EURO PM2023
CONGRESS & EXHIBITION

Technical Programme Committee
15th February 2023

ABSTRACTS BOOK – GROUP 5

CONSOLIDATION TECHNOLOGIES

AM sinter based technologies

EPMA
european powder metallurgy association

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.

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 : 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.

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 : 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.

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 : 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.

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 : 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.

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 : 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.

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 : 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.

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 : 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 ☐

Withdraw ☐ Reason : .....

Notes to author : .....

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EURO PM2 23
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.

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 : 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.

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 : 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) :

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 : 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 ☐

Withdraw ☐ Reason : .....

Notes to author : .....

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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☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : .....

Notes to author : .....

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EURO PM2 23
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

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 : 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.

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 : 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 cm³|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) :

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 : 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.

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 : 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.

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 : 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 ☐

Withdraw ☐ Reason : .....

Notes to author : .....

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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.

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 : 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.

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 : 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☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : .....

Notes to author : .....

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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 ☐

Withdraw ☐ Reason : .....

Notes to author : .....

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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.

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 : 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.

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 : 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.

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 : 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.

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 : 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) :

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 : 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) :

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 : 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.

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 : 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% N2 – 75% H2 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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EURO PM2023
CONGRESS & EXHIBITION
01-04 October 2023

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.

Reviewer's name : .....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : .....

Notes to author : .....

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