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.

Reviewer's name : .....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

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Notes to author : .....

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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.

Reviewer's name : .....

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

OTHER CONSOLIDATION TECHNOLOGIES

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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.

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 : 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 : .....

Notes to author : .....

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EURO PM2 23
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 Al2O3 & GNPs prepared by PSM & Hot Coining techniques. Al2O3 and GNPs are coated with 10wt.% nano Ag by electroless deposition. 10 wt% Al2O3 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 Al2O3 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 Al2O3- 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.

Reviewer's name : .....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : .....

Notes to author : .....

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