WORLD PM2022 CONGRESS & EXHIBITION

ABSTRACTS – GROUP 5

AM BEAM BASED TECHNOLOGIES

WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225352603

Requested paper type: Oral Presentation

Topic: Consolidation technologies / **Subtopic:** AM beam based technologies

Author: Dr Ing Hartmann Goetz (MAGMA GmbH, Germany)

Co-author(s):

Title: Virtual Assessment And Optimization Of LAM Processes For Automotive Structural Components - Tackling Of Multiscale Physics By Multiscale Virtual Process Assessments In The CUSTOMAT3D Research Project

Keyword(s):
Laser Additive Manufacturing, Virtual Process Chain, Multi-scale Physics, Multi-scale Modeling, Coupled Thermo-mechanical Model

Abstract:
AM processes provide a freedom of design being a key to highly function-integrated components optimized for minimum weight with maximum rigidity. In comparison to metal casting's lead for light structural component production, AM processes are not yet established. For the industrial introduction of innovative AM components and manufacturing processes, the virtual proof of feasibility is strictly required. It is today the only way to check and compare countless designs and variants of manufacturing processes in the shortest possible time. But computational simulation of LAM is still in its infancy. In the research project Customat3D, developers and automotive users of structural components, material developers, LAM producers and simulation technologists have come together for a joint approach to innovative LAM automotive structural components. In the proposed article, computational multi-scale modelling of LAM with its thermomechanical phenomena is discussed. The relevant results of the funded Customat3D R&D project are summarized.

Innovative Aspect(s):
The following, currently highly regarded, innovative topics are touched upon: Laser Additive Manufacturing of automotive structural components. Topology optimized lightweight components. Digital Twin for Laser Additive Manufacturing. Multiscale modeling approach from powder scale to component scale. Virtual regression method for synthetic thermal conductivity of powders. Meso-scale model for laser melt pool and patch movement. Scale coupling methodologies. Coupled thermomechanical model for warpage and residual stress of LAM components.

TPC Reviewer name: .....

Keynote ☐ Oral ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐

Poster ☐ Poster & Reserve Oral ☐

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WORLD PM2022
CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225363936

Requested paper type: Oral Presentation

Topic: Consolidation technologies / **Subtopic:** AM beam based technologies

Author: Dipl-Ing Dubiez-Le Goff Sophie (Linde GmbH, Germany)

Co-author(s): Dipl-Ing Fischer Marie ; Mr Volpi Gaël (Marle | 3D Medlab, France) ; Dipl-Ing Forêt Pierre (Linde GmbH, Germany)

Title: Processing Of Nitinol For Medical And Aerospace Applications: Material, Process Gas And Laser Parameters

Keyword(s):
Nitinol, LPBF, Shape memory alloy, Process gas

Abstract:
Nitinol, a metal alloy of nickel and titanium, is an excellent candidate for many functional designs due to its particular shape memory and superelastic properties. Difficulties are encountered with Nitinol for conventional manufacturing and pose impediments to its widespread application. Hence, processing Nitinol through additive manufacturing could solve those challenges and lead to the development of functional medical devices or aerospace components. The aim of this study is to develop an optimized laser powder bed fusion process for high quality Ni-Ti parts combining tight composition requirement, ultra-low O2 process and adapted exposure parameters. Resulting parts are thus evaluated regarding their transformation temperature and shape memory or superelastic capacity as well as their mechanical properties with a specific focus on their ductility.

Innovative Aspect(s):
Printing with different process gas mixtures

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Keynote ☐ Oral ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐

Poster ☐ Poster & Reserve Oral ☐

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225365123

Requested paper type: Oral Presentation

Topic: Consolidation technologies / **Subtopic:** AM beam based technologies

Author: Dipl-Ing Bergmüller Simon (University of Innsbruck, Austria)

Co-author(s): Prof Dr Leichfried Gerhard (University of Innsbruck, Austria)

Title: In-situ and ex-situ heat treatment of LPBF PM HSS : Solid Phase Transformation And Carbide Precipitation Behavior During Laser Powder Bed Fusion And Tempering Of High Speed Steel Parts

Keyword(s):
LPBF, High Carbon Steel, Laser, HSS, Additive Manufacturing, AM, Heat treatment, In-Situ Heat Treatment

Abstract:
In this work, Boehler's powder metallurgical high speed steel (PM HSS) S390 was processed crack-free and dense via Laser Powder Bed Fusion (LPBF) for the first time, and the resulting mechanical properties and microstructure were investigated. High-alloy tool steels, such as the high-performance PM HSS S390 of Boehler with 1.64 wt% C and W-Mo-V-Co-Cr (10-2-5-8-5 wt%.), processed using LPBF are prone to cracking due to high contents of carbon and carbide-forming alloying elements. Cracks may be induced by thermal stresses and solid phase transformation combined with weak grain boundaries due to segregated primary carbides. Heating the substrate plate reduces thermal stresses and allows in-situ heat treatment, thus controlling solid phase transformation and carbide precipitation, preventing cracking during cooling. The resulting microstructure, precipitations, and mechanical properties of the in-situ at 600 °C and 800 °C heat-treated and conventionally post heat-treated specimens are presented.

Innovative Aspect(s):
The LPBF processing of tool steels allows the implementation of new functions and complex geometries such as internal cooling channels and aims to extend the lifetime of tools or components. The application of high temperatures during the process allows for the first time the processing of high-alloy tool steels that are susceptible to cracking and thus represents an extension of the LPBF process. In addition, the exceptionally high cooling rates and small dimensions of LBPF allow small grains and fine distribution of primary carbides compared to conventionally produced PM or HIP (hot isostatic pressing) HSS.

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Keynote ☐ Oral ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225366523

Requested paper type: Oral Presentation

Topic: Consolidation technologies / **Subtopic:** AM beam based technologies

Author: Dr Diaz Agustin (REM Surface Engineering, USA)

Co-author(s):

Title: Surface Texture Optimization Of Metal Additive Manufactured Components Through Chemical-Mechanical Polishing To Improve Mechanical And Corrosion Resistance Performance

Keyword(s):
Surface finishing, Surface-related defects, Porosity, Lack of fusion, Corrosion-resistance, Fatigue, Self-limiting reactions, Powder quality, Post-processing

Abstract:
Metal additive manufacturing (AM) has revolutionized the manufacturing industry by increasing the complexity of the components while reducing operation steps, component lead-time, and costs. However, these components must comply with strict requirements and standards, especially for safety-critical applications. Requirements such as fatigue performance and corrosion resistance are a couple of the most problematic in the field, mainly due to their close relationship with surface texture and the usual surface-related defects (partially melted|sintered powder, v-notches, and near-surface porosity) associated with AM builds. For most aerospace and space exploration applications, these defects limit their applicability, hindering a broad-scale adoption of AM in these fields. This presentation will present a newly developed surface finishing process capable of removing surface-related defects on external and internal surfaces of metal AM components. Furthermore, the developed method can achieve a defect-free consistency with roughness lower than 0.8 µm. Part of this work was funded by NASA (SBIR-18-P2-Z3.01-5453) and USAF (SBIR-FA864921P0854 and SBIR-FA864921P0815).

Innovative Aspect(s):
The innovation of the technology resides in the use of a self-limiting chemical reaction at the surface of metal-additive manufactured components to eliminate surface and near-surface defects (surface-related defects = SRD) intrinsic to the technology. SRD such as partially melted|sintered powder, v-notches, and near-surface porosity can be eliminated by removing enough surface material during a post-processing operation. The developed process can uniformly remove 500 µm of surface material, achieving a defect-free surface with roughness lower than 0.8 µm in less than 24 hours. In addition, powder-associated problems, such as lack of fusion or powder impurities, can be identified during the chemical surface finishing operation, and in some cases remediated. The surface finished components show significant improvement in mechanical and corrosion-resistant properties.

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Keynote ☐ Oral ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐

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WORLD PM2022
CONGRESS & EXHIBITION
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Paper number: WP225366563

Requested paper type: Oral Presentation

Topic: Consolidation technologies / **Subtopic:** AM beam based technologies

Author: Dr Tian Yang (Monash University, Australia)

Co-author(s): Dr Jiang Derui ; Prof Huang Aijun ; Prof Wu Xinhua (Monash University, Australia)

Title: Effects Of Powder Characteristics On Building Quality Of Laser Powder Bed Fusion Of Hastelloy X

Keyword(s):

Abstract:
Little understanding of powder characteristics presents a major limitation to the widespread use of laser powder bed fusion (LPBF) technology. In this study, systematic research has been carried out to investigate the influences of different powder properties (e.g. powder size distribution, recycling times and chemical composition) on the building quality of LPBFed Hastelloy X. Processing window is proposed to help identify appropriate laser parameters and meet specific demand with different powder size ranges. Low alloying addition of Si, Mn and C in powder is required to reduce the hot tearing susceptibility and cracking. Powder characterization study revealed that the number of powder conglomerate increases with the recycling times while the chemical composition remains unchanged as powder is reused multiple times. Other factors such as influence of powder packing and recoating features are also explored to provide a more comprehensive understanding of the relationship between powder behaviours and LPBF building quality.

Innovative Aspect(s):
The characteristics of the raw powder used in LPBF process greatly affect the material properties that are obtained in the finished component. We are addressing some of the fundamental issues with powder bed techniques by combining process technology with powder characterisation to help meet the demands of production. In-depth knowledge is offered on batch-to-batch variations in metal powders and variations in build location, orientation and positioning, powder-powder|powder-laser interaction, by-product powder characteristics and powder recycling processes.

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WORLD PM2022 CONGRESS & EXHIBITION
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Paper number: WP225366826

Requested paper type: Oral Presentation

Topic: Consolidation technologies / **Subtopic:** AM beam based technologies

Author: Dr Li Xiaoshuang (Aerosint SA, Belgium)

Co-author(s): Mr Gianfolcaro Nicolas (Aerosint SA, Belgium)

Title: Microstructure And Properties Of Multi-Material Parts By LPBF

Keyword(s):
Multi-material LPBF, Cu alloy, Thermal, FGM

Abstract:
Fabrication of multi-material parts in a single step is the next innovation in the field of additive manufacturing. The unique Selective Powder Deposition (SPD) system developed by Aerosint was integrated into Aconity machines, enabling manufacturing of bi-metallic parts by Laser Powder Bed Fusion (LPBF). In the present study, the focus lies on the processing of steels with high strength and Cu alloy with high thermal|electrical conductivity. Parts with different material interface configurations were fabricated by LPBF. The microstrucutre of the parts, especially the interface integrity, was charaterized using OM, SEM. A various scanning strategies were developed to reduce the defect level at the interface. Finally, the mechnical and thermal properties of the parts were evaluated, which were further improved by developing post heat treatment.

Innovative Aspect(s):
The innovative aspects of this work are as follows: Manufacturing multi-material parts with complex geometries by LPBF with fully automated system for the first time. Scanning strategies developed specfically for improving material interface quality. Function Graded Materials

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WORLD PM2022 CONGRESS & EXHIBITION
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Paper number: WP225367586

Requested paper type: Oral Presentation

Topic: Consolidation technologies / **Subtopic:** AM beam based technologies

Author: Dr Gargalis Leonidas (CONIFY P.C., Greece)

Co-author(s): Dr Deligiannis Stavros ; Dr Kousiatza Chara ; Mr Barbakos Nikos ; Dr Karaxi Evangelia (CONIFY P.C., Greece) ; Mr Graff Joachim S. ; Mr Fahlstrom Johan ; Dr Diplas Spyros (SINTEF, Norway)

Title: Laser-based AM Of Duplex And Super Duplex Stainless Steels: An Investigation Of Process-Structure-Properties Relationships

Keyword(s):
Duplex stainless steel, Super duplex stainless steel, Laser-based additive manufacturing, Metallographic analysis

Abstract:
In this study, duplex|super duplex stainless steel grades are processed by laser-based additive manufacturing techniques. Samples were produced with a wide range of processing parameters, to assess their impact on the phase formation, grain structure, texture and nano-mechanical properties. An optimal set of processing parameters for producing high density (>99.9%) defect-free alloys is established. A multi-technique characterisation protocol combining metallographic analysis through scanning electron microscopy (SEM), electron backscatter diffraction (EBSD) and nanomechanical response assessment is presented, aiming at determining process-microstructure-properties correlations.

Innovative Aspect(s):
Despite the application potential, and the successful processing in powder form by traditional powder metallurgy methods, laser powder bed fusion (LPBF) of duplex and super duplex stainless steels has not been studied extensively. The impact of a fast-moving laser source and the critical responses of duplex powders are unknown and signify a gap in the literature due to reheating phenomena during LPBF and complex microstructural transformations, affecting the α|γ phase balance in the steel. The innovation of this research lies in the in-depth analysis of the response of duplex and super duplex stainless-steel alloys to processing by LPBF with varying process conditions through a multi-technique characterisation protocol. The microstructure of both alloys is evaluated, the amount of γ and α volume fractions is assessed and correlated to the mechanical properties of the final parts.

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WORLD PM2022
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09-13 OCTOBER

Paper number: WP225368199

Requested paper type: Oral Presentation

Topic: Consolidation technologies / **Subtopic:** AM beam based technologies

Author: Mr Blackwell Cameron (Manufacturing Technology Centre (MTC), United Kingdom)

Co-author(s): Dr Dawes Jason ; Dr Turner Nathanael (Manufacturing Technology Centre (MTC), United Kingdom) ; Dr Heikkilä Irma ; Mr Strandh Emil (Swerim AB, Sweden) ; Dr Lockowandt Christian (Swedish Space Corporation, Sweden) ; Dr Meisnar Martina (European Space Agency

Title: Investigation Of The Variance In The AM Powder Supply Chain And Its Effect On Part Properties

Keyword(s):
Supply chain, ASi10Mg, Powder property impacts

Abstract:
The control of the entire AM process chain, encompassing the material supply, design, AM processing, post-processing, and part verification is critical to the success of the AM industry. Although intrinsically linked, existing studies evaluate one aspect of the AM process chain. Currently, an understanding of the complex relationship between powder and printed part properties is lacking. This paper establishes a holistic view of the AM process chain highlighting differences in part properties due to the variation in the powder feedstock material. Four AlSi10Mg powder batches procured from four suppliers were processed by metal laser powder bed fusion at three AM bureaus. A series of representative space parts and test bars were manufactured, followed by an exhaustive powder and part test campaign. This work has been completed as part of the ESA GSTP funded study "Additive Manufacturing Powder Supply Chain: Validation and Verification".

Innovative Aspect(s):
Cross-comparison of powders of the same alloy manufactured by multiple suppliers, and the impacts of part properties.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225370222

Requested paper type: Oral Presentation

Topic: Consolidation technologies / **Subtopic:** AM beam based technologies

Author: Dr Ing Heikkilä Irma (Swerim AB, Sweden)

Co-author(s): Dipl-Ing Blackwell Cameron ; Dr Ing Turner Nathanael (MTC, United Kingdom) ; Dr Ing Meisnar Martina (ESA, United Kingdom) ; Dr Ing Pambaguian Laurent (ESA, Netherlands) ; Dr Ing Lockowandt Christian ; Dr Ing Daab Dominique (Swedish Space Corporation, Swed

Title: A Comparative Investigation On Shape Accuracy Of Space Parts Produced By Different L-PBF Processes And AlSi10Mg Powders

Keyword(s):
Shape accuracy, L-PBF process, AlSi10Mg powder, Trends, Space design

Abstract:
The effect of variability of metal laser powder bed fusion (L-PBF) processes and raw materials for the shape accuracy of the part is a poorly understood area. A suite of designs covering bulky designs of complex shape and delicate fine features were created and manufactured by different machine hardware, process parameters and four AlSi10Mg powders sourced from different suppliers. The designs were relevant for use in space applications. The aim was to evaluate the relationship between the process and powder characteristics for the shape accuracy using a systematic approach for the investigation. The results showed the shape accuracy was clearly connected to the applied process and indirectly to the powder.

Innovative Aspect(s):
The investigation was made on a large text matrix covering varying designs, processes and raw materials and provided therefore a substantial amount of data for observing trends on the effect of the process and raw material variables for the part shape accuracy.

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Keynote ☐ Oral ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225370742

Requested paper type: Oral Presentation

Topic: Consolidation technologies / **Subtopic:** AM beam based technologies

Author: Mr Mehta Bharat (Chalmers University of Technology, Sweden)

Co-author(s): Prof Dr Nyborg Lars ; Prof Dr Hryha Eduard (Chalmers University of Technology, Sweden) ; Dr Frisk Karin (Höganäs AB, Sweden)

Title: High Temperature Properties In Novel Al-Mn Based Aluminium Alloys Tailored For Laser-based Powder; Bed Fusion

Keyword(s):
Additive Manufacturing, Laser-based Powder Bed Fusion, Aluminium Alloys, Alloy Design

Abstract:
Novel Aluminium alloys tailored for laser-based powder bed fusion have been developed by the authors. They were designed by leveraging negligible solidification range (dT|(df_s^(1|2))) close to solidification, leading to the ability to avoid solidification cracking completely. These alloys have been designed keeping in mind the benefit of dissolving higher amount of solutes in solid solution, which can later be precipitated via direct ageing in a controlled manner to achieve high peak hardness. Since the alloying elements were selected having very low bulk diffusivities, the growth| coarsening models suggested a slower coarsening of precipitates, which suggests retention of high strength even after low temperature ageing on peak hardened condition. Such a type of alloy design is thus beneficial for applications requiring medium-high strengths in temperatures up to 573-623 K.

Innovative Aspect(s):
Introduction of novel Al-alloys tailored for laser-based powder bed fusion process. High temperature properties of these alloys are showcased wherein it is shown that due to selection of certain solutes, this alloy has great potential for high thermal stability applications. Experiments run at 523 K 2500 hours and 623 K 1000 hours showcase the stability of these alloys and resulting microstructure. This shows that the potential of these alloys to increase service temperatures for Al-alloys up to 523-573 K, which is 100-150 degrees more than conventional Al-alloys. Such an improvement could enable products wherein Ti- or Fe- based alloys could be replaced by such high performance Al-alloys enabled by additive manufacturing.

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Keynote ☐ Oral ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225370795

Requested paper type: Oral Presentation

Topic: Consolidation technologies / **Subtopic:** AM beam based technologies

Author: Dr Freeman Felicity (University of Sheffield, United Kingdom)

Co-author(s): Dr Thomas Ben ; Mr Chechik Lova ; Prof Todd Iain (University of Sheffield, United Kingdom)

Title: In-Line Control Of Powder Flow Rate In Directed Energy Deposition

Keyword(s):
Directed energy deposition, Powder flow rate, Closed-loop control

Abstract:
Powder flow rate is a key parameter in Directed Energy Deposition (DED) metal additive manufacturing processes. At typical build rates, if flow rate is reduced for just 1 second, it can affect 30 mm of melt track. Consequently, even a small variation in flow rate can significantly impact build quality. Here, we have monitored flow rate variation using a combination of methodologies including offline weight measurements, flow imaging, in-situ build data and coaxial imaging. Variation was identified across all measurement platforms, correlated with the powder hopper turntable rotation frequency, and at sufficient magnitude to impact build quality and be observable in coaxial melt pool imaging. We addressed this variation by developing in-line flow rate control, using a 'hopper-agnostic' approach suitable for retro-fitting to other DED systems. This improves process control, eliminating the impact of flow rate variation on build quality and on melt pool monitoring systems.

Innovative Aspect(s):
This project is innovative through the use of a multi-faceted approach to the high-frequency measurement of powder flow at different stages of the DED process, and the development of an in-line control system to protect build quality. While powder flow rate is known to be a critical parameter for a good DED build, the impact of flow rate variation on build quality has not previously been considered. Further, we have demonstrated that flow rate variation can be observed in coaxial melt pool imaging, which has implications for systems using these images for melt pool temperature monitoring and control. Rather than pursuing root-cause-analysis to eliminate the variation at source through optimisation and modification of this specific hopper design, we have instead focussed on the development of a 'hopper-agnostic' system for in-line control of powder flow rate, which we believe will be useful to a wider sector of the AM community.

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Keynote ☐ Oral ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐

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WORLD PM2022
CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225371467

Requested paper type: Oral Presentation

Topic: Consolidation technologies / **Subtopic:** AM beam based technologies

Author: Dr Khademzadeh Saeed (University of Padova, Italy)

Co-author(s): Prof Persson Cecilia (Uppsala University, Sweden)

Title: Additive Manufacturing Of Functional Mechanical Mechanisms Using Micro Laser Powder Bed Fusion

Keyword(s):
Micro-laser powder bed fusion, Non-assembly mechanisms, Micro-computed tomography

Abstract:
Additive Manufacturing (AM) of non-assembly metallic mechanisms is highly desirable because of their high performance and low costs due to removing the need for labor-intensive procedures. However, fabrication of such mechanisms using metal AM techniques faces many challenges. For instance, down-skin inclined surfaces suffer from an insufficient quality due to the staircase effect and partially melted attached particles that may deteriorate the function of the mechanism since residuary stuck material can block the clearance space. In this work, a novel scanning strategy was employed for the fabrication of non-assembly functional micromechanisms. A threshold angle was defined for activation of a new set of process parameters for down-skin surfaces. Non-assembly ball joints were additively manufactured using laser powder bed fusion technology. The effects of threshold angle, overlap between in-skin and down-skin surfaces, and input energy on the functionality of non-assembly joints was investigated using state-of-the-art techniques such as micro-computed tomography.

Innovative Aspect(s):
Introduction of new parameters for the definition of down-skin inclined surfaces in laser powder bed fusion. Applying a new configuration of laser powder bed fusion technology for microfabrication, such as using a small spot laser diameter of 30 um. Using micro-computed tomography to measure clearance space in functional mechanisms such as ball joints.

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WORLD PM2022
CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225371471

Requested paper type: Oral Presentation

Topic: Consolidation technologies / **Subtopic:** AM beam based technologies

Author: Mr Gärtner Eric (Leibniz Institute for Materials Engineering - IWT, Germany)

Co-author(s): Prof Dr Mädler Lutz (University of Bremen, Germany) ; Dr Ing Uhlenwinkel Volker (Leibniz Institute for Materials Engineering - IWT, Germany)

Title: Increasing The Fine Particle Content In Metal Powders For LPBF Through Nanoparticle Dry-coating

Keyword(s):
Additive manufacturing, LPBF, Flowability, Nanoparticles, Dry-coating

Abstract:
In powder-bed-based additive manufacturing (AM) processes, such as laser powder bed fusion (LPBF) typically the fine particles (<20 µm) are removed from metal powders in order to decrease powder cohesion that often results in inhomogeneous powder spreading. Nanoparticle dry-coating effectively reduces particle adhesion and allows for direct usage of the fine particles. A gas-atomized Cr25Co25Ni25Fe25 powder (<90 µm) with varying fine content was dry-coated with SiO2 nanoparticles (13 nm) in increasing concentrations up to 200 ppm. Measurements of flowability (dynamic angle of repose) and powder packing (Hausner-ratio) indicated a better processability of dry-coated powders upon nanoparticle addition. Nanoparticle dry-coated metal powders with a fine particle content of 20 vol.% showed a homogenous processing in a LPBF machine and a high relative part density >99.9%. The utilized fine fraction increased the powder yield, clearly highlighting the potential of dry-coating for AM technologies.

Innovative Aspect(s):
This work aims at establishing the use of nanoparticles in additive manufacturing and powder metallurgy (PM). The primary working principle of coating metal powders with additional nanosized particles offers the potential of improving various conveying and feeding processes in PM. Both L-PBF users and powder metallurgical companies providing such metallic materials will greatly benefit from this conditioning step. From an economical and resource efficient perspective, powder size fractions may solely be limited by an upper cut-off size (e.g. 45-63 µm) realizing absolute powder yields up to 80 % of an as-sprayed raw powder, while fine particle fractions can be directly utilized in AM technologies.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225371602

Requested paper type: Oral Presentation

Topic: Consolidation technologies / **Subtopic:** AM beam based technologies

Author: Dr Bosio Federico (Technology Innovation Institute, United Arab Emirates)

Co-author(s): Mr Phutela Chinmay ; Miss Alhammadi Alya ; Dr Aboulkhair Nesma (Technology Innovation Institute, United Arab Emirates)

Title: High Power And Temperature In-situ Alloying Of Metal Powder Blends Via Laser Powder Bed Fusion

Keyword(s):
High powder laser powder bed fusion, Platform heating, In situ heat-treatments

Abstract:
In-situ alloying is a thriving method used in Laser Powder Bed Fusion (L-PBF) for exploring new alloys with unique characteristics directly from elemental powder mixtures. Although in-situ alloying has shown interesting capabilities in alloy development, there is still a long way before the concept is ready for industrialization. For instance, when processing metal powders with distinct thermo-physical properties, the consolidation process often results in heterogeneous microstructures showing un-melted particles and elements' segregations. Therefore, in this work, L-PBF was conducted employing high power levels (up to 1 kW) to provide sufficient energy for homogeneously melting elemental powders with dissimilar densities and melting temperatures. In addition, the effect of elevated build plate temperatures (up to 500C) on processability and defects, including crack propensity, was investigated. The potential for in-situ heat treatments is also explored using multi-lasers.

Innovative Aspect(s):
High power laser powder bed fusion to improve metal alloys processability. Laser powder bed fusion at elevated temperature to reduce cracking. High power at high temperatures to promote in situ heat-treatments.

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Keynote ☐ Oral ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐

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WORLD PM2022 CONGRESS & EXHIBITION
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Paper number: WP225371679

Requested paper type: Oral Presentation

Topic: Consolidation technologies / **Subtopic:** AM beam based technologies

Author: Dipl-Ing Reijonen Joni (VTT Technical Research Centre of Finland, Finland)

Co-author(s): Dipl-Ing Antikainen Atte ; Dipl-Ing Lagerbom Juha ; Dr Lindroos Matti ; Dr Pinomaa Tatu ; Dipl-Ing Lindroos Tomi (VTT Technical Research Centre of Finland, Finland)

Title: Laser Powder Bed Fusion Of High Carbon Tool Steels

Keyword(s):
High carbon tool steel, K110, S600, Laser powder bed fusion, Additive manufacturing

Abstract:
Tool steels are martensitic steels alloyed with carbide forming elements, thus having high strength, hardness and wear resistance. These characteristics, however, make them costly materials to shape into complex geometries. Laser powder bed fusion (PBF-LB) enables the consolidation of near-net-shape complex shapes from powders, which is a highly resource efficient way of producing tools. However, processing tool steels with PBF-LB is problematic due to hardening and segregation generated during the process leading to high stresses and eventually to cracking. To diminish these problems, we utilized a tailored high temperature building platform in PBF-LB to process gas atomized high carbon tool steels such as K110 and S600. Calphad method was used to evaluate the stress formation and cracking tendency of these alloys. The microstructure, hardness and tendency to form residual stresses of the manufactured samples were characterised. Properties comparable to conventionally manufactured quenched and annealed tools steels were achieved.

Innovative Aspect(s):
The material selection of carbon tool steels for PBF-LB is today rather limited, H13 with medium carbon content being the most commonly utilized, yet providing only moderate wear resistance. High carbon, high performance tool steels investigated here are novel materials not yet commercially available for PBF-LB additive manufacturing. We have developed innovative strategies to assess the cracking and residual stress formation tendency during PBF-LB processing of such high carbon content tool steels. Elevated building platform temperature was utilized to diminish cracking. New insights on process-structure-property-performance relationship due to rapid solidification during PBF-LB of high carbon tool steels were generated.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225371758

Requested paper type: Oral Presentation

Topic: Consolidation technologies / **Subtopic:** AM beam based technologies

Author: Dipl-Ing Chivel Yuri (MerPhotonivs, France)

Co-author(s):

Title: Multi-material parts production by selective laser melting

Keyword(s):
Selective laser melting, Multi-material parts, New approach, Algorithm of recoating, Cross-contamination, Dissolution

Abstract:
The use of multi-materials may be viewed as a technically challenging and economically favorable manufacturing method . New patented method and SLM machine prototype for 3D multi-material parts production has been elaborated , where standard recoating systems with roller or blade can be used. A narrow fraction of powders of various materials with different medium particle size and special algorithm of powder layer recoating are used. Method enables to separate the overflow powders of a various materials for re-use. The main mechanisms of SLM machine have been elaborated , physically modelled and produced. The cross-contamination effect has been studied experimentally. Not more than 0.1% cross-contamination are fixed. The influence of dissolution in liquid pool and shrinkage on accuracy of the position of a contact surface between various material have been given adequate consideration. The first industrial multi SLM machine is under consideration.

Innovative Aspect(s):
A new method developed for the manufacture of 3D multimaterial products from several powders by selective laser melting is presented. Designed and created machine for the implementation of the method.

TPC Reviewer name: .....

Keynote ☐ Oral ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225371765

Requested paper type: Oral Presentation

Topic: Consolidation technologies / **Subtopic:** AM beam based technologies

Author: Dipl-Ing Chivel Yuri (MerPhotonics, France)

Co-author(s):

Title: Laser cladding with conical beams

Keyword(s):
Laser cladding , Conical laser beams, Powder stream,Wire, Substrate, Separate heating

Abstract:
Laser cladding process with powder or wire should be an outstanding performer in additive manufacturing The new approach in selective laser cladding using conical laser beams has been elaborated. Initial circular laser beam is divided into two annular beams with regulated distribution of the laser power throughout the annular beams. Annular beams are transformed to conical beams , which are focused separately on the surface and on the deposited material for heating. The laser energy delivery to powder stream is very efficient because a total uniform absorption of laser energy in the dense powder stream (104-105 1|cm3). Under wire deposition the heating of substrate reduces the residual stresses due the reduction temperature gradients and compensates heat losses from deposition zone. The power density for melt contact formation is significantly reduced as well as dissolution, while increasing accuracy. The optimal regimes of laser cladding can be achieved using new approach.

Innovative Aspect(s):
A method has been developed for laser cladding on two conical beams that separately heat the deposited material and the substrate, which significantly increases the efficiency and quality of products.

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Keynote ☐ Oral ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225371862

Requested paper type: Oral Presentation

Topic: Consolidation technologies / **Subtopic:** AM beam based technologies

Author: Mr Schroeder Timo (Fraunhofer IGCV, Germany)

Co-author(s): Mr Kindermann Philipp ; Mr Schmitt Matthias ; Dr Ing Schlick Georg (Fraunhofer IGCV, Germany)

Title: Investigation Of The Potentials And Current Limitations Of Multi-material Manufacturing Of Metals By Powder Bed Fusion Based On A Copper And Steel Material Combination

Keyword(s):
Multi-material, Additive manufacturing, Powder purity, MM PBF-LB|M

Abstract:
Multi-material manufacturing of metals by powder bed fusion (MM PBF-LB|M) combines the ability of building complex structures with the capability to create an arbitrary material distribution in one process. The possibility of the arbitrary material distribution in one part enables future applications. However, one challenge in MM PBF-LB|M is to ensure powder purity during the build process that is influenced by the technology maturity of the MM PBF-LB|M-system. Impurities in the manufactured component can lead to the deterioration of material properties and therefore must be avoided. This paper investigates the current state of the MM PBF-LB|M-systems technology and the achievable material purity. The resulting material properties in dependency of the powder purity and reprocessing ability are determined for copper and steel specimens. As critical sub-systems, the application mechanism and the powder extraction module required for the holohedral application mechanism are identified. Finally, improvement measures for the MM PBF-LB|M-process are derived.

Innovative Aspect(s):
This presentation intends to show the scientific and industrial community the technological maturity level that MM PBF-LB|M-systems technology has already reached at the current time. The evaluation of this maturity level is based on the generable material properties with the MM PBF|LB-M-process, compared to the reachable properties in the mono-material PBF-LB|M-process. For this purpose, the influence of the MM PBF-LB|M-process on the material properties is comprehensively analyzed, based on various material tests. In addition to the MM PBF-LB|M-process itself, the influence of powder reprocessing and a magnetic separation process are considered. The investigated material combination of copper and steel shows that the magnetic separation process with the currently available systems technology enables high powder purities after separation. The existing cross-contamination after powder separation now has a significantly lower influence on the component quality than the material blending during the actual MM PBF-LB|M process.

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Keynote ☐ Oral ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐

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WORLD PM2022
CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225371865

Requested paper type: Oral Presentation

Topic: Consolidation technologies / **Subtopic:** AM beam based technologies

Author: Prof Dr Simchi Abdolreza (Sharif University of Technology, Iran)

Co-author(s): Prof Dr Petzolfdt Frank ; Dr Hartwig Thomas ; Dr Hain Sebastian Boris ; Dr Ing Reineke Lea ; Dr Ing Barthel Bastian (Fraunhofer Institute IFAM, Germany)

Title: Binder Jetting Additive Manufacturing Of Complex-shaped Parts With Minimum Sintering Anisotropy

Keyword(s):
3D binder jet printing, Sintering shrinkage, Microstructure, Mechanical property, Stainless steel, Titanium alloy

Abstract:
Sintering anisotropy of 3D binder jetted parts is the major challenge limiting the fabrication of large and complex-shaped parts from versatile powder materials. We employed 3D shell binder jetting to fabricate green parts with a minimum heterogeneity in the pore structure. The advantages of the process include fast printing speed, minimum consumption of the binder, easier de-powdering and de-binding processes, and homogeneous sintering shrinkage. The applicability of the shell printing for the fabrication of 316L and Ti-6Al-4V parts is demonstrated. By employing dilatometric analysis, we show that the sintering shrinkage in different directions only varies for about 1%; hence, deflection during high-temperature sintering is greatly prohibited. The fine and uniform pore structure of the green parts also render reduced sintering temperature and time, yielding microstructural features and mechanical properties comparable to MIM parts. It isdemonestrtaed that 3D shell printing could overcome the main limitations of the 3D binder jetting process.

Innovative Aspect(s):
We propose and demoestrate a novel procedure to reduce the sintering anisotropy and deflection of large and complex-shaped parts manufactured by 3D binder jetting additive manufacturing.

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Keynote ☐ Oral ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225371915

Requested paper type: Oral Presentation

Topic: Consolidation technologies / **Subtopic:** AM beam based technologies

Author: Ms Soares Barreto Erika (Leibniz-Institute for Materials Engineering IWT, Germany)

Co-author(s): Mr Wegner Jan ; Dr Ing Kleszczynski Stefan (University Duisburg-Essen, Germany) ; Mr Frey Maximilian ; Prof Dr Busch Ralf (Saarland University, Germany) ; Prof Dr Mädler Lutz ; Dr Ing Uhlenwinkel Volker (Leibniz-Institute for Materials Engineering IWT, Ge

Title: Influence Of Oxygen In The Production Chain Of Metallic Glasses Via Laser Powder Bed Fusion

Keyword(s):
Metallic glasses, Gas-atomization, Laser-based powder bed fusion of Metals (PBF-LB|M), Oxygen

Abstract:
Laser powder bed fusion of metals (PBF-LB|M) is advantageous for the manufacturing of bulk metallic glasses (BMGs) with size and geometrical freedom. However, the oxygen uptake occurring along the production chain can negatively impact the generation of high-quality, amorphous parts. Thus, evaluating the oxygen absorption in each production step and analyzing its impact on the BMG properties is relevant for the qualification of PBF-LB|M processability of glass-formers. In this matter, Cu-Ti-based alloys were gas-atomized for powder synthesis using commercial purity feedstocks accounting for economic applicability. Samples were additively manufactured and characterized. The oxygen absorption before, during, and after powder production and additive manufacturing was mapped. The formation of the amorphous phase and the glass-forming ability of the powders and PBF-LB|M samples were assessed and compared. The present contribution enables significant knowledge gains to the processability and economical production of amorphous metal components by PBF-LB|M.

Innovative Aspect(s):
One novelty in our study is the alloy selection. While Zr-based glass-forming alloys have been broadly investigated, the Cu-Ti-systems remain scarcely studied for PBF-LB|M processability, although possessing high strength and suitable glass-forming ability. Due to lower oxygen affinity, commercial purity feedstocks were selected, justifying the economic viability of these alloys. Moreover, the original investigation of the oxygen uptake along the production chain permits establishing new industrial applications for LPBF-produced metallic glasses. It elucidates critical steps for oxygen contamination, besides pointing out the oxygen influence on the glass-forming ability of the material, which can be crucial for crystallization and deterioration of mechanical properties.

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Keynote ☐ Oral ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225371920

Requested paper type: Oral Presentation

Topic: Consolidation technologies / **Subtopic:** AM beam based technologies

Author: Mr Alinejadian Navid (Tallinn University of Technology, Estonia)

Co-author(s): Dr Ing Wang Pei (Shenzhen University, China) ; Dr Kollo Lauri ; Prof Konda Gokuldoss Prashanth (Tallinn University of Technology, Estonia)

Title: Selective Laser Melting Of Commercially Pure Molybdenum By Laser Re-scanning

Keyword(s):
Additive Manufacturing, Selective laser melting, Molybdenum, High-temperature structures

Abstract:
commercially pure molybdenum (cp-Mo) is one of the high-temperature materials of immense potential. It has a body-centered cubic (bcc) structure so it is hard to fabricate using non-equilibrium processes such as selective laser melting (SLM) without the formation of cracks due to its inherent brittleness. This work deals with the fabrication of dense and near crack-free cp-Mo samples produced by the SLM. The laser scan strategy is adjusted from a single scan to a double scan to reduce the solidification cracks. Samples produced with a laser double scan strategy show a density of ~99% with a hardness of ~222 HV.

Innovative Aspect(s):
Dense cp-Mo samples were successfully fabricated by SLM using changes in the laser scan strategy. The following observations were made: a stable melt pool in laser double scanning (LDS) led to a reduced amount of internal stresses compared to the laser single scanning (LSS) samples.. by using LDS the solidification rate may be reduced since the initial scan selectively heats the powder bed.. the LDS with no scan rotation has led to coarse columnar grains with a higher density.. the solidification cracks were nearly eliminated using the LDS strategy.

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WORLD PM2022
CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225371951

Requested paper type: Oral Presentation

Topic: Consolidation technologies / **Subtopic:** AM beam based technologies

Author: Ing Gaillard Quentin (École des Mines de Saint-Étienne, France)

Co-author(s): Dr Boulnat Xavier ; Dr Cazottes Sophie ; Dr Dancette Sylvain (Institut National des Sciences Appliquées de Lyon, France) ; Prof Desrayaud Christophe (Ecole des Mines de Saint-Étienne, France)

Title: Influence Of Interstitials Content On Martensite Decomposition And Beta Transus Temperatures Of Ti-6Al-4V Built By Laser Powder Bed Fusion

Keyword(s):
Laser powder bed fusion, Ti-6Al-4V, Heat treatment, Transformation temperatures

Abstract:
Laser powder bed fusion (L-PBF) is capable of producing dense and functional metallic parts which are of great interest for many applications in the aerospace sector. L-PBF made Ti-6Al-4V parts show a fine martensitic microstructure and significant residual stresses that are disastrous for their mechanical performance. Consequently, post-processing heat treatments are necessary to relieve the internal stresses and lead to a microstructure adequate for the mechanical requirements. Due to the various powder compositions and processing parameters, there is a large scattering of properties of as-built and stress-relieved parts. As such, this study aims at quantifying the link between interstitials (oxygen, nitrogen, carbon) content and the transition temperatures (martensite decomposition, beta transus) of as-built parts and as-atomized pre-alloyed powders as a reference. To do so, differential scanning calorimetry, high-temperature X-Ray diffraction and electron microscopy were performed. This insight provides a guide for designing post-processing heat treatments of Ti-6Al-4V as-built parts.

Innovative Aspect(s):
The effects of interstitials (oxygen, nitrogen) content on the mechanical properties of Ti-6Al-4V are already well defined. Several studies also report that contamination is often happenning during the L-PBF process and thus the interstitials concentrations are higher is the as-fabricated parts than in the as-atomized pre-alloyed powders used. However, to our knowledge, there is no work yet that study the influence of this potential interstial elements pick-up on the martensite decomposition and beta transus temperatures for Ti-6Al-4V. Knowing these transformation temperatures is necessary to design post-processing heat treatments in the suitable range.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225371955

Requested paper type: Oral Presentation

Topic: Consolidation technologies / **Subtopic:** AM beam based technologies

Author: Dr Celebi Ahu (Manisa Celal Bayar University, Turkey)

Co-author(s): Mr Imanc Mustafa Mertcan ; Mr Cetinkaya Semih (Manisa Celal Bayar University, Turkey) ; Mr Atik Ilker (TUBITAK, Turkey)

Title: Evaluation Of Post-Processing On The Corrosion Behavior Of AlSi10Mg By Selective Laser Melting Process

Keyword(s):
Metal Additive Manufacturing, Selective Laser Melting, AlSi10Mg Alloys, Corrosion behavior of AlSi10Mg Alloys

Abstract:
The study looks into the impact of low heat treatment processing and the build orientation on the microstructural and corrosion behavior properties development in AlSi10Mg alloy fabricated using Selective Laser Melting (SLM) and casting method. SLM is very complex, from a physical point of view, due to the interaction between a concentrated laser source and metallic powders, and to the extremely rapid melting and the subsequent fast solidification. AlSi10Mg samples were fabricated using the SLM technique on an SLM Solution machine with a fiber laser system. The corrosion properties of samples were analyzed by electrochemical corrosion test. The microstructures of the produced alloy were investigated using X-Ray diffractometer (XRD), Energy diffuse X-Ray analysis (EDX) and by scanning electron microscope (SEM). Annealing heat treatment caused serious changes in the microstructure and corrosion properties of the material. The sample produced by SLM gave better corrosion resistance than the conventional sample.

Innovative Aspect(s):
After heat treatment at 300 °C, the applied heat treatment cycle caused the Si network to be interrupted, and Si from the supersaturated α-Al matrix (as T > 273.2 °C) stimulates precipitation. However, the improved uniformity of the microstructure may contribute to a lower corrosion current density by suppressing penetrating selective corrosion at-tacks. It is thought that increased homogeneity of the microstructure is achieved with limited coarsening of Si particles as a result of spontaneous formation of a more uniform and stable passive layer in the air after heat treatment.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225372066

Requested paper type: Oral Presentation

Topic: Consolidation technologies / **Subtopic:** AM beam based technologies

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

Co-author(s): Mr Wahman Clarence ; Prof Persson Cecilia (Uppsala University, Sweden) ; Dr Mellin Pelle (Swerim AB, Sweden)

Title: Influence Of Laser Power On The Corrosion Behavior Of An Mg-Y-Nd-Zr Alloy Produced By Powder Bed Fusion - Laser Beam

Keyword(s):
Magnesium alloys, Powder bed fusion - laser beam, WE43, Biodegradable metal, Implants

Abstract:
Powder bed fusion – laser beam (PBF-LB) of Mg-Y-Nd-Zr alloys has recently been gaining increasing attention for the development of biodegradable orthopedic implants with optimized mechanical properties and enhanced biocompatibility. However, the corrosion rates remain too high. Thus, the goal of this study was to investigate the influence of the laser power on the structure and microstructure of as-built Mg-Y-Nd-Zr surfaces and the resulting corrosion properties over 28 days. Samples were produced with three different laser powers (60W, 80W and 90W), while keeping all other parameters constant. The 60W samples had the best corrosion resistance, despite having a higher surface roughness. At higher energy input there is an increase in magnesium evaporation, which causes an increase in the amount and size of secondary phases, and thus an increased micro galvanic corrosion. This study gives an important insight into the influence of the PBF-LB process on the corrosion properties of Mg-Y-Nd-Zr alloys.

Innovative Aspect(s):
Magnesium alloys have shown great promise as biodegradable implants, with Mg-Y-Nd-Zr based orthopedic screws already clinically implemented. Combining the biological properties of magnesium alloys with PBF-LB, it is possible to develop new biodegradable orthopedic implants with controlled mechanical properties, enhanced cell viability and designed according to the patients' needs. Moreover, the corrosion properties of magnesium alloys are also hampering a general implementation of these alloys in other fields, such as aerospace. However, the corrosion rates of magnesium alloys processed by PBF-LB remains too high. To improve the corrosion properties, a greater understanding of the influence of the PBF-LB process on the microstructure of magnesium alloys is needed. This study provides an insight into the influence of the PBF-LB process on the microstructure and resulting corrosion properties of an Mg-Y-Nd-Zr alloy, and thus takes us one step closer to the successful implementation of a magnesium alloy implant produced by PBF-LB.

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225372122

Requested paper type: Oral Presentation

Topic: Consolidation technologies / **Subtopic:** AM beam based technologies

Author: Mr Langer Lukas (Fraunhofer Institute for Casting, Composite and Processing Technology IGCV, Germany)

Co-author(s): Mr Vickner Peter (Aubert&Duval SAS, Eramet, France) ; Mr Schmitt Matthias ; Dr Ing Schlick Georg (Fraunhofer Institute for Casting, Composite and Processing Technology IGCV, Germany)

Title: Stainless Steel X15TN For Laser Based Powder Bed Fusion: Material Properties For Tooling Applications

Keyword(s):
Additive Manufacturing, Tooling, Martensitic steel, Cutting blades

Abstract:
The X15TN steel (Euro number 1.4123) in wrought form has broad applications such as fuel injection components, pollution control systems in abrasive or corrosive environments, cutting blades with high requirements on corrosion resistance, surgical instruments and mold components. A previous study has shown that gas atomized X15TN by Aubert&Duval is possible to be processed in powder bed fusion via laser beam (PBF-LB|M) in spite of its relatively high carbon content. Being both Cobalt free and with an excellent corrosion resistance combined with a hardness of up to 59 HRC makes it of high interest for additive manufacturing. In this study, process parameters for PBF-LB|M will be presented. The material properties for different heat treatments will be presented and compared to the wrought form of the material.

Innovative Aspect(s):
After an initial study, the processability of gas atomized X15TN in powder bed fusion has been proven. For enabling industrial applications, further knowledge needs to be gained concerning the material and mechanical properties of the resulting parts. To obtain the alloys corrosion resistance different heat treatments such as tempering are necessary. The resulting properties as well as optimized heat treatment parameters are presented. Since no other research in additive manufacturing with X15TN is be known, this knowledge is a key aspect of innovation for powder metallurgy.

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Keynote ☐ Oral ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225372124

Requested paper type: Oral Presentation

Topic: Consolidation technologies / **Subtopic:** AM beam based technologies

Author: Mr Ibrahim Mohammad (University of Agder, Norway)

Co-author(s): Dr Elizabeth Aune Ragnhild (Norwegian University of Science and Technology, Norway) ; Dr Saetre Tor Oskar (University of Agder, Norway)

Title: Characterization Of Nickel Silicide Deposited On Steel And Nickel Substrate

Keyword(s):
Additive manufacturing, Laser metal deposition, Nickel silicide, Silicon, Nickel

Abstract:
Silicide based materials offer a lot of promise in efficiency improvement of turbines and offshore systems due to their exceptional oxidation, corrosion, and wear resistance. The common requirement of materials used in these systems is the ability to withstand high temperatures. Nickel silicide is generally known to possess these abilities, but its inherent brittleness makes large scale production difficult using ordinary metal forming techniques. Laser metal deposition is an additive manufacturing technique similar to cladding that allows pore-free microstructure formation of the metal with fine grains, which enables excellent mechanical properties. In the present study NiSi16 is deposited on structural steel and nickel substrates, and microstructure development is observed in both cases. The deposited beads are characterized using conventional analytical techniques (i.e., SEM, XRD, EDS, Microhardness evaluation) and changes in surface porosity and composition discussed.

Innovative Aspect(s):
Converting conventionally brittle and easily-crackable materials into finally workable materials so parts can be manufactured from them.

TPC Reviewer name: .....

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WORLD PM2022
CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225372132

Requested paper type: Oral Presentation

Topic: Consolidation technologies / **Subtopic:** AM beam based technologies

Author: Mr Deckers Tobias (Linde GmbH, Germany)

Co-author(s): Mr Ammann Thomas ; Mr Forêt Pierre (Linde GmbH, Germany) ; Prof Dr Witt Gerd (University Duisburg-Essen, Germany)

Title: A Study On The Influence Of Different Process Gases On Selectively Laser Melted Nickel-Chromium Powder By Means Of Process Monitoring: Melt Pool Geometries And Process By-Product Characteristics

Keyword(s):
Additive Manufacturing, Melt Pool Monitoring, IN718, Melt Pool Geometry, Process By-Products

Abstract:
This paper aims to investigate the influence of the process gas atmosphere during the Powder Bed Fusion of Metals using a Laser Beam (PBF-LB|M) of a Nickel-Chromium alloy on the melt pool geometries of single laser tracks and on the discoloration of process by-products. The trials were performed on an EOS M290, which was equipped with a photodiode-based melt pool monitoring system (MPM). First results indicated differences in the intensity levels of the MPM signal and in the penetration depths. Furthermore, a correlation between the discoloration of the sampled powder material and the intensity level of the MPM signal was detected.

Innovative Aspect(s):
Increasing process understanding. Melt pool monitoring. Correlation between process and part characteristics and process monitoring signals. Increased productivity by means of higher layer thicknesses.

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Keynote ☐ Oral ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐

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WORLD PM2022
CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225372159

Requested paper type: Oral Presentation

Topic: Consolidation technologies / **Subtopic:** AM beam based technologies

Author: Dr Saby Quentin (INSA Lyon, France)

Co-author(s): Dr Buffière Jean-Yves ; Dr Boulnat Xavier ; Dr Maire Eric (INSA Lyon, France) ; Dr Joffre Thomas (CTIPC, France)

Title: Effect Of Heat Treatment On Strength, Toughness And Fatigue Properties Of Cobalt-free Martensitic Stainless Steels Manufactured By Laser Powder Bed Fusion

Keyword(s):
Additive Manufacturing, Laser Powder Bed Fusion, Martensitic steels, Heat treatment, Fatigue behavior

Abstract:
Laser Powder Bed Fusion (LPBF) is an additive manufacturing process used to produce conformal cooling injection molds with complex internal channels, mainly using cobalt-rich 18Ni300 maraging steel. Yet, built parts with this steel powder still demand improved toughness and fatigue strength. As an alternative, this work describes the manufacturibility of two alternative cobalt-free martensitic stainless steels by LPBF. After a quantitative characterisation of the microstructure, defects and mechanical properties of as-built parts, different heat treatments were performed to (i) age the precipitation-hardenable low-carbon maraging steel (CX) or (ii) temper the high-carbon martensitic steel (PM420). The hardness, tensile strength, ductility, impact energy and fatigue behavior of as-built and treated parts were compared. The influence of the microstructure and the critical defects on the mechanical behavior is discussed, with an emphasis on the fatigue life. Finally, the manufacturing of complex injection molds using PM420 powder was assessed.

Innovative Aspect(s):
Two main innovative aspects: The comparaison of fatigue behavior before and after heat treatment of additively manufactured parts, which allows a deep insight into the role of microstructure Vs defects on the fatigue life. The quantitative study of the microstructure (X-Ray diffraction, electron microscopy), the defects (using X-ray tomography) and the mechanical properties, from the simple as-built parts to the final demonstrator (injection mold).

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225372164

Requested paper type: Oral Presentation

Topic: Consolidation technologies / **Subtopic:** AM beam based technologies

Author: Mr Bilgin Guney Mert (TUSAS ENGINE INDUSTRIES INC., Turkey)

Co-author(s): Mrs Kutlu Zuhal ; Mr Orhangul Akin (TUSAS ENGINE INDUSTRIES INC., Turkey)

Title: Investigation Effects Of The Thermal Treatments On High Temperature Mechanical Properties Of Ti-48Al-2Cr-2Nb Alloy Produced By Electron Beam Melting Method

Keyword(s):
Additive Manufacturing, Electron Beam Melting, Ti48-Al-2Cr-2Nb Alloy, Microstructure, Mechanical Properties, Heat Treatment, Hot Isostatic Pressing

Abstract:
High strength and improved elevated temperature properties along with their low density make γ-TiAl alloys attractive for aircraft engines. In this study, Ti-48Al-2Cr-2Nb samples were produced by electron beam melting (EBM) method. As-built EBM γ-TiAl mechanical properties significantly differ from those of the parts produced by conventional methods due to several issues including microstructural instabilities, porosity and residual stresses. Therefore, a subsequent heat treatment was found to be vital to eliminate those issues generated from the nature of the EBM layered process. The γ-TiAl alloy typically contains two main phases, γ-TiAl as the matrix and α2-Ti3Al with various morphologies depending on the type of the processing and heat treatment history. The present study was conducted to characterize the microstructure, high temperature tensile strength, and stress rupture behavior of EBM manufactured Ti-48Al-2Cr-2Nb samples in the as-built, HIP and heat-treated conditions within the purpose of utilizing this alloy for structural aerospace appications.

Innovative Aspect(s):
The existing studies in the literature mainly focused on a single mechanical property of the material by applying heat treatment at a certain temperature to the Ti-48Al-2Cr-2Nb alloy produced by EBM. However, in this proposed study, the final properties were compared with each other by applying heat treatments at different temperatures to see effects of the lamellar, duplex and equiaxed microstructure on mechanical properties. In addition, it has been revealed that the mechanical properties of the Ti-48Al-2Cr-2Nb alloy are optimized both in parallel and perpendicular to the built direction when HIP is applied in addition to the heat treatment. A serious knowledge has been created for structural aerospace applications by evaluating the microstructural examinations, phase analyzes and high temperature tensile, stress rupture tests for this alloy. For all these reasons, it is thought that the proposed study differs from the existing studies and will contribute to the literature.

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WORLD PM2022
CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225372183

Requested paper type: Oral Presentation

Topic: Consolidation technologies / **Subtopic:** AM beam based technologies

Author: Ing Amirabdollahian Sasan (University of Trento, Italy)

Co-author(s): Dr Eslami Maryam (Ohio University, USA) ; Prof Bosetti Paolo ; Prof Molinari Alberto (University of Trento, Italy) ; Dr Perini Matteo (Trentino Sviluppo, Italy)

Title: Heat Treatment And Properties Of AISI 415 Martensitic Stainless Steel Manufactured By Laser-Directed Energy Deposition

Keyword(s):
Laser directed energy deposition, Martensitic stainless steel, Microhardness, Heat treatment, Corrosion

Abstract:
Laser-directed energy deposition (L-DED) is one of the most practiced additive manufacturing (AM) methods that provides opportunities for production of parts as well as repair and cladding. AISI 415 Martensitic stainless steels demonstrate high mechanical properties, excellent toughness and weldability, with wide range of applications. In current work, crack free and full-dense parts were deposited after developing proper processing parameters using Design of Experiment (DOE). As-built microstructure comprised lath martensite with a microhardness of 400HV. Effect of two different heat treatment scenarios of direct tempering of the as-built part (DT), and austenitization and quenching prior to tempering (QT) on the microstructure and hardness were investigated. The tempering curves for the two scenarios were similar, demonstrating a hardening peak at 450˚C and while DT samples possessed slightly higher hardness due to the finer martensite substructure. Polarization tests revealed AM sample demonstrate 110 mV higher pitting potential compared to the conventional.

Innovative Aspect(s):
Developing processing parameters for L-DED for AISI 415 martensitic stainless steel that can be used in wide range of applications. Studying heat treatment behavior of L-DED 415 steel. Comparing the corrosion behavior of AM- material with that of conventional steel.

TPC Reviewer name: .....

Keynote ☐ Oral ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason: .....

Notes to author: .....

WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225372187

Requested paper type: Oral Presentation

Topic: Consolidation technologies / **Subtopic:** AM beam based technologies

Author: Mr Hearn William (Chalmers University of Technology, Sweden)

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

Title: Influence Of Carbon On The Microstructure Of Carbon Steels Produced By L-PBF

Keyword(s):
Additive Manufacturing, Laser Powder Bed Fusion, Carbon Steel, Microstructure, Martensite

Abstract:
The recent development of carbon steel for laser powder bed fusion (L-PBF) has shown that these alloys can be produced using the process. However, knowledge regarding their as-built microstructure remains limited. This work explores the microstructure of carbon steels (0.06-1.1 wt.% C) produced by L-PBF to examine the effect of carbon on phase formation and grain structure. Analysis found that the microstructure of these alloys was primarily composed of tempered martensite that contained nano-sized carbides. Retained austenite was also observed at elevated carbon contents (≥0.75 wt.%) due to the suppression of the martensite transformation temperature. With increasing carbon content noticeable changes in the parent austenite grains was not observed, however, the fineness of individual martensite grains did increase. Additionally, a transition from lath to plate martensite was observed at 1.1 wt.% C. These findings establish an understanding of carbon steels that can further their development for L-PBF.

Innovative Aspect(s):
In this work a variety of innovative aspects were examined. First, the feedstock material consisted of six tailored, pre-alloyed, gas-atomized carbon steel powders that had carbon contents between 0.06 to 1.1 wt.%. These tailored alloy compositions allowed for a systematic evaluation of carbon steels that could examine the effect of carbon without the noticeable influence of other alloying elements. This systematic approach was followed by a variety of analysis techniques. To examine phase formation a combination of XRD, OM, SEM and EBSD was utilized. While evaluation of the grain structure was conducted using OM, SEM, and EBSD, with EBSD data undergoing additional post-processing in order to evaluate the characteristics of the parent austenite grains. These experimental results were then correlated to results from ThermoCalc and JMatPro software to explain the formation of retained austenite, the expected type of stable carbides, and the observed transition in martensite morphology.

TPC Reviewer name: .....

Keynote ☐ Oral ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason: .....

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WORLD PM2022 CONGRESS & EXHIBITION
09-13 OCTOBER

Paper number: WP225368660

Requested paper type: Oral Presentation

Topic: Consolidation technologies / **Subtopic:** AM beam based technologies

Author: Ms Schwerz Claudia (Chalmers University of Technology, Sweden)

Co-author(s): Prof Dr Nyborg Lars (Chalmers University of Technology, Sweden)

Title: Pixel Intensity Of Near-infrared Long-exposure Images Acquired In-situ As A Quality Control Tool In Laser Powder Bed Fusion Of Ni-base Hastelloy X

Keyword(s):
Defects, Process monitoring, Laser powder bed fusion, Pixel intensity, Process parameters

Abstract:
Reliability improvement of laser powder bed fusion relies on implementing in-situ process monitoring and control. One of the monitoring systems that has shown promising advances towards this goal is long-exposure near-infrared layer-wise imaging. The system outputs grayscale images that require adequate processing to flag undesirable deviations. This study aims to assess the viability of analysis of pixel intensity values to identify systematic internal defects. Hastelloy X specimens were manufactured with varying process parameters to generate varying defect types and contents. The outputs of the long-exposure near-infrared monitoring system were used for estimating the defect content in the specimens. The results show the suitability of pixel intensity analysis to discriminate processability and occurrence of systematic defects to have limited applicability, which is attributed to confounding and predominant influence of process parameters in the pixel intensity values.

Innovative Aspect(s):
This study is the first systematic analysis of pixel-wise interpretation of long-exposure near-infrared images for the assessment of internal defects. The limitations of this approach become clear once the experimental design is comprehensive enough.

TPC Reviewer name: .....

Keynote ☐ Oral ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐

Poster ☐ Poster & Reserve Oral ☐

Withdraw ☐ Reason: .....

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WORLD PM2022 CONGRESS & EXHIBITION
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Paper number: WP225377471

Requested paper type: Oral Presentation

Topic: Consolidation technologies / **Subtopic:** AM beam based technologies

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Title: A Round Robin Test To Investigate The Printing Quality Of PBF-LB|M Processed AlSi10Mg

Keyword(s):
PBF-LB|M, AlSi10Mg, Additive manufacturing, Reproducibility, Scatter, High cycle fatigue

Abstract:
When it comes to higher accuracies, new technologies and real applications in additive manufacturing, there is one topic which cannot be avoided: The material response on the chosen processing parameters and its agreement and correspondence with literature data of the wrought material grade counterpart. In industrial additive manufacturing standards in terms of printing parameters, protection gas atmospheres or powder handling instructions are not obligatory. Therefore, the question must be answered whether the additive manufacturing process is reproducible and reliable over different printing companies. This was the motivation to realize a round robin test between 8 European printing companies and academic partners. The consortium had printed and tested fatigue and tensile testing bars under plant-specific conditions. A commonly used cast aluminum alloy, AlSi10Mg, was chosen as test material for the PBF-LB|M process. Differences of the results between the partners and the scatter itself were discussed in detail.

Innovative Aspect(s):
It was a large round robin to demonstrate the reproduceability of PBF-LB|M components.

TPC Reviewer name: .....

Keynote ☐ Oral ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐

Poster ☐ Poster & Reserve Oral ☐

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