EURO PM2024

CONGRESS & EXHIBITION

Technical Programme Committee

8th of February 2024

ABSTRACTS BOOK

GROUP 5 - CONSOLIDATION TECHNOLOGIES

AM SINTER BASED TECHNOLOGIES

EPMA

european powder metallurgy association

EURO PM2024
CONGRESS & EXHIBITION
Malmö, Sweden
29 September - 02 October 2024

Paper Number : C32
ID : 6233737

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); Mrs Schlegel Regina (Fraunhofer IFAM, Germany)

Title : Influence Of Binder Characteristics On Binder Saturation And Wetting Behavior In Metal Binder Jetting

Keyword(s) :
Metal Binder Jetting, Powder-Binder-Interaction, Wetting Behavior, Binder 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 binder characteristics the equilibrium saturation and wetting behavior changes. A better understanding of binder viscosity and surface tension 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 binder and powder characteristics as well as 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 binder charactertics.

Reviewer's name : .....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : .....

Notes to author : .....

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EURO PM2024 CONGRESS & EXHIBITION
Malmö, Sweden
29 September - 02 October 2024

Paper Number : C33
ID : 6275809

Requested presentation type : Oral Presentation

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

Author : Prof Dr Kate Kunal (University of Louisville, USA)

Co-author(s) : Dr Ajjarapu Pavan Kumar (University of Louisville, USA); Prof Dr Bhatia Bikram (University of Louisville, USA); Mr Izquierdo Julio (University of Louisville, USA); Prof Dr Malhotra Rajiv (Rutgers, USA); Mr Khanjar Saleh (University of Louisville, USA); Prof Dr Roussel Tommy (University of Louisville, USA)

Title : Material Extrusion Additive Manufacturing (MEX-AM) Of Copper Heat Sinks: Process Development, Product Design, And Process Optimization

Keyword(s) :
3D-Printing Copper, Heat Sinks, Lattice-Structure, Sintering, Hot Isostatic Pressing

Abstract :
Copper heat sinks (electronic applications) typically manufactured using conventional techniques tend to have simple fin|pin structures due to limitations in processing capabilities. To transform these traditional designs, intricate lattice structures of high surface area were 3D-printed and sintered via Material Extrusion Additive Manufacturing (MEX-AM). Copper powder-filled filaments (> 90wt.%) were developed and 3D-printed via MEX-AM. Three types of structures – planar, strut and surface lattices were 3D-printed to facilitate efficient heat-transfer pathways within the heat sinks. Subsequent post-processing steps, including polymer removal, sintering, and hot-isostatic-pressing (HIP), were performed to achieve 98% dense and 100% IACS copper parts. Finite element analysis (FEA) was conducted to assess the heat transfer efficiency of the designs, and heat transfer experiments were performed using a custom setup to validate the simulation results. The investigation combines experimental analysis and simulations to gain insights into the structure-material property relationships and optimize the thermal performance of the printed.

Innovative Aspect(s) :
This talk elucidates the advancements and challenges in 3D-printing, sintering, and HIPing of copper parts fabricated via MEX-AM. This study is at the forefront of presenting superior mechanical and electrical attributes through copper 3D printing, offering a pathway for both 3D printing and HIPing as a viable strategy for crafting high-performance copper components for applications in electronics, aerospace, and automotive sectors. Feedstocks and filaments with 61vol.% solids loading of copper were compounded and extruded to 3D print and sinter test coupons and heat sinks. Incorporating pre-sintering holds in a reducing atmosphere alongside HIP resulted in remarkable mechanical and electrical properties. Sintering yielded 93% density, while HIP yielded 98% density relative to pure copper. HIPed parts exhibited improved mechanical (190 MPa UTS, 32% elongation at failure) and electrical (100% IACS) characteristics. Finally, the talk culminates with understanding the effect of change in infill density leading to part warpage and defects.

Reviewer's name : .....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : .....

Notes to author : .....

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EURO PM2024
CONGRESS & EXHIBITION
Malmö, Sweden
29 September - 02 October 2024

Paper Number : C34
ID : 6276985

Requested presentation type : Oral Presentation

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

Author : Mr Malti Abolfazl (The University of Melbourne, Australia)

Co-author(s) : Dr Brandl Christian (The University of Melbourne, Australia); Dr Molla Tesfaye (The University of Melbourne, Australia)

Title : Role Of Process Parameters On The Effective Properties Of The Print-bed During Binder Jet Additive Manufacturing: A DEM-based Study

Keyword(s) :
Powder Spreading, Discrete Element Method, Binder Jet Printing, Additive Manufacturing

Abstract :
Analysis of the powder spreading process in additive manufacturing (AM) is often based on formation of a single layer of powders on a smooth substrate. While this approach is valid for powder-bed fusion AM techniques, it can oversimplify the printing process in binder jet (BJ-AM), where parts are built through multi-layer spreading of powders with liquid binder added in between. This study analyses the printing process based on multi-layer spreading of powders during BJ-AM process by using DEM simulation. The influence of printing parameters including layer thickness, roller velocity and substrate surface roughness on the bulk properties of the print-bed (e.g., density, structural homogeneity, and surface quality) are investigated. The study shows convergence of the relative density of the print-bed towards an asymptotic limit, while structural homogeneity and surface roughness vary significantly with process parameters. A process map is suggested showing parameter insensitive window for optimal powder spreading.

Innovative Aspect(s) :
The current work focuses on the advancement of multi-layer powder spreading in the binder jet printing process. In addition to the horizontal structural homogeneity, the vertical structural homogeneity as a considerable feature in multi-layered samples is investigated.The study can extend our understanding of the various mechanisms involved in multi-layer powder spreading and enable optimizing the process for BJ-AM to achieve print-beds with improved density, structural homogeneity, and surface quality.

Reviewer's name : .....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : .....

Notes to author : .....

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EURO PM2024
CONGRESS & EXHIBITION
Malmö, Sweden
29 September - 02 October 2024

Paper Number : C35
ID : 6278376

Requested presentation type : Oral Presentation

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

Author : Dipl-Ing Vogel Lucas (MetShape GmbH, Germany)

Co-author(s) : Dr Khan Qaiser Ali (MetShape GmbH, Germany); Dr Ing Baum Andreas (MetShape GmbH, Germany); Prof Dr Burkhardt Carlo (University Pforzheim, Germany)

Title : Characterisation Of Microstructure And Mechanical Properties Of 17-4PH Parts Produced With The Lithography-based Metal Manufacturing Technology

Keyword(s) :
LMM, Lithography-based Metal Manufacturing, MetShape, 17-4PH, Mechanical Properties

Abstract :
The lithography-based metal manufacturing (LMM) process is a novel additive manufacturing technique that enables the sinter-based manufacturing of metal parts with high dimensional precision and exceptional surface quality o effectively apply this technology, comprehending the relationship between mechanical properties and printing orientation is imperative. Given the relative novelty of this technology, our study seeks to explore the influence of manufacturing orientation on both the mechanical properties and shrinkage behaviour of stainless steel 17-4PH. In most additive manufacturing technologies typical variations in mechanical properties is observed in every axis, our investigation focuses on assessing the tensile properties of the material in all orientations. Tensile bars are fabricated accordingly and evaluated in terms of density and dimensions as both green and sintered components. Subsequent to the sintering process, an in-depth analysis of mechanical properties and microstructure is conducted to elucidate the inherent correlations between the technology and material.

Innovative Aspect(s) :
This study aims to contribute valuable insights into the optimization and application of Lithography-based Metal Manufacturing (LMM) for stainless steel 17-4PH in diverse manufacturing scenarios. The research focuses on the critical aspect of manufacturing orientation and its impact on mechanical properties and densification behaviour. Also, it demonstrates the first analysis of the microstructure of 17-4PH Parts manufactured with the LMM technology. Thereby the study offers insights on both the porosity and phase distribution in the material´s evolution during the manufacturing process.

Reviewer's name : .....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : .....

Notes to author : .....

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EURO PM2024
CONGRESS & EXHIBITION
Malmö, Sweden
29 September - 02 October 2024

Paper Number : C37
ID : 6280667

Requested presentation type : Oral Presentation

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

Author : Dr Muñoz Moreno Rocio (HP, Spain)

Co-author(s) : Ms Marin Camara Ariadna (HP, Spain); Dr Pérez Prado Maria Teresa (IMDEA Materials Institute, Spain); Dr Bafaluy Sergi (IMDEA Materials Institute, Spain); Dr Sket Federico (IMDEA Materials Institute, Spain)

Title : 3D Metal Binder Jetting Green Parts Microstructure Metrics For Sintered Parts Macroproperties Prediction

Keyword(s) :
Additive Manufacturing Sinter Based Technologies, Metal Binder Jetting , Green Parts Properties, Microstructures Metrics

Abstract :
3D Metal Jet is currently disrupting manufacturing and accelerating mass production of 3D-printed parts. Metal Jet excellent balance between part quality and productivity rates are founded on powerful R&D investigations and metrics development on support to applications for user cases. In this study, it will be explained the technical physics description of the binder jet fundamentals empowered by key advantage assets founded in the latex binders and printheads. Powder properties, green and sintered microstructures, together with final parts performance derived from their macroproperties will be evaluated. In particular, focus will be devoted to describe novel green parts microstructure metrics obtained by scanning electron microscope (SEM) and X-ray computed tomography (XCT), as binder and porosity local fractions, together with possible period or amplitudes patterns. The use of these metrics in support to printmode development and materials integration, as a predictive and more sustainable method will be discussed.

Innovative Aspect(s) :
Novel metrics of Metal Binder Jetting green parts to predict sintered parts performance New Methodologies more sustainable to develop materials and processes development by minimizing iterations and resources consumption Investigations driven by novel 3D Metal Binder Jetting applications user cases.

Reviewer's name : .....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : .....

Notes to author : .....

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EURO PM2024
CONGRESS & EXHIBITION
Malmö, Sweden
29 September - 02 October 2024

Paper Number : C38
ID : 6280682

Requested presentation type : Oral Presentation

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

Author : Ing Garcia Grau Marc (HP, Spain)

Co-author(s) : Ing González Daniel (HP, Spain); Ing Jiménez Xavier (HP, Spain); Ing Barreda David (HP, Spain); Ing Puigardeu Sergi (HP, Spain); Ing Sole Macia (HP, Spain); Mr Sala Casanovas Marti (HP, Spain)

Title : 3D Metal Binder Jetting Powder Consumption Reduction

Keyword(s) :
Additive Manufacturing Sinter Based Technologies, Metal Binder Jetting , Powder Consumption Reduction , Closed-loopPrintmodes, Computer Vision System

Abstract :
3D Metal Jet is currently disrupting manufacturing and accelerating mass production of 3D-printed parts. Metal Jet excellent balance between part quality and productivity rates are also complemented with sustainable efforts of minimizing the used resources. In this case, powder consumption reduction has been confirmed by the development of a novel functionality that enables the minimum powder use for certain job heights. Utilizing a cutting-edge closed-loop algorithm in conjunction with a computer vision system within the printer chamber not only significantly reduces the amount of powder required for constructing base layers in a job but also facilitates the extraction of essential powder metrics. This print mode that minimizes powder loading is of great value when powder production constraints, powder elevated costs and, overall, it is highlighted thanks to the ensurance of efficient sustainable processes.

Innovative Aspect(s) :
New printing functionalities enabling minimum powder consumption and metrics identification, Efficient and sustainable closed-loop printmodes supported by computer vision system, Optimal printing resources use for quality, robustnes and throughput purposes

Reviewer's name : .....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : .....

Notes to author : .....

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EURO PM2024
CONGRESS & EXHIBITION
Malmö, Sweden
29 September - 02 October 2024

Paper Number : C39
ID : 6281550

Requested presentation type : Oral Presentation

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

Author : Dr Fregeac Arnaud (NORIMAT, France)

Co-author(s) : Dr Epherre Romain (NORIMAT, France); Dr Ing Larignon Céline (NORIMAT, France); Dr Mackie Jennifer (NORIMAT, France); Ing Beynet Yannick (NORIMAT, France)

Title : FAST|SPS: New Industrial Post-process For Full Densification Of 3D Complex Shape From AM Sinter Based Technologies

Keyword(s) :
Sinter Based Additive Manufacturing, Binder Jet, FAST|SPS

Abstract :
The FAST|SPS process is recognized as an R&D method capable of producing high-performance parts from a wide range of materials. In recent years, significant progress has been made in overcoming the two main constraints of the technology: production capacity and geometric limitations, thanks to important advances in research and technology.This conference will focus on the progress made in the production of dense 3D complex shapes using FAST|SPS. An innovative and versatile approach, combining additive manufacturing (SBAM mostly binder jetting) and FAST|SPS, will be presented, along with original use cases involving various ceramic and metallic materials designed for applications in the aerospace, space, or defense sectors. Numerical tools to define the green part, chemical analisys and mechanical properties of the 3D parts will also be presented.

Innovative Aspect(s) :
Norimat has made an important industrial breakthrough by developing a unique and easy process which enables the consolidation of 3D green parts frome SBAM processes by FAST|SPS. It allows to fully densify (porosity <1%) green parts made from SBAM just after printing in only one step and less than 1h of thermal treatment. The debinding of the green parts made of AM has been optimized and is in situ realize in the FAST|SPS process. That's allowed to limit the thermal treatment time and to enhance the quality of the part in terms of chemistry and deformation. Moreover, the first FAST|SPS software suite dedicated to the FAST|SPS process has been developed to help the users with all aspects of SPS, from R&D (Digital Twin) to production monitoring (Statistical Process Control). Numerical simulation has ensured that thermal gradients during sintering of 3D parts are kept to a minimum.

Reviewer's name : .....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : .....

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EURO PM2024
CONGRESS & EXHIBITION
Malmö, Sweden
29 September - 02 October 2024

Paper Number : C41
ID : 6281562

Requested presentation type : Oral Presentation

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

Author : Prof Biasetto Lisa (University of Padova, Italy)

Co-author(s) : Ing Gastaldi Vanessa (University of Padova, Italy); Prof Bolzon Gabriella (Politecnico di Milano, Italy); Prof Bellucci Devis (University of Modena and Reggio Emilia, Italy); Prof Cannillo Valeria (University of Modena and Reggio Emilia, Italy)

Title : Material Extrusion Of Multi-material Components: Comparison Between Direct Ink Writing And Fused Deposition Modelling Technologies

Keyword(s) :
Direct Ink Writing, Fused Deposition Modelling, Core-shell Structures

Abstract :
The use of 3D printing for fabricating multi-material structures presents a formidable task laden with multifaceted prospects. The challenge lies in the combination of materials (metallic alloys and ceramics) which engenders intricacies in managing processing parameters, spanning the gamut from the initial printing phase to subsequent post-processing stages. Conversely, this challenge is concomitant with a profusion of opportunities, as the coupling of distinct metallics and ceramics offers the potential to conjoin both structural and functional attributes within a singular component.The present study will focus on the production of metal-ceramic (316L-Al2O3 and 316L-CaTiSiO5) components by mean of two different technologies: direct ink writing of core-shell structures and extrusion of pellets by fused deposition modelling. Microstructural characteristics and mechanical properties of the two different technologies will be analyzed and compared.

Innovative Aspect(s) :
Multi-materials 3D printing represents the next step toward the production of components capable of showing multi-functional properties. Co-extrusion of metallic and ceramic inks by DIW so as FDM of modified pellets by multi-extrusion systems are two innovative technologies that are here analyzed showing the potentials for scalability of the process.Inks and pellet engineering for 3D printing intricated shapes so as their consolidation by de-binding and sintering step without cracks is the most significant result of the proposed work. Practical examples will be presented, underscoring the tangible real-world implications and innovative potential of this technology within the field of advanced manufacturing.

Reviewer's name : .....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : .....

Notes to author : .....

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EURO PM2024
CONGRESS & EXHIBITION
Malmö, Sweden
29 September - 02 October 2024

Paper Number : C42
ID : 6281677

Requested presentation type : Oral Presentation

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

Author : Mr Cogotti Andrea (Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM, Germany)

Co-author(s) : Dr Hein Sebastian Boris (Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM, Germany); Ms Reineke Lea (1Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM, Germany)

Title : Monitoring Of Powder Bed Temperature And Its Influence On Properties In Metal Binder Jetting

Keyword(s) :
Metal Binder Jetting, Temperature Measurement, In-Situ Measurement, Powder Bed Temperature

Abstract :
The focus on Metal Binder Jetting is increasing due to its potential for serial production. To control the printing process, in situ measurements are becoming essential. These measurements are commonly used in laser-based additive manufacturing processes. The objective of this study is to utilise a thermal camera during a Metal Binder Jetting process to determine the temperature distribution of the powder bed and its correlation with the properties of green parts. The temperature development was determined for each printed part, and a correlation with the final properties was established. To ensure homogeneity of properties and to achieve repeatable improvements in process control, it was suggested to standardize this measurement process.

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 PM2024
CONGRESS & EXHIBITION
Malmö, Sweden
29 September - 02 October 2024

Paper Number : C43
ID : 6281810

Requested presentation type : Oral Presentation

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

Author : Dipl-Ing Abel Johannes (Fraunhofer IKTS Winterbergstraße 28, 01277 Dresden, Germany)

Co-author(s) : Dr Ing Scheithauer Uwe (Fraunhofer IKTS Winterbergstraße 28, 1277 Dresden, Germany); Dr Matthey Björn (Fraunhofer IKTS Winterbergstraße 28, 1277 Dresden, Germany); Dipl-Ing Kunze Steffen (Fraunhofer IKTS Winterbergstraße 28, 1277 Dresden, Germany); Dipl-Ing Müller-Köhn Axel (Fraunhofer IKTS Winterbergstraße 28, 1277 Dresden, Germany); Dipl-Ing Pötschke Johannes (Fraunhofer IKTS Winterbergstraße 28, 1277 Dresden, Germany); Dr Moritz Tassilo (Fraunhofer IKTS Winterbergstraße 28, 1277 Dresden, Germany)

Title : Thermoplastic Additive Manufacturing Of Very And Super Hard Ceramics By Means Of Fused Filament Fabrication

Keyword(s) :
Additive Manufacturing, Ceramics, Diamond, Fused Filament Fabrication, AM, FFF, Boron Carbide

Abstract :
The near net shaping of super hard ceramic materials such as WC-Co, RBB4C or diamond|SiC becomes particular interest when it comes to high performance applications. Additive Manufacturing (AM) plays a special role when complex shapes which can be manufactured with a low loss of material in low or medium quantities are needed. A very promising AM method to utilize a very broad material variety and particle size is CerAM FFF, which uses cost-effective equipment. On the other hand, machining and structuring of very hard materials is often costly which justifies AM additionally. For the precision machining of diamond composites for example water guided laser cutting can be applied which reduces the processing time and costs dramatically. The presentation gives an overview about current works and results in terms filament and component manufacturing as well as first results of water guided laser cutting of very and super hard ceramic materials.

Innovative Aspect(s) :
AM of complex super hard ceramic materials using cost effective FFF; Precision machining of super hard ceramic materials by water guided laser cutting

Reviewer's name : .....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : .....

Notes to author : .....

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EURO PM2024
CONGRESS & EXHIBITION
Malmö, Sweden
29 September - 02 October 2024

Paper Number : C44
ID : 6281341

Requested presentation type : Oral Presentation

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

Author : Dr Etiemble Aurélien (ECAM Lasalle, France)

Co-author(s) : Dr Simon Sandra (ECAM Lasalle, France); Dr Rigollet Claire (ECAM Lasalle, France)

Title : Influence Of Feedstock Formulation On Steel Processability By Extrusion Based Additive Manufacturing

Keyword(s) :
Formulation, Steel, Extrusion-based AM, Printing, Debinding, Sintering

Abstract :
Material extrusion additive manufacturing (EAM) offers a versatile range of applications for various metallic materials. In indirect processes, a mixture of metal powder and a polymer binder is extruded and deposited to shape the layers of the part, analogous to traditional polymer 3D printing. Subsequently, debinding and sintering steps are indispensable to achieve the final metallic component. Each of these stages may induce impurities and defects, significantly impacting geometric tolerances and mechanical properties. These defects such as warpage, shrinkage, porosity, residual carbon, and undesired phases result from complex mechanisms, due to insufficient or heterogeneous loading of feedstock, thermomechanical distortion during printing, partial debinding and inefficient sintering. This presentation will delve into these challenges, mechanisms, and EAM optimization strategies in the case of stainless and tool steels. The influence of feedstock formulation and associated process parameters on defects, microstructure, and resulting mechanical properties will be discussed.

Innovative Aspect(s) :

Reviewer's name : .....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : .....

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EURO PM2024
CONGRESS & EXHIBITION
Malmö, Sweden
29 September - 02 October 2024

Paper Number : C45
ID : 6281354

Requested presentation type : Oral Presentation

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

Author : Dr Etiemble Aurélien (ECAM Lasalle, France)

Co-author(s) : Dr Simon Sandra (ECAM Lasalle, France); Dr Faye Romain (Nanoe, France); Dr Boulnat Xavier (MATEIS, INSA-Lyon, France); Dr Maire Eric (MATEIS, INSA-Lyon, France); Ing Lacorne Jordan (Nanoe, France)

Title : Insight Into Sintering Mechanism And Optimization Of Fused Filament Fabrication Of H13 Tool Steel

Keyword(s) :
Extrusion-based AM, Debinding, Sintering, H13 Work Tool Steel, Mechanical Characterization

Abstract :
In sinter-based additive manufacturing, such as metallic fused filament fabrication (mFFF), the sintering mechanism must be carefully understood and controlled to end up with the expected density, microstructure and mechanical behaviour. In the case of mFFF H13 tool steel, the considerations especially include carbon content, due to binder residue, porosity and pore size, associated with the densification step, as well as martensitic and carbide formations. This work will discuss the influence of sintering parameters (temperature, ramp rate and atmosphere) on its mechanism, based on in situ shrinkage measurements and the characterization of green, brown and sinter parts. The outcome on the final composition, microstructure and hardness will be highlighted.

Innovative Aspect(s) :

Reviewer's name : .....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : .....

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EURO PM2024
CONGRESS & EXHIBITION
Malmö, Sweden
29 September - 02 October 2024

Paper Number : C46
ID : 6281371

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 (Incus GmbH, Austria); Dipl-Ing Bosters Johannes (Incus GmbH, Austria); Dipl-Ing Sperling Clemens (Incus GmbH, Austria); Ms Mödder Denise (Incus GmbH, Austria); Dr Stögerer Johannes (Incus GmbH, Austria)

Title : Effect Of The Powder Size Distribution On The Lithography-based Metal Manufacturing Process

Keyword(s) :
Lithography, Powder Selection, Additive Manufacturing, Stainless Steel, Surface Analysis

Abstract :
Lithography-based Metal Manufacturing (LMM) is an additive manufacturing (AM) technology that delivers components with high feature resolution and surface quality. By utilizing common Metal Injection Molding grade powders (d90 <25 µm) in the process, a surface roughness of Ra < 2 µm can be achieved, with stable geometric features down to 100 µm. Although these as-printed component parameters surpass those of other metal AM technologies, some applications demand lower surface roughness.To enhance part quality, one approach is the introduction metal powders with smaller size distribution. This not only improves the surface roughness, but also augment the sintering process by facilitating better powder packing. In pursuit of this objective, steel alloys of 316L and 17-4PH with varying size distribution have been analysed, with a specific focus on their processability in the LMM technology and their effectiveness in raising the quality of the components.

Innovative Aspect(s) :
LMM has the potential to produce currently unattainable designs for various applications. This work explores the opportunities to further improve the quality of the produced part. This opens the possibilities to design higher performance components for various applications, especially geometries difficult to polish efficiently.More specifically, this study explores the powder – resin interactions, from the standpoint of the physical characteristic of the metal powder, which is not a deeply explored field. By exhibiting this initial work, we show the powder metallurgy community a starting point for future work in sinter-based AM about powder selection, physical interaction of chemicals and powders and the effects of the physical form of the powder on sintered parts.

Reviewer's name : ……..

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : ……

Notes to author : ……

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EURO PM2024
CONGRESS & EXHIBITION
Malmö, Sweden
29 September - 02 October 2024

Paper Number : C47
ID : 6281459

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) : 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 Materials IFAM; TUD Dresden University of Technology, Germany); Dr Ing Dollmeier Klaus (Georgsmarienhütte Holding GmbH, Germany)

Title : Additive Manufacturing Of Components From Pressure-embroidered Stainless Steel Using The MoldJet Process

Keyword(s) :
Additive Manufacturing, Moldjet, Sinter-Based, Nitrogen Alloyed Steel

Abstract :
This study deals with the processing of a developed nitrogen alloyed steel, containing additionally chromium, manganese and molybdenum (X13CrMnMoN18-14-3), using additive manufacturing. Applying the MoldJet process, the powder is first processed into a metal powder paste used for the printing of components. The MoldJet process is a novel, sinter-based additive manufacturing process, which enables the production of a wide range of geometries without the need of support structures. The high productivity of up to 1600 $cm^3|h$ also enables series production of components. The material can be used for components submitted to elevated stress levels, exhibiting at the same time a high degree of biocompatibility and enhanced corrosion resistance. The study will examine the powder itself, the processing into a paste and the mechanical properties after additive manufacturing. The aim is to show how an increase in performance can be achieved in combination with the use of the MoldJet process.

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 PM2024
CONGRESS & EXHIBITION
Malmö, Sweden
29 September - 02 October 2024

Paper Number : C48
ID : 6283049

Requested presentation type : Oral Presentation

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

Author : Dr Ing Friso Andrea (Legor Group S.p.A., Italy)

Co-author(s) : Dr Ing Lago Mattia (Legor Group S.p.A., Italy); Dr Ing Friso Andrea (Legor Group S.p.A., Italy)

Title : Binder Jetting Additive Manufacturing For Fashion And Jewellery Items Production

Keyword(s) :
Binder Jetting Technology, Additive Manufacturing, Sintering, MIM, Investment Casting, PANACEA, AISI 316L, 17-4PH, Steel, Silver 925, Platinum 950, Fashion Production, Decorative, Surface Quality

Abstract :
The presentation is focused on introducing Binder Jet technology in its applications for jewellery and fashion items making, showing results from two years of use of 3D binder jet printers at our laboratories in Bressanvido, Italy. Despite being well known in other industries, binder jetting additive manufacturing is still not used in the jewellery sector; after a presentation of the technique and its possibilities, our practical experiences over two years of testing and production will be shared. Materials worked in our project span from steels suitable for fashion and watchmaking industry, to precious metals alloys (Silver 925 and Platinum 950). The experience so far proves Binder Jetting to be a realistic player in the world of jewelry production by additive manufacturing, although still undergoing a learning curve.

Innovative Aspect(s) :
Discussion of a new technology, Binder Jetting, that is still not well known in different manufacturing sectors; Offers the results in terms of quality and feasibility of alloys that have never printed with Binder Jetting, such as Silver 925, Platinum 950 and PANACEA steel, and on which there is little or no literature available.

Reviewer's name : .....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : .....

Notes to author : .....

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EURO PM2024
CONGRESS & EXHIBITION
Malmö, Sweden
29 September - 02 October 2024

Paper Number : C49
ID : 6283017

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, Germany); Dr Ing Reuter Kay (Fraunhofer IFAM, Germany); Dr Zhong Chongliang (Fraunhofer IFAM, Germany); Prof Dr Höft Michael (Kiel University, Germany); Dipl-Ing Boe Patrick (Kiel University, Germany)

Title : Multi-material Printing Tungsten-copper For Future 5G And 6G High-frequency Applications

Keyword(s) :
High Requency Application, Sinter-Based Addtive Manufacturing, Screen Printing, Tungsten, Copper

Abstract :
Rectangular waveguides are widely used in communications satellites due to its low insertion loss and high power-handling. Additionally, near field communication in the upcoming 5G and 6G mobile communication standards are in this frequency range. As high quantities and tight tolerances are required for future applications, only a few manufacturing technologies come into consideration. In this work, the mass productive and cost-effective 3D screen printing was successfully used for this pupose. To achieve the goals, both a master alloy route tungsten-copper and a printing of tungsten with subsequent copper infiltration were investigated. Structures sizes of 300 µm with deviation of less than 10 µm with a surface roughness von 2 µm were successfully printed and sintered. The manufactured waveguides were characterised metallographically, tested for their function and compared with the design simulation. The specifications were well achieved, proving that 3D screen printing is an important candidate for digital communication technology.

Innovative Aspect(s) :
Conventionally manufactured (i.e. milled) components are manufactured successively one after the other. Additionally, depending on the center frequency, the milling machine is required to have very small tolerances for the realization of low-loss and well-matched filter responses. Mass-production of these components is therefore cost- and time-intensive. Furthermore, a lot of material is removed during milling, which is critical from an environmental point of view. The number of possible other both cheap and productive technologies is also limited. Screen-printed waveguide devices reveal the advantage to be suitable for mass-production, which also offers the possibility of cost-reduction. The tight tolerances of just a few µm pose a particular challenge for sinter-based additive processes, which could be successfully met here with a multi-material tungsten-copper approach. This approach is therefore a door opener for corresponding high-frequency applications that were previously closed to additive manufacturing.

Reviewer's name : .....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : .....

Notes to author : .....

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EURO PM2024
CONGRESS & EXHIBITION
Malmö, Sweden
29 September - 02 October 2024

Paper Number : C51
ID : 6283231

Requested presentation type : Oral Presentation

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

Author : Dr Lores Asier (Tecnalia, Spain)

Co-author(s) : Ing Agote Iñigo (Tecnalia, Spain); Ing Gómez Xabier (Tecnalia, Spain); Ing Andrés Unai (MIM-Tech Alfa S.L., Spain)

Title : Exploring The Impact Of Cost-Effective Surface Treatments On The Roughness, Geometry, And Dimensional Stability Of FFF Sintered Parts

Keyword(s) :
FFF, 17-4PH, Surface Rougness, Post-processing, SBAM

Abstract :
Many requirements and applications in various industrial sectors demand high-quality finishes on parts. These finishes, whether due to tolerances or surface quality, are often challenging to achieve through additive manufacturing technologies, necessitating additional post-processing. This study aims to investigate the effect of specific surface treatments on parts produced through Sintering Based Additive Manufacturing (SBAM), such as Fused Filament Fabrication (FFF). With the premise of employing affordable post-processing methods that can potentially maintain competitive prices for the parts, the study analyzes the post-processing techniques of shot blasting and vibratory polishing on parts with different geometries. Additionally, the study examines the effect of surface treatments on part walls manufactured at various angles. The results obtained demonstrate significant improvements in surface roughness, although there is potential for them to modify the geometry and round the edges of the parts.

Innovative Aspect(s) :
The innovative aspect of this study focuses on correlating the effect of different surface post-processing techniques with both the achieved surface improvement and the adverse effects such as rounding of edges or geometric and dimensional modifications experienced by the parts. By varying processing parameters or the type of shot material, for example, we can observe and quantify the dimensional, roghnes and geometrical effects on the parts. The main goal, with all this, is twofold: on one hand, to select optimal conditions|processes for specific application requirements, and on the other hand, to be able to adapt or redesign the parts to compensate for the adverse effects of the treatment. In conclusion, this work aims to shed some light on the effect of post-processing on parts produced through SBAM.

Reviewer's name : ……..

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : ……

Notes to author : ……

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EURO PM2024
CONGRESS & EXHIBITION
Malmö, Sweden
29 September - 02 October 2024

Paper Number : C52
ID : 6283366

Requested presentation type : Oral Presentation

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

Author : Mr Aguilar-García José Luis (Carlos III University, Spain)

Co-author(s) : Mr Martínez Rodríguez Dayron (Carlos III University, Spain); Prof Dr Jimenez-Morales Antonia (Carlos III University, Spain); Prof Dr Ruiz-Navas Elisa M. (Carlos III University, Spain)

Title : Comparing Of Metal Injection Moulding And Composite Extrusion Modelling For Two Aluminium Alloys

Keyword(s) :
Aluminium Alloy, Metal Injection Moulding (MIM), Composite Extrusion Modeling (CEM), Sustainable Feedstock, Pellet

Abstract :
This work studies the processing of two industrial aluminium alloys, Al2024 and Scalmalloy, obtained by Metal Injection Moulding (MIM) and a novel additive manufacturing technology, Composite Extrusion Modelling (CEM), from sustainable feedstocks in pellets shape. For this purpose, both aluminium alloy powders were combined with water-soluble polymer, polyethylene-glycol (PEG), and low-CO2 emitting polymer, cellulose acetate butyrate (CAB). By means of the rheological characterisation of the feedstock and the subsequent microstructural characterisation and evaluation of the mechanical properties of the parts obtained, a comparison has been made between two different aluminium alloy powders consolidated by MIM and CEM, validating the processability of parts of these alloys using an innovative 3D printing technology. Compared to the injection moulding process, this technology offers advantages such as freedom in the shape of the parts obtained, and it also offers cost savings as it is a cost-effective process without the need for mass production.

Innovative Aspect(s) :
The processability of parts of two aluminium alloys using an innovative 3D printing technology by extrusion with feedstock in pellet form.

Reviewer's name : .....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : .....

Notes to author : .....

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EURO PM2024
CONGRESS & EXHIBITION
Malmö, Sweden
29 September - 02 October 2024

Paper Number : C54
ID : 6282804

Requested presentation type : Oral Presentation

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

Author : Ing Sandoval Neyder A. (Universidad Carlos III de Madrid, Spain)

Co-author(s) : Dr Murillo Edwin A. (Universidad Francisco de Paula Santander, Colombia); Dr Tsipas Sophia A. (Universidad Carlos III de Madrid, Spain)

Title : Evaluation Of Biopolymers To Produce Metal Or Metal-ceramic Feedstocks For Eco-sustainable Composite Extrusion Modelling

Keyword(s) :
Composite Extrusion Modelling, Biopolymer, Feedstocks, Environmental

Abstract :
Sinter-based additive manufacturing of metallic materials offers advantages in terms of design and efficiency but poses environmental concerns due to the use of chemicals and the generation of pollutant gases during the elimination of binders which are harmful to the environment. To improve this problem, the study of biopolymeric binders derived from renewable sources is proposed. This work explores composite extrusion modelling of metallic or metal-ceramic alloys. using biopolymers to produce environmentally friendly feedstocks. Comprehensive evaluation of biopolymer blends based on poly lactic acid and polyvinyl alcohol were carried out for their use as binders. A study of critical solidity loads, microstructural and rheological characterisation, densification, homogenisation, and thermogravimetric studies was performed. The deposition parameters of the material to produce parts were also optimised.

Innovative Aspect(s) :
Innovates by addressing environmental issues inherent in current AM sinter- based methods, proposing the use of biopolymer binders to mitigate chemical use and pollutant gas generation; Conducts thorough characterization of biopolymer blends for their use a binder in composite extrusion modelling.

Reviewer's name : .....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : .....

Notes to author : .....

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EURO PM2024
CONGRESS & EXHIBITION
Malmö, Sweden
29 September - 02 October 2024

Paper Number : C123
ID : 6283117

Requested presentation type : Oral Presentation

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

Author : Mr Zissel Kai (Linde GmbH, Germany)

Co-author(s) : Mr Forêt Pierre (Linde GmbH, Germany); Prof Dr Hryha Eduard (Chalmers University of Technology, Sweden)

Title : Study On Deoxidation Of Binder Jetted 17-4 PH Stainless Steel In Hydrogen Atmosphere

Keyword(s) :
Binder Jetting, Debinding, Deoxidation, Residual Carbon, 17-4 PH, Sintering, Hydrogen, Dilatometry

Abstract :
The final dimensions and material properties of metal components manufactured via Binder Jetting (BJT) depend on sintering densification, which requires precise control of the shrinkage to reach required tolerances. Sintering studies are typically limited to parameters such as heating rate, sintering temperature and dwell time. Processing atmospheres, especially during the debinding stage are, however, often not considered despite their significant impact on binder decomposition and powder oxidation. Maximizing binder removal and lowering powder oxidation at the same time by lowering the oxygen content during debinding is crucial to enhance sintering densification and material properties of stainless steels. The impact of processing atmosphere during debinding of 17-4 PH stainless steel green parts was studied in Ar, Ar + 1 vol.% O2 and N2 + 20 vol.% O2 through sintering in a dilatometer under pure hydrogen atmosphere. The results were correlated with the resulting microstructure and material properties.

Innovative Aspect(s) :
Decreasing oxygen content during debinding to improve sintering densificationDeoxidation during debinding and sinteringStudy on densification behavior via dilatometry in pure hydrogenCorrelation between debinding atmosphere, binder residuals and material propertiesFocus on underexplored aspect of debinding atmospheres 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 PM2024
CONGRESS & EXHIBITION
Malmö, Sweden
29 September - 02 October 2024

Paper Number : P-C55
ID : 6281742

Requested presentation type : Poster Presentation

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

Author : Mr Wu Jianzhang (Delft University of Technology, Netherlands)

Co-author(s) : Mr Wu Jianzhang (Delft University of Technology, Netherlands)

Title : The Study Of Sintering Of Binder Jet 316L Stainless Steel

Keyword(s) :
Binder Jetting, 316L Stainless Steel, Sintering Process, Mechanical Properties, Microstructure

Abstract :
Notably, bidner jet technology enables swift prototyping of materials, attracting considerable interest in industrial applications. While 316L stainless steel is extensively utilized for its superior processability and mechanical attributes, its conventional production processes are typically intricate and exhibit low material efficiency. BJ thus emerges as a viable method for the expedited fabrication of 316L stainless steel parts. However, challenges persist with BJ-produced 316L components, particularly concerning porosity and mechanical performance, which often necessitate further post-processing treatments like sintering to improve the quality of the final product.This study seeks to enhance the density and mechanical characteristics of 316L stainless steel components fabricated using BJ technology by investigating the microstructure and mechanical performance of BJ 316L stainless steel components.

Innovative Aspect(s) :
This project primarily focuses on enhancing the density and mechanical properties of 316L stainless steel components through Binder Jetting (BJ) technology. A comprehensive study of the entire BJ process applied to 316L stainless steel materials is conducted, with particular attention to optimizing the sintering parameters for 316L stainless steel.

Reviewer's name : .....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : .....

Notes to author : .....

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EURO PM2024
CONGRESS & EXHIBITION
Malmö, Sweden
29 September - 02 October 2024

Paper Number : P-C56
ID : 6283238

Requested presentation type : Poster Presentation

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

Author : Ms Gastaldi Vanessa (University of Padova, Italy)

Co-author(s) : Prof Biasetto Lisa (University of Padova, Italy); Prof Dr Bolzon Gabriella (Politecnico di Milano, Italy); Prof Bellucci Devis (University of Modena and Reggio Emilia, Italy); Prof Cannillo Valeria (University of Modena and Reggio Emilia, Italy)

Title : Direct Ink Writing Of 316L-sphene Core-shell Structures

Keyword(s) :
Direct Ink Writing, Core-shell Structures, 316L, Sphene

Abstract :
Direct Ink Writing allows to produce structures characterized by a personalized geometry, using different types of materials and keeping the costs low. Thanks to the versatility of this technology, it's also possible to increase the complexity of the obtainable structures by combining different materials, using multi-extruder printers or coaxial nozzles. One of the main advantages is to give the components hybrid and unique properties, tunable in accordance to the specific application.In this study the main focus is the production of core-shell metal-ceramic structures (316L-CaTiSiO5) with suitable mechanical, microstructural and functional properties for bone tissue regeneration. The effect of the sintering process on materials shrinkage, metal-ceramic interface and in particular on mechanical properties of the final components will be discussed.

Innovative Aspect(s) :
The production of multi-material components allows a flexible control over the final construct's properties: metal-ceramic match could lead to components with improved mechanical characteristics, compared with total ceramic objects, and keeping also functional properties related to the bio-ceramic contribution.The production of structures for bone tissue regeneration requires suitable properties for the interaction with the human body, such as bioactivity and biocompatibility, but the intrinsic fragility of ceramic materials could be limiting because of the mechanical stresses related to the type of application. The use of a coaxial printing nozzle enables to increase the performance of the components thanks to the presence of a metallic core, keeping the functional bio-ceramic properties required for a successful permanence inside a biological environment.

Reviewer's name : .....

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : .....

Notes to author : .....

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EURO PM2024
CONGRESS & EXHIBITION
Malmö, Sweden
29 September - 02 October 2024

Paper Number : C355
ID : 6301454

Requested presentation type : Oral Presentation

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

Author : Dr Sainz Shandra (CEIT, Spain)

Co-author(s) : Dipl-Ing Perez de Arriluzea Julia (CEIT, Spain); Dipl-Ing Iglesias Iñigo (CEIT, Spain); Dipl-Ing Cardozo Evelin (CEIT, Spain); Mr Ruiz Odei (CEIT, Spain); Dr Ordás Nerea (CEIT, Spain); Dr Iturriza Iñigo (CEIT, Spain)

Title : Sinterability Assessment And Microstructural Development In Metal Binder Jetting

Keyword(s) :
Binder Jetting, Solid State Sintering, Liquid Phase Sintering, Microstructure Evolution, Density, Materials Development

Abstract :
In Sinter based AM the printing is just a shaping process for the powder, separated from the high temperature densification step. After printing, the density of a part will be around 55-60 % TD. In addition, most of the applications need final densities higher than 95 %TD. Consequently, the sinterability of the powder is a key factor that has to be carefully studied. Solid state or liquid phase sintering, thermal profile, interaction with the sintering atmosphere, reduction of superficial oxides, compositional homogeneity, shrinkage … need to be studied for each powder grade. Solid State Sintering is effective at relatively high temperatures for materials like Cu and its alloys whereas Liquid Phase Sintering allows reducing sintering temperature and opens different scenarios for the AM BJ massive production of metal parts. These alternatives are discussed in the present paper together with an in-depth microstructural characterization.

Innovative Aspect(s) :
Binder Jetting is a rather innovative AM technology for producing components as an alternative route that offers certain advantages over traditional ones (complex shapes, near net shape, material saving, etc). The comprehension of sintering mechanisms can be used as a tool for materials development by Binder Jetting; improving densification level, obtaining appropriate microstructures, control of distortions, etc.

Reviewer's name : ……..

Keynote ☐ Oral ☐ 1☐ 2☐ 3☐ 4☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason : ……

Notes to author : ……

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