Metal Additive Manufacturing Conference - MAMC 2024

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Book of Abstracts

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Plenary Talk / 1

Redefining Manufacturing with NextGen-AM: The Power of Innovative Technologies

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Additive manufacturing has made significant progress in recent years, particularly with the advent of next-generation technologies. This lecture explores cutting-edge innovations that are reshaping the Additive Manufacturing landscape and propelling it into a new frontier. The focus is on innovative AM processes, including the state-of-the-art of processing of metallic materials such as Ti-, Al-, Fe-, Cu-, and Ni-based alloys. Additionally, we examine the impact of these innovations on industries like aviation, medical, and automotive, through case studies, practical examples, and success stories. Looking towards the future, we discuss emerging trends and developments in additive manufacturing, highlighting how these innovative processes are revolutionizing the industry and paving the way for an exciting industrial transformation.

Speaker Country:

Germany

Process- and Quality Control & Sustainability / 2

A topographical methodology for in-situ process control in Laser Powder Bed Fusion (LPBF) Metal 3D Printing

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The heat evolution and thereby the densification rate in Laser Powder Bed Fusion (LPBF) Metal 3D Printing may vary during the print depending upon the build geometry variation along the height. Such variations in densification, even at fixed print parameters, are a major cause of defective parts in metal AM, as well as the poor consistency of print quality form part to part. We present a cutting-edge process control methodology in LPBF Metal 3D Printing via in-situ surface profiling. i.e., enabling a real-time correction of heat input (i.e., via adjusting the laser power and/or velocity) maintaining the densification rate regardless of print geometry variations along the build direction, Z, i.e., thus eliminating the Z-dependency of densification. The proposed methodology correlated the in-situ generated high-resolution surface profiles of the build's individual layers to its densification. The obtained surface profile of each layer is assessed and analyzed, providing a set of representative scalar values, that are experimentally verified to correlate well to the build's internal densification. Building upon the well-known relationship between the print parameters (e.g., laser beam velocity and power) and densification, our methodology can incorporate Machine Learning (ML)-enabled feedback loops for a real-time process control during the print, i.e., via algorithms trained for a given set of input material. The proposed methodology can enable an LPBF system to dynamically track and control the surface profile evolution in situ, in accordance with a known trend linked to the corresponding evolution of internal densification. The proposed methodology not only caters to the needs of research-oriented institutions but also offers a robust solution for industrial R&D application. It can potentially mark a significant leap in the field of LPBF Metal 3D Printing, offering unprecedented control and insight into the printing process.

Speaker Country:

Canada

Plenary Talk / **3**

MPBF Production Cost & How to overcome the challenge

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In a time characterized by uncertainty, metal 3D printing is undergoing a transition from a purely futuristic research endeavor to a technology that must demonstrate tangible profitability in real-world applications. Users must leverage the benefits of 3D printing, including design freedom and elimination of tooling costs, without investing additional time and resources in research. As one of the most established 3D printing technologies, Laser Powder Bed Fusion (LPBF) has the potential to produce high-quality components but must clearly demonstrate its profitability.

This presentation illustrates how Eplus3D and its users are addressing this urgency by focusing on strategies to enhance the value proposition and deliver measurable benefits to end-users. Participants gain insights into practical approaches used by industry leaders to effectively harness the capabilities of metal 3D printing and manage the transition from theoretical promises to tangible economic profitability.

Speaker Country:

Germany

Plenary Talk / **5**

"Update on the World Market for Powder Metallurgy & Special Steels"

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The speech will also focus on the production of Metal Powders and Powder Metallurgical Steels and especially its associated production technologies like HIP, MIM and AM. As they are and will become key future core technologies for a number of demanding products and thus for the usage in different associated industries. The presentation will also highlight the actual supply and demand situation of metal powders and the manufactured metal powder steels, will introduce leading manufacturers of both powders and steels, and summarizes installed capacity and new capacity that are on the way as well as new players that enter this high value industry. The presentation will also highlight the recent developments in the world of Forged Special Steels and remelted steels (nickel alloys, stainless steel, alloy tool steel and alloy steel) as well as will give an overview about end-user demand and structures of these special steels and also summarize the actual status of installations on a global scale.

Speaker Country:

Germany

Tools, Space and Aircraft, Automotive and others / 6

Corrosion morphology of 316L stainless steel manufactured by laser powder bed fusion.

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Abstract

This work investigates the corrosion morphology of AISI 316L stainless steel produced by laser powder bed fusion (L-PBF). The behavior of the as printed surface is compared with that of the bulk material to understand the effect of microstructure and roughness of the as printed surface on its corrosion behavior.
The L-PBF specimens investigated in this work were manufactured with a Concept Laser M2 Cusing machine, equipped with a 400 W single-mode CW ytterbium-doped fiber laser with emission wavelength of 1070 nm. Process parameters were optimized in order to obtain samples with very low porosity. The L-PBF stainless steel specimens were tested in the as produced condition without stress relief or recrystallization heat treatments.
A detailed characterization of the microstructure of the L-PBF 316L stainless steel samples was carried out by FE-SEM and EDXS. The as printed surface was investigated by optical microscopy and profilometry. Galvanostatic polarization measurements were carried out to evaluate the morphology of attack in 0.1M NaCl solution. After galvanostatic tests, the surface of the corroded samples was characterized by FE-SEM to highlight the higher corrosion susceptibility of the as printed surface relative to the bulk.

Speaker Country:

Italy

Laser Melting, Electron Beam Melting & Direct Energy Deposition Processes / 7

Investigation of 3D Plasma Metal Deposition with Aluminium powder

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Investigation of 3D Plasma Metal Deposition (3DPMD) with Aluminium powder

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As additive manufacturing (AM) continues to revolutionize industrial production, 3D Plasma Metal Deposition (3DPMD), a novel directed energy deposition (DED) variant based on the plasma-transferred arc welding process, is emerging as a promising technology, offering distinctive capabilities for fabricating high-quality metal components with unique properties. [1,2] Despite its potential, there has been very limited exploration of its application, especially with aluminium powder.

This work aims to fill this research gap by investigating the feasibility and challenges of utilizing 3DPMD with aluminium powder, addressing both process and material related complexities. Moreover, it should highlight the inherent difficulties encountered when working with aluminium alloys in DED, drawing insights from more extensively studied DED processes like Wire Arc Additive Manufacturing and Laser-based DED. [3–6]

Key objectives include conducting fundamental research to understand the process-structure-properties relationships specific to 3DPMD with aluminium. Several test series with single deposits and multilayer build-ups have been performed to investigate different aspects of the process. The key parameters identified were the main current, plasma gas flow, powder feed rate, travel speed and standoff distance. Additionally, the thermal behavior of the substrate plate has been varied. The investigations focused on dimensional characteristics, microstructure, process defects, and mechanical properties, particularly hardness. The substrate plate material was a 5082 alloy, and the powder was AlSi10Mg.

The test series of the single deposits showed the influence of the selected process parameters on the geometric properties such as deposition height, width, and penetration depth. For improved deposition efficiency, the tracks were aimed to have a maximized height-to-width ratio. The right penetration depth is important to ensure proper structural bonding of the layers. Both were achieved by reducing the plasma gas flow, decreasing the travel speed, and increasing the powder feed rate. The samples of the multilayer build-ups revealed the characteristic microstructure and process defects observed in DED of aluminium. In particular, long columnar dendritic grains oriented along the build-up direction and elevated porosity due to gas inclusions were observed. The average density of the cross-sections ranged from 96% to 97%. The respective heat-affected zones of each layer showed a significantly finer microstructure compared to the rest of the sample. The predominant phases of AlSi10Mg processed with 3DPMD were identified. The observed hardness data did not indicate correlations with the microstructure.

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Speaker Country:

Germany

Additive Design & Engineering / 8

Comparison of the 3D printing processes PMD and WAAM on the properties of Inconel 718

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High temperature alloys are used for aerospace applications e.g. turbine blades. Within this study, results on IN718 powder deposited with the Plasma Metal Deposition (PMD) will be compared with the Wire Arc Additive Manufacturing (WAAM) process. The IN718 alloys have been prepared to improve their mechanical properties and characterize them at high temperatures of ˜800℃ to 1000℃. With commonly used mechanical testing equipment such measurements would take usually a day because of slow heating and cooling. In this research, existing equipment has been updated with a fast heating and cooling system allowing the measurements of the mechanical properties of the alloys at elevated temperature within 30 minutes. A new modified heat treatment was found to be effective in dissolving Laves phase, whereas a standard treatment precipitated δ phase. The deposited materials were evaluated in both: as deposited and after heat treatment condition. Results showed for the PMD manufactured IN718 an increased performance at 1000℃ in particular after applying a new heat-treatment.

Speaker Country:

Austria

Laser Melting, Electron Beam Melting & Direct Energy Deposition Processes / 9

On the repair of industrial steel parts with a robotized Directed Energy Deposition system

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The energy sector uses a large amount of moving metallic parts, for example stainless steel pumps or collectors. Such kind of parts can be damaged during the use life and small cracks can appear after some years. Classically, the cracks are manually repaired with conventional welding techniques and the parts can still be used several years after the repair. However, the manual repair leads to large internal stresses that can be an issue and the quality of the repair depends on the operator ability. So, an automatized and reproducible repair could be very advantageous for this sector.

In this study, we have developed repairs by using Directed Energy Deposition (DED). Firstly, we have validated the technology on small coupons in which cracks have been machined. The impacts both on the substrate and on the deposited layer have been studied and a robust process window has been defined for the studied stainless steel. The quality of the repair is excellent in terms of level

of porosity, chemistry and mechanical properties. Moreover, the temperature increase during the repair is five times lower with DED compared to classical welding leading to less residual stresses. Secondly, the automatization of the process has been studied by used of a robotized directed energy deposition system enabling to have reproducible repair conditions. The different steps of the repair have been defined and validated. Finally, various types of cracks have been simulated on industrial parts to checked the developed process.

Speaker Country:

Belgium

Powder for MAM / 10

Development of new alloys for additive manufacturing : application to aluminium alloy for DED process and to titanium alloy for SLM process

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The development of new alloys for additive manufacturing, aiming at specific tailored properties, constitutes a topic of high interest.
• For instance, aluminum alloys are gaining significant attention in additive manufacturing, with numerous commercial alloys entering the market. However, most of these alloys primarily target Laser Powder Bed Fusion (L-PBF) applications i.e., they are optimized to perform exceptionally well under the high solidification and cooling rates characteristic of this additive manufacturing technique. When these alloys are employed in Direct Energy Deposition (DED) applications, such as Laser Metal Deposition (LMD), Wire+Arc Additive Manufacturing (WAAM), and Wire+Laser Additive Manufacturing (WLAM), they often fall short in terms of mechanical performance due to the relatively lower cooling rates compared to L-PBF.
• On the other hand, titanium alloy Ti-6Al-4V has long been the favored choice in the additive manufacturing community due to the ready availability of high-quality powder feedstock. However, there is no fundamental scientific basis to assume that Ti-6Al-4V should inherently show superior mechanical performance in additive-manufactured components. In fact, Ti-6Al-4V exhibits a notable decrease in fatigue and toughness properties due to the intrinsic porosity introduced during the additive manufacturing process. Consequently, post-process Hot Isostatic Pressing (HIP) is routinely applied to critical 3D printed components, increasing both production costs and erasing the initial microstructure achieved during printing.
Those drawbacks call for new alloy development, for both type of alloys.
In this presentation, we aim to introduce the methodologies used for the development of the new alloys, as well as the preliminary results achieved in these studies.

Speaker Country:

Belgium

Post-Processing of AM Parts / 11

Surface finishing of metal parts made by LPB-F process : application to complex aeronautical parts

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The surface finishing of complex metallic parts made by additive manufacturing, remains a challenge. Indeed, this kind of treatment is required to enhance the properties of the parts (cleanliness, mechanical properties, etc.) so that they are made compatible with their final use.

During this presentation, results of the FITFAME project (ESA GSTP GT1A-314MS), focusing on the finishing of additively manufactured components with complex geometries, will be shared.

Two case studies were selected for this project. In both cases, the selected elements were completely redesigned in order to exploit the benefits of additive manufacturing to improve functional performances while reducing weight. End-to-end manufacturing processes were proposed for the two components and evaluated from coupon level to full-scale demonstrators.

The first application case is a hydraulic manifold, belonging to the Ariane 6 thrust vector control (TVC) actuator. Laser Powder Bed Fusion (LPBF) processing in Scalmalloy was selected for the manufacturing. The manifold features bent and interconnected internal channels with different diameters, which constitutes a real challenge in terms of surface finishing. Different technologies were evaluated for the finishing of the inner of the channels and of the outer surfaces after the additive manufacturing process.

The second application case is a gear of Callisto reusable launch vehicle. E-beam melting (EBM) processing in Ti6Al4V was selected for the manufacturing. The gear features a peripheral groove with poor accessibility. Several finishing procedures were tested in order to provide a complete removal of particle contaminants from the surface and bring the surface roughness to low values.

According to the selected methodology, the most efficient route was chosen and applied to each demonstrator.

In this presentation, the efficiency of the selected surface finishing treatments, as well as the performances achieved with the re-designed and surface treated parts will be introduced. An overview of the project outcomes and lessons learned will be presented.

Speaker Country:

Belgium

Powder for MAM / 12

Numerical investigation on the homogeneity of the deposited powder mixture during the powder spreading process of PBF-LB/M

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A powder bed fusion – laser beam / metal (PBF-LB/M) process and hot isostatic pressing (HIP) combined producing route was developed to manufacture nitrogen (N) in high-alloyed stainless steels in which mechanically mixed base AISI stainless steel 304L (SS304L) powder and silicon nitride (Si3N4) powder was manufactured by PBF-LB/M and further homogenized by HIP. Due to the partially undissolved Si3N4 powder in the intermediate product, sufficient N-content was kept and pore formation was reduced in the final product. The greatest difficulty of this producing route is to maintain the homogeneity of the deposited powder mixture during the powder spreading process. Therefore, this study aimed to identify the influencing factors on the homogeneity of the powder mixture during the powder spreading process and to achieve the target N-content in the intermediate product. On the one hand, microstructural characterization by the scanning electron microscope (SEM) was conducted on the deposited powder mixture sampled from the powder bed in a PBF-LB/M machine for qualitative mapping of the local Si3N4 fraction and N-content. On the other hand, numerical studies based on the discrete element method (DEM) were carried out to study the effects of layer thickness, substrate surface roughness, and powder properties on the intermediate product. By cross-correlating the experimental and numerical results, the required optimal process conditions can be determined for PBF-LB/M.

Speaker Country:

China

Laser Melting, Electron Beam Melting & Direct Energy Deposition Processes / 13

Adaptive process control strategies for variable wall thickness in laser metal deposition: a framework utilizing articifical neural networks

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Adaptive process control strategies for variable wall thickness in laser metal deposition: a framwork utilizing articifical neural networks

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ABSTRACT

Laser Metal Deposition (LMD) offers significant potential for optimizing local component properties through local reinforcement or coating, leading to enhanced performance and functionality. Moreover, LMD finds extensive application in repair and remanufacturing processes, where precisely controlling material deposition is crucial for restoring components to their original specifications. However, realizing this potential requires the development of robust and dynamic process control strategies, including local and temporal power modulation.

In this context, this paper presents an approach to achieve a variable wall thickness in LMD based on an artificial neural Network (ANN) input. The framework utilizes a multilayer feed-forward neural network based on the principles of supervised learning. Input parameters for the ANN are derived from geometric data of the target geometry of a single track, while the process parameters necessary for achieving this geometry are captured in the output layer of the ANN. This allows to investigate the correlations between the input parameters laser power P, scanning speed v, and powder feed rate mp as well as the geometric output parameters (width w, depth d, and height h). Track width and height from experimental data extended by data from a developed melt pool model is used for the training data set. Experimental validation of the ML model is performed on a demonstrator geometry to show the control of the track geometry by realizing a given geometry with variable wall thickness by adaptive process control. The results show the potential of the proposed approach to improve quality and efficiency in LMD.

KEYWORDS

Additive Manufacturing (AM), Laser Metal Deposition (LMD), Machine Learning (ML), Remanufacturing

Speaker Country:

Germany

Tools, Space and Aircraft, Automotive and others / 14

3D-Master-Based Method for Optimizing the Cost Calculation of PBF-LB/M Manufactured Parts

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The 3D Master method aims to reduce effort and misinterpretation while transferring product information from the design office to the production department, thanks to 3D model files containing all the product manufacturing information (PMI).
Thus, for a metal additive manufacturing (MAM) part, the 3D Master method gives direct access to crucial data, such as the product's materials and 3D models associated with their respective geometric dimensions and tolerances (GD&T) for each manufacturing step. By providing this valuable set of data, the 3D Master can enable the automatic selection of the most relevant additive manufacturing (AM) technology regarding a specific MAM part and allows a more accurate calculation of the manufacturing cost.
This paper presents a method that relies on the 3D Master to automatize the calculation of precise manufacturing costs for MAM parts with powder-based fusion (PBF) processes. It is shown that an ideal set of information (raw and final part models and PMI) combined with a thorough theoretical and statistical approach to calculating the optimal volumetric energy density enables accurate manufacturing cost calculation. With the help of 15 reference MAM parts with three different geometrical complexity levels, it has been demonstrated that values lower than 10 % can be reached for the standard deviation of the normalized actual and calculated cost difference.
Our 3D-Master-based cost calculation method, when associated with a PMI generator powered by artificial intelligence (AI), provides a solid foundation for a commercial online platform offering a trustable quote for producing AM parts within a few minutes. A brief introduction is also given in this regard.

Speaker Country:

Switzerland

Laser Melting, Electron Beam Melting & Direct Energy Deposition Processes / 15

Influence of LPBF printing parameters on the porosity of Ni3Al for catalytic applications

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Porous materials have always been a necessary component in application of catalysts, fuel cells or capacitors in the field of energy conversion and storage. They can be obtained by a variety of production methods, however a novel emerging method has been demonstrated by the use of additive manufacturing. With laser powder bed fusion (LPBF) several printing parameters, such as laser power, hatching distance, layer height or beam diameter are available to modify the printing process and to create mechanically stable yet porous structure. Here, the influence of mentioned printing parameters on the porosity of in-situ alloyed Ni3Al is addressed. To investigate the inner pore structures as well as the elemental distribution and homogeneity of the samples, scanning electron microscopy was used. Within the larger pores, unmelted powder particles were found to have sintered to the walls. The porosity was quantified by means of light optical microscopy (LOM). Additional microcomputed tomography (μCT) measurements were conducted to verify the LOM results. Furthermore, μCT allowed the distinction between open and closed porosity by 3d reconstruction. With decreasing energy input, the lack of fusion porosity increases, while the size of the pores varies in dependence of the printing parameters. In summary, it is shown that it is possible to create bulk samples with a network of open pores suitable for future energy applications by means of LPBF.

Speaker Country:

Austria

Process- and Quality Control & Sustainability / 16

Maximizing Sustainability in Additive Manufacturing: A Comprehensive Study on CX Steel Powder Reusability via LPBF

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Metal powders used in additive manufacturing (AM) are expensive and energy-intensive to manufacture desired engineering parts. Reusing these powders reduces material waste, lowers production costs, and minimizes the environmental footprint of AM processes to support sustainable manufacturing routes. Therefore, this study investigates the reusability/degradation of CX steel powders via laser powder bed fusion (LPBF) through the employment of multiple powder handling strategies and in/ex-situ process monitoring. The impact of powder handling and reusing strategies, up to a total of 50 builds, are assessed based on the microstructure and mechanical properties of LPBF-built components. Microstructural analysis is conducted to evaluate the evolution of powder morphology throughout manufacturing cycles. Mechanical properties, assessed using hardness, tensile and impact toughness tests, are meticulously examined to determine any potential degradation due to powder reuse. The findings demonstrate that while the powder morphology undergoes a transformation upon completion of each build slightly, the LPBF-built CX steel exhibits negligible alterations in its mechanical properties after post-process heat treatments. This remarkable outcome is attributed to the effectiveness of the implemented powder handling strategies, which mitigate potential detrimental effects associated with powder recycling. These observations signify the viability of reusing CX steel powders in LPBF without compromising the structural integrity of LPBF-built parts. This paves the way for significant advancements in sustainability efforts within the domain of AM by reducing waste generation and minimizing the environmental impact of the LPBF process.

Speaker Country:

Singapore

Process- and Quality Control & Sustainability / 17

Implementing an active strategy to the conservation and advancement of Laser Powder Bed Fusion (LPBF) powder feedstock

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Additive manufacturing (AM), particularly Laser Powder Bed Fusion (LPBF), is rapidly advancing due to its increasing adoption as an advanced manufacturing technique capable of producing intricate and reliably consistent parts. However, this heightened interest in AM has prompted concerns regarding its sustainability. In response, a recent study conducted a comprehensive experimental effort spanning several months, completing over 25 prints of a high-alloyed corrosion-grade stainless steel. The primary objective was to extend the lifespan of LPBF powder feedstock by salvaging powder that would otherwise be discarded and identifying the properties that render it unusable. Additionally, the study aimed to mitigate the detrimental effects of unusable powder by reapplying it into the LPBF print cycle and evaluating the resulting part quality. Moreover, alternative applications for powders deemed unsuitable for LPBF technology post-rejuvenation were explored. Throughout the printing window, various avenues for powder disposal were identified, including i) oversized powders collected post-sieving, ii) powders captured in the LPBF system's filtration system, and ii) powders contaminated with oxidation effects that have exceeded their reusable lifespan. These powders underwent extensive physical (such as powder size distribution, flowability, porosity, and morphology) assessment and chemical property analyses to identify deviations from virgin or reusable LPBF feedstock powders. Based on the identified deviations, rejuvenation methods such as milling of larger particles were applied, and the powders were reintroduced into the LPBF process. The results of these experiments contribute to improving the sustainability of LPBF technology and improve industry reliance on LPBF.

Speaker Country:

Singapore

Additive Design & Engineering / 18

Examination of the Influence of Contact Regions in Island Scan Strategies on the 3D Metal Printing Process

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Powder Bed Fusion of Metals with Laser Beam is an emerging Additive Manufacturing technology that builds metal parts layer by layer from metal powder. For each layer, metal powder is scanned and fused selectively by a laser beam to create a solid part. The laser follows a predetermined path at a specified speed and power defined in the scan strategy. This scan strategy determines the manufactured parts' quality, material properties, and build-up rate. In island scan strategies, the laser

beam scans the geometry of a layer patch by patch.
Contact regions between adjacent patches are located by the overlap of the patches within the same layer. They can be arranged directly on top of each other, shifted in one direction, or shifted in two directions for preceding layers. This work investigates the influence of the overlap and geometric arrangement of patches on part quality. The results show a non-trivial reduction of the risk of cracks for the multidimensional arrangement of the contact regions, as well as a lack of porosity for high-overlapping regions.

Speaker Country:

Germany

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Refractory-based complex concentrated alloys fabricated by means of L-PBF and in-situ alloying

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Laser powder bed fusion (L-PBF) has become a widely used process in the additive manufacturing of metals, for it combines the assets of a high degree of freedom in the design of parts with a high flexibility in the production process itself. In addition, material properties of L-PBF parts have been demonstrated to be able to equal or, in some cases, even exceed those of comparable, yet conventionally manufactured parts. Here, we address a further aspect inherent to L-PBF: the possibility of producing varied alloys of complex chemical composition based on elemental powders. The primary focus of our investigation is on refractory-based complex concentrated alloys (R-CCAs) within the Ti-Al-Cr-Mo(-Nb) system. Recently, these alloys have been attracting increasing attention because of their promising high-temperature properties. A common production method of bulk R-CCAs is conventional casting, which is, however, according to literature also associated with a strong segregation phenomenon. In this work, the potential of L-PBF is explored with regard to the fabrication of fine-grained, homogeneous bulk material from powder blends. R-CCA specimens were prepared by means of in-situ alloying. According to this approach, an alloy was formed from a pre-mixed blend of elemental powders directly in the powder bed of the 3D printer, and the best possible homogeneity was obtained by making use of the small melt pools and a high localized heat input inherent to the L-PBF method. Different printing parameter sets were tested. Based on X-ray diffraction as well as light-optical and scanning electron microscopy, these parameter sets were further correlated with the microstructural features of the printed parts. In this presentation, the achieved porosity, homogeneity, and prevalent crystallographic phases will be critically discussed.

Speaker Country:

Austria

Process- and Quality Control & Sustainability / 20

Developing Zr-Based Bulk Metallic Glass through Laser Powder Bed Fusion Employing Second Generation of Non-Standard Beam Shaping Technology

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Limitations in bulk metallic glass (BMG) additive manufacturing arise from the relaxation of solidified layers, diminishing free volume, and adversely affecting part quality. The first generation of freeform laser beam shaping technology has demonstrated its capacity to produce Zr-based BMG test coupons devoid of any detectable crystalline phases, thereby minimizing the reheating of preceding layers or tracks; an achievement that could revolutionize material processing in LPBF. Modifying the laser beam shape additionally offers control over the molten pool's configuration and temperature distribution, encouraging productivity. Employing this uniform beam distribution results in a shallow and molten pool. The second generation of this technology with improved laser power handling stability and developed the capability to freeform shaping, in combination with laser tool path optimization approaches, has been used in this investigation, showing an enhancement in the 3D fabrication of Zr-based BMGs

Speaker Country:

Austria

Post-Processing of AM Parts / 21

Metal binder jetting and post treatment of a nickel free stainless steel

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Additive manufacturing processes are becoming increasingly popular. Metal Binder Jetting (MBJ) is emerging as a promising technique for high productivity in the simultaneous production of highly complex components. The limited number of materials available for MBJ creates a high potential for research. Especially in the field of nickel-free austenitic stainless steels, the choice of materials is limited.

In this study, a newly developed metal powder X15CrMnMoNi17-11-3 was fabricated by MBJ and samples with a high density greater than 97,2 vol% were obtained. The mechanical properties due to sinter-based additive manufacturing microstructures were elaborated. After a hot isostatic pressing (HIP) post-treatment, an increase in strength of about 10% could be achieved. Microstructural analysis and thermodynamic calculations were used to explain this differences.

Speaker Country:

Germany

Process- and Quality Control & Sustainability / 22

Successful remanufacturing through data-based decision-making and intelligent process planning

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Remanufacturing is a comprehensive and rigorous industrial process by which a previously sold, leased, used, worn, remanufactured, or non-functional product or part is returned to a like-new, same-as-when-new, or better-than-when-new condition from both a quality and performance perspective, through a controlled, reproducible, and sustainable process. Remanufacturing is an archetype of a hybrid process.
A hybrid process chain combines additive and subtractive processes. Additive processes serve the application of material, for example to enrich worn areas or holes with additional material. Subtractive processes involve the removal of material and substitute additive processes to restore the properties of the functional surfaces in a precise way.
In this work, a highly automated hybrid process chain for remanufacturing purposes is presented. The process includes process specific tool path planning for subtractive (milling) and additive (wire arc additive manufacturing) manufacturing steps. Before the actual manufacturing, control parameters for the processing are estimated based on temperature (additive) and cutting force (subtractive) FEM simulations. During manufacturing these parameters are controlled, and anomalies are detected.
The results of the automated CAM planning, the target-performance comparison for the control parameters and the final part quality are presented. Lastly, the potential of Additive Manufacturing in the field of circular economy is evaluated.

Speaker Country:

Germany

Process- and Quality Control & Sustainability / 23

Advancing Metal Additive Manufacturing through Innovative Optical solutions

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The landscape of LPBF process has evolved significantly during recent years, exceeding its origins in simple test production and prototyping towards manufacturing functional parts for real-world applications. Despite its potential, the current limitations in cost and efficiency of the process have held back the broader application of metal 3D printing. Various solutions have been proposed, yet some of these new approaches either increase maintenance costs or introduce unintended effects on the final quality of the parts.

In this talk, the recent developments of the advanced optical platforms at Switzerland Innovation Park will be presented. Modifying the laser wave front by advanced free form laser beam shaping

based on liquid crystal on silicon, integration of multiple laser sources (continuous and ultra short pulsed),application of different wavelengths (e.g., blue light), advanced monitoring techniques, and finally innovative AI-based software aimed at analyzing, correcting, and optimizing LPBF laser toolpaths to enhance both quality and productivity are among the applied solutions.
These innovative solutions significantly enhance our control over the manufacturing process by enabling us to modify the temperature distribution during the LPBF process. The initial results indicate the improvement of productivity to tenfold per laser. This efficiency is evidenced by a reduced energy requirement to achieve densities greater than 99.9%, alongside a substantial reduction in spatter production.
This holds immense significance, not only in improving process efficiency but also in facilitating the printing of challenging materials like high-strength Aluminum-based alloys, Ni-based alloys, reflective materials such as gold and copper, as well as bulk metallic glasses.

Speaker Country:

Switzerland

Sinter based MAM processes / 24

Heat treatment challenges for direct and indirect AM methods

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This study reports on the oxygen content measured by EDX analysis of samples which were heat treated in either atmospheric pressure or in high vacuum. The samples were manufactured by Laser-Powder-Bed Fusion (L-PBF) technology, where subsequent heat treatment is required. In theory and in practice, it could be shown, that oxygen in high vacuum is always lower than at atmospheric pressure. This results in a reduction in oxidation by 38 % on the titanium (Ti6Al4V) samples used in this report.

Additionally, a brief outlook is given on handling different types of binder during heat treatment for indirect methods of Additive Manufacturing.

Speaker Country:

Germany

Tools, Space and Aircraft, Automotive and others / 26

Investigation of design potentials for welding PBF-LB/M manufactured pure copper busbars to conventional copper conductors

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The advantages of the PBF-LB/M process, such as geometric complexity due to increased design freedom or function integration, offer great potential for optimizing products in the automotive sector. However, it often does not go beyond prototyping and small series, as productivity is too low for the required quantities and economies of scale can rarely be exploited lucratively. In the field of e-mobility, hairpin technology has dominated the copper winding of traction drives in recent years. The research field of additive manufacturing of copper windings for e-machines has made significant progress in recent years, but additive manufacturing has not yet prevailed over conventional technologies, despite the product advantages.
In this study the approach of transferring the complexity of conventional hairpin windings into additively manufactured busbar assemblies and then joining them to conventional windings using laser welding is therefore researched. The advantage is that the less complex components of an electric machine can still be manufactured conventionally with high productivity.
For this purpose, different design variants of the connection geometry are developed at the interconnection area of the busbars and manufactured from copper using PBF-LB/M. The manufactured design variants are then joined to the conventional copper conductors using a laser welding process. A comprehensive analysis and evaluation of the connections is then carried out in four main categories. For this purpose, the design, the electrical conductivity, the critical heating and the weldability are examined. Three designs with promising results and requirement fulfilling properties were identified. The results show that functions like form fitting can directly be added to the AM parts and by the complexity transfer, both advantages of additive manufacturing and conventional manufacturing can be combined by means of laser welding.

Speaker Country:

Germany

Additive Design & Engineering / 27

Expediting additive manufacturing with ICME

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Integrated Computational Materials Engineering (ICME) expedites integration of Additive Manufacturing (AM) in industry by addressing emerging challenges. Common challenges include rapidly identifying process windows to avoid processing defects and optimizing materials compositions to align with property requirements of AM-fabricated components for high demand applications. This presentation highlights an ICME framework designed to accelerate optimization of processing parameters and development of material solutions for single or multi-material additive manufacturing, enhancing component performance through addressing the process-structure and structure-property relationships. This approach not only mitigates manufacturing defects and optimizes material compositions, but also markedly reduces development costs and time in AM. By leveraging predictive modeling of microstructures and properties and therefore enabling composition and process optimization, ICME plays a critical role in facilitating the swift adoption and industrialization of AM technologies.

Speaker Country:

Sweden

Laser Melting, Electron Beam Melting & Direct Energy Deposition Processes / 28

L-PBF process parameter optimization for thin structures

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Laser Powder Bed Fusion (L-PBF) technology offers the capability to manufacture a diverse range of components and features, which span from thin or hollow structures to massive elements. Typically, the primary parameters in the L-PBF process, such as laser power, scan speed, and hatching distance, are optimized for components with significant print areas, which can be divided into core and border regions. Nevertheless, L-PBF technology also empowers the creation of intricate lattice structures, based on the repetition of thin struts and nodes or thin curved surfaces. In the case of thin structures, the printed area's width often falls below 10 times the meltpool width, potentially resulting in a notable increase in material porosity or surface roughness.
In the present work, the effects of the laser scanning parameters and the scanning strategy on the material density, microstructural features, and surface roughness were experimentally investigated. A wide set of process parameters and scanning strategies has been developed. Thin planar specimens, having a section angled 60° to the baseplate and a vertical one, were printed. The surface roughness of the vertical and angled surfaces was measured using an optical profilometer. The material microstructure and the local surface irregularities were investigated through metallographic sections containing the specimen build direction. The most promising process parameter sets were validated through a specifically devised specimen, which consisted of a sinusoidal-shaped thin foil, built in the vertical direction. It presented a series of upward- and downward-facing surfaces with an angle ranging from 90° to 10° to the baseplate.
The correlations between the scanning strategy, energy density, surface roughness, and material porosity were finally obtained. It allowed us to define a robust strategy for the process parameters optimization in the case of thin structures.

Speaker Country:

Italy

Laser Melting, Electron Beam Melting & Direct Energy Deposition Processes / 29

Optical Coherence Tomography (OCT) for Real-Time Layer Thickness Monitoring in High-Speed Laser Metal Deposition process

Authors: Simone Maffia[1]; Christoph Krull[1]; Helena Wexel[2]; Frederik Zanger[2]; Stephan Koß[3]; Tobias Stittgen[1]

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In the field of Laser-Based Directed Energy Deposition (DED-LB) processes, real-time process monitoring is a critical aspect that ensures the quality and integrity of the final product. While established methods exist for monitoring other process signatures such as molten pool size and temperature, the monitoring of the layer thickness presents a unique challenge, especially for processes which require

layer thicknesses down to 50 µn.
This work delves into the complexities of real-time layer thickness monitoring in the High-Speed DED-LB process, like the Ponticon's 3D Dynamic Material Deposition (3DMD) process. The 3DMD process, characterized by its high speeds up to 200 m/min and the need for precise standoff distance maintenance, necessitates a fast responding and robust method for layer thickness monitoring. Existing solutions, such as post-layer completion laser scanning, and the use of lateral and coaxial triangulation systems, have been explored. However, these methods often come with limitations. Layer thickness is also difficult to predict by other monitoring variables, such as temperature and molten pool size. Hence, the research of an alternative and more robust method is of great industrial interest.
This research introduces the use of an Optical Coherence Tomography (OCT) system integrated into our Ponticon pE3D machine, comparing it to other layer height measuring techniques like line laser scanner. The OCT system has demonstrated its capability to accurately monitor layer thickness in real time, and to detect process shifts or drifts due to variations in process parameters or geometric characteristics of the realized part as soon as they occur This demonstrates the feasibility of effectively using the OCT system for monitoring the layer thickness in the Hish-Speed DED-LB process, opening the path also for the active control of the layer thickness in the 3DMD processes.
Through this work, we aim to shed light on the potential of the OCT system in overcoming the challenges of layer thickness monitoring in High-Speed DED-LB process, paving the way for significant advancements in Metal Additive Manufacturing.

Speaker Country:

Germany

Laser Melting, Electron Beam Melting & Direct Energy Deposition Processes / 30

High-throughput exploration of alloys for additive manufacturing using experimental and machine learning approaches

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The development of novel alloys that are specifically tailored for additive manufacturing (AM) is one of the current major challenges of the AM material science research community. However, the existing approaches can be further made efficient in exploring the vast material and process design space in AM.

In the present work, we applied extreme high-speed laser material deposition (EHLA) to rapidly screen a wide range of chemical compositions and processing conditions within a single specimen. Combined high-throughput sample production and alloy characterization were used to explore the microstructure evolution and mechanical properties of additively manufactured advanced high strength steel. In-situ alloying of a base alloy (an austenitic steel) with pure Al in the range of 0-8 wt.% and flexible adjustment of the volumetric energy input enabled high-throughput sample production consisting of 20 individual chemistry-EHLA parameter combinations. These conditions were characterized using large-area EBSD analysis combined with EDS and spherical micro indentation stress-strain protocols. The significant influence of Al content and processing conditions on the

behaviour of the investigated metastable base alloy allowed for efficient exploration of the respective mechanical properties. The derived process-structure-properties relationships are discussed based on the underlying physical mechanisms. The experimentally identified microstructure-property (SP) relationship was generalized using a machine learning (ML) approach. With this selected approach, the data-driven SP relationship can be described in terms of its uncertainty. In addition, the applicability of the methodology is critically evaluated.

Speaker Country:

Germany

Plenary Talk / 31

Process development supported by machine learning for demanding materials and applications - insights from development and customerbenefits

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This study investigates the utilization of machine learning for optimizing additive manufacturing processes, focusing on Laser PowderBed Fusion (L-PBF) and Laser Metal Deposition (LMD). By leveraging domain expertise, machine learning demonstrates significant potential in enhancing efficiency and quality. Through specific case studies, we highlight the benefits and limitations of employingmachine learning in additive manufacturing, emphasizing the importance of informed user engagement for realizing tangible customer advantages.

Speaker Country:

Germany

Plenary Talk / 32

Laser powder bed fusion: what we have achieved in 30 years

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The development history of LPBF began 30 years ago at the Fraunhofer ILT in Aachen. LPBF is now the most important additive manufacturing process for metalliccomponents. This presentation will take a look back at the beginnings of the process and the key development steps, present the current technological and economic status and provide an insight into current development trends.

Speaker Country:

Germany

Plenary Talk / 33

Closed-loop laser control in L-PBF current progress and limitations

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Within the presentation an overlook of Aconity3D's endeavor in providing the first closed-loop power laser control of the applied laser sourceswithin L-PBF is given. At this, current progress and limitations are provided, highlighting the state of the art in fully controlled first-time right approaches which forms a precondition for truly industrial manufacturing via Additive Manufacturing.

Speaker Country:

Germany

Plenary Talk / 34

Industrialization in Metal Additive Manufacturing – From Prototyping to Production

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The different technologies in Metal Additive Manufacturing evolved to a technology and manufacturing readiness to apply them in serial production of functional as well as critical parts. Still industrialization in datamanagement, automation and lean production is ongoing to enable a stronger penetration in the manufacturing sector. An overview with production examples is given on the progress and achievements being made in several production technologies paving the wayfor broader acceptance of Metal Additive Manufacturing by end users.

Speaker Country:

Germany

Laser Melting, Electron Beam Melting & Direct Energy Deposition Processes / 35

On the interaction of ceramic fillers with metal matrix during laser action under LPBF synthesis

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Fabrication of metal matrix composites with improved properties requires an understanding of how laser action interacts with ceramic fillers and metal matrices in laser powder bed fusion (LPBF) synthesis. This work investigates the dynamic behavior and chemical reactions that occur during LPBF synthesis when laser energy is applied to the interface between metal matrices and ceramic fillers. The mechanisms underlying the interaction process are elucidated through a combination of computer modeling and experimental investigation, paying particular attention to the phenomena of diffusion, melting, solidification, and phase changes. A particular focus is on understanding how the laser parameters – power, scanning speed, and energy density – affect interfacial interactions and subsequent microstructural development. In addition, the influence of the size, shape, and composition of the ceramic filler on the morphology of the ceramic-metal interface, the formation of intermetallic compounds, and the overall properties of the composite is investigated. The insights gained from this research advance the use of additive manufacturing to produce high-performance 3D components for a range of industrial sectors by optimizing LPBF processes for the production of metal matrix composites with tailored microstructures and enhanced mechanical, thermal, and electrical properties.

Speaker Country:

Deutschland

36

Enhancing Tool Durability through Additive Manufacturing Innovations

Author: Josef Hodek[1]

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Forging tools endure extreme conditions, being subjected to both high temperatures and mechanical stresses on their operational surfaces. Enhancing resistance to external influences is crucial for extending their service life. This paper investigates the efficacy of incorporating a material layer, manufactured via Additive Manufacturing using Directed Energy Deposition (DED), to bolster the durability of forging tools and dies. Specifically, it focuses on the application of a protective layer made from Nimonic 80A and a combination of Nimonic 80A and tungsten carbide material deposited on tool steel. The study encompasses comprehensive analyses, including powder characterization, determination of depositing parameters, evaluation of mechanical properties, and pin-on-disc measurements. Furthermore, Finite Element (FE) analysis is employed to simulate wear analysis processes.

Speaker Country:

Česko

Tools, Space and Aircraft, Automotive and others / **37**

Introduction of New Powder Alloys for Metal 3D Printing

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Additive manufacturing technology has initiated a transformative phase in the industrial landscape, particularly in the realm of metal 3D printing. A key element for the success of this revolutionary manufacturing method lies in the availability of high-quality metal powders that meet the specific requirements of various applications. This work sheds light on the innovative development of new alloys for metal 3D printing by a leading powder manufacturer. The first alloy presents a cobalt-free alternative to the established 1.2709 maraging steel, aiming to reduce dependence on cobalt-containing materials while offering comparable mechanical properties. By analyzing printability, strength, and hardness, the suitability of this alloy for various applications is assessed.
The second alloy showcases exceptional corrosion and wear resistance, specifically engineered for compatibility with glass fiber-reinforced plastics. This alloy aims to enhance the durability of tools and components in environments with abrasive materials. The investigation focuses on optimizing alloy composition and evaluating its mechanical properties and suitability for the 3D printing process.
Introducing these new alloys expands the range of available materials for metal 3D printing, opening possibilities for innovative applications across various industries.

Speaker Country:

Österreich

Sinter based MAM processes / 38

Digital Goldsmith: Evaluating the Traditional Methods & Exploring the Potential of Binder Jetting 3D Process for the Indian Jewelry Industry

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The Indian gold jewelry industry, a cornerstone of the nation's cultural heritage and economic engine, faces challenges like rising gold prices and limited design flexibility in traditional manufacturing methods. This paper explores the potential of Binder Jet 3D printing as a disruptive innovation to revolutionize the industry. We delve into established gold jewelry manufacturing processes, highlighting their limitations in terms of material waste and design constraints. We then introduce Binder Jet 3D printing technology, explaining its core principles and emphasizing its advantages for jewelry production: reduced waste, intricate design freedom, and the creation of lightweight pieces. Furthermore, the paper analyses the current landscape of the Indian gold jewelry market, including consumer preferences and trendy design styles. We identify potential opportunities for Binder Jet 3D printing to cater to modern trends in design and personalization (mass customization). It envisions a future where sustainability, innovation, and the fusion of traditional craftsmanship with innovative technology create a glittering future for this vibrant sector.

Speaker Country:

India

Sinter based MAM processes / 39

MoldJet® - Productive sinter-based additive manufacturing for a wide range of components and materials

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The limitations of existing additive manufacturing processes often include long printing times and time-consuming post-processing steps due to the removal of components from a powder bed or the removal of support structures.
The MoldJet® process developed by Tritone® Technologies Ltd. is a sinter-based additive manufacturing process that is equally suitable for the productive fabrication of metal and ceramic components. Compared to alternative AM technologies, this process is characterized by the fact that no support structures consisting of the processed component material are required. As part of the powder-free printing process, the MoldJet process also has the potential to avoid time-consuming depowdering following the printing process.
Regarding the printing process, the MoldJet technology also allows simultaneous component production on up to six building platforms in just one production system, so that large series can be economically realized in addition to prototype and small series production.
It will be shown how the MoldJet process compares to other technologies in the field of additive manufacturing. Furthermore, it will be explained how the layer-by-layer printing process is carried out without using loose powder. In addition, it is explained how the printing process, the subsequent process chain and the processable feedstock systems enable the production of metal as well as ceramic components with an almost unlimited variety of materials and designs.

Speaker Country:

Germany

Laser Melting, Electron Beam Melting & Direct Energy Deposition Processes / 40

Process development and risk assessment for processing magnesium alloys using LPBF technology

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Lightweight design is very closely associated with additive manufacturing. Besides the design possibilities offered by this technology, the material used also plays a key role. Especially in the LPBF process, the production of the powder and the processing of the material is a major challenge. This applies in particular to magnesium alloys as a lightweight material. Due to its low density and good strength and rigidity properties, this material is ideal for lightweight engineering applications. The basis of this paper is a risk assessment (including a detailed FMEA and measures to minimize risks) for the processing and handling of magnesium powder in the LPBF process. As part of the practical tests, several test specimens with existing parameters for AZ91 were printed and their properties (relative density, microstructure and bonding behavior) have been analyzed. By adjusting the alloy composition (improved evaporation characteristics) and optimizing the process (e.g. optimum inert gas flow, platform temperature) and the process parameters, it is possible to process magnesium more economically in the LPBF process. The result of the research activities is the additive manufacturing of a demonstrator component made of magnesium, which in addition to a high relative density (>99%) also has the dimensional accuracy and surface quality typical for the LPBF process.

Speaker Country:

Austria

Sinter based MAM processes / 41

Overview of emerging sinterbased AM technologies

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Laser Powder Bed Fusion (LPBF) remains a predominant process in the additive manufacturing for metals, and is widely adopted by equipment manufacturers, within research circles, and across a spectrum of industrial applications. Despite its prominence, LPBF faces inherent limitations regarding the complexity of geometries it can produce, the diversity of processable materials, and its overall productivity levels. In contrast, other emerging technologies such as Electron Beam Melting (EBM) and especially sinter-based additive manufacturing (SBAM) methods such as Metal Binder Jetting (MBJ) and Fused Filament Fabrication (FFF) are increasingly being recognized for their versatility, particularly in their capacity to handle a wider array of materials beyond the typical metal alloys suitable for LPBF, thus offering solutions where LPBF may not be applicable. Additionally, emerging techniques like MoldJet (MJ), Lithography-based Metal Manufacturing (LMM), and Cold Metal Fusion (CMF) are entering the market and drawing considerable interest for their innovative process new part possibilities. To get significant market share, it is also becoming clear that intensive development is needed in auxiliary processes like heat treatment and sinter simulation. This overview highlights the current state of key sinter-based processes and compares them with LPBF and EBM. Moreover, the paper discusses potential future developments and evaluates the market prospects of various SBAM technologies.

Speaker Country:

Germany

42

TiAl6V4 bistable mechanism produced by Laser Powder Bed Fusion

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The bistable mechanisms use the deformation of the compliant segment (elastic deformation of the material) to transition from one equilibrium position to another. The deformation character eliminates friction and improves the reliability of the mechanism. Both the numerical model and experiments were used to determine the parameters of the bistable mechanism. The mechanism was designed to hold a load of 175 N, which corresponds to the switching force from the second to the first position. Finite element analysis (FEA) was used to determine the influence of the geometry parameters on the switching forces of the bistable mechanism. The material model for the FEA was defined based on the bending properties of TiAl6V4 lamellae, which represent the compliant segment. The modulus of elasticity and yield strength of the material varied with the thickness of the lamellae. The designed mechanism was produced by laser powder bed fusion (LPBF). The results showed good agreement between the experiment and the FEA analysis. The force required for the transition from the second to the first equilibrium position reached 173 N, which fulfilled the initial condition. Therefore, the mechanism could be used in applications that require minimization of energy for long-term control. Typically, these are battery-powered systems in space.

Speaker Country:

Czech Republic

Laser Melting, Electron Beam Melting & Direct Energy Deposition Processes / 43

Investigations on the numerical modeling of the plasma arc wire additive manufacturing process using a Ti-6Al-4V alloy

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Additive manufacturing using wire arc technology has become increasingly popular in the generation of large-scale and complex shaped 3D parts. However, heat input and solidification shrinkage during deposition causes distortions and residual stresses. These can significantly affect the geometric accuracy and mechanical properties of the deposit. Process simulation offers the possibility to predict the evolution of such stresses and distortions numerically. Possible violations of geometric tolerances and high stress concentrations can be identified in advance. Expensive trial-and-error can be reduced or eliminated.
The investigations of this study focus on the precise thermal calibration of the numerical simulation of the plasma arc wire additive manufacturing process using a Ti-6Al-4V alloy. This involves examining variations in thermal boundary conditions, such as convection and efficiency, as well as the geometries of heat sources when simulating the welding process for both the initial and subsequent layers of a thin-walled structure. Additionally, methods are presented on how simulation can be used to adjust process parameters or build strategies in order to reduce geometric deviations.

Speaker Country:

Österreich

Process- and Quality Control & Sustainability / 44

Advancements in Wire-Based Aluminum Additive Manufacturing: Molten Metal Deposition, Parameter Optimization, and Finite Element Analysis

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Molten Metal Deposition (MMD) represents an advanced wire-based aluminum additive manufacturing (AM) methodology wherein wire feedstock is directly liquified and extruded onto a heated substrate. This technique obviates the necessity for auxiliary energy sources such as lasers, as well as binders or additional support structures, thereby mitigating thermal stress implications and enhancing throughput. A distinctive attribute of MMD technology is its capacity to facilitate the automation and fabrication of high-strength aluminum alloys, specifically within the 6xxx and 7xxx series. To expedite the process of parameter optimization inherent to this method, a comprehensive finite element analysis (FEA) is undertaken. This involves the employment of an element-birth technique to accurately model the dynamic process conditions prevalent during deposition. Subsequent to the computational analysis, experimental validation is conducted to ascertain the thermal profiles of the manufactured component, ensuring congruence with the simulated outcomes. The paper elaborates on the resultant model's efficacy in enabling the fabrication of diverse geometrical configurations.

Speaker Country:

Belgium

Process- and Quality Control & Sustainability / 45

Material Circularity Through Reusing LBPF AlSi10Mg Waste in 3DPMD

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This study explores a sustainable approach within the metal Additive Manufacturing (AM) field by focusing on the reuse of AlMg10Si waste powder from Laser Beam Powder Bed Fusion (LBPF) processes in Plasma Directed Energy Deposition (DED). Aimed at advancing material circularity, particularly for the automotive industry, this research investigates the mechanical properties and heat treatment effects on recycled AlSi10Mg specimens, a material well-regarded for its strength and lightweight characteristics crucial in automotive applications.

We embarked on a methodical investigation to evaluate the potential of repurposed LBPF AlSi10Mg waste in fabricating parts via plasma DED. The study analyzed porosity, hardness, tensile strength, and the impact of T6 heat treatment on these recycled materials. The process involved preparing the AlSi10Mg waste powder, employing it in plasma DED to create test specimens, and subsequently assessing their mechanical integrity through standardized testing protocols. A selected group of these specimens was further subjected to T6 heat treatment to determine its effectiveness in enhancing the material properties post-recycling.

Preliminary results indicate that recycled AlSi10Mg powder is not only viable for plasma DED processes but, with proper parameter optimization and post-process heat treatment, can yield materials possessing comparable mechanical properties to their virgin counterparts. Specifically, the application of T6 heat treatment significantly improved the mechanical performance of the specimens, highlighting its potential to offset the typical drawbacks associated with recycled materials, such as increased porosity.

Our findings advocate for a circular economy model in metal AM, emphasizing the reutilization of LBPF waste powders. The successful integration of recycled AlMg10Si in plasma DED processes opens new avenues for sustainable manufacturing practices in the automotive sector, promoting environmental stewardship while maintaining the performance standards critical to the industry. This research not only paves the way for increased material efficiency and sustainability in AM but also aligns with broader environmental objectives by demonstrating practical pathways for waste reduction and resource optimization in industrial manufacturing.

Speaker Country:

Germany

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Geometry Adaptive Processing Strategies for Laser Powder Bed Fusion

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In the Laser Powder Bed Fusion (LPBF) process, metallic components are manufactured layer by layer by selectively melting metal powder using laser radiation. While the additive manufacturing principle allows parts ofalmost unlimited complexity to be produced, LPBF process control strategies are largely static according to the state of the art and only take into account the component geometry to be manufactured to a limited extent. In practice, this results in locallyvarying process conditions with deficits in component quality, process robustness, restrictions in design freedom such as the need for support structures and a relatively low build-up rate. Using the example of the titanium alloy TiAl6V4, the deficits of conventionalLPBF process control are shown in the present work and an adaptive LPBF process control is developed on this basis, in which the LPBF process parameters, such as the laser power, are adapted locally for specific geometries. The adaptive LPBF process controlavoids local material elevations and undesirable deviations in the melt pool dimensions without changes to the system hardware, produces test specimens with overhang angles of up to 10° without supports and increases the real build-up rate by over 20 %. Inaddition, the adaptations to the system and control technology required for adaptive LPBF process control are identified and implemented. The transferability of adaptive LPBF process control to complex components is demonstrated by developing a software demonstratorfor generating the build data.

Speaker Country:

Germany

Plenary Talk / 47

Integrated Multi-Scale Solutions for Accelerated Additive Manufacturing Materials and Process Development and Qualification

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Additive Manufacturing technologies are growing rapidly and moving towards industrial-grade production technology; however the development and qualification of materials and processes remain time-consumingand costly challenges for faster AM adoption. An integrated multi-scale approach designed to accelerate AM materials and process development and qualification will be discussed as a potential solution to overcome these challenges. Our approach combines smartDOE methods, high throughput materials testing and characterization, and process monitoring and control to enable rapid and efficient qualification of new AM materials and processes. Smart utilization of non-destructive testing (NDT) techniques, as well asan Integrated Computational Materials Engineering (ICME) approach, can significantly reduce the time and cost required for materials and process development and qualification in both DED and L-PBF AM technologies.

Speaker Country:

USA

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L-PBF OF DIFFERENT TITANIUM ALLOYS MIXED WITH MOLYBDENUM: STATIC AND DYNAMIC MECHANICAL PROPERTIES

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In this research, investigation is focused on Laser Powder Bed Fusion (L-PBF) of non-standard titanium-molybdenum-aluminium-vanadium alloys. The aim of the research is to develop additive manufacturing (AM) process parameters that can achieve full density of titanium alloys with different molybdenum contents with satisfactory static (tensile strength) and dynamic (fatigue behaviour) mechanical properties. One expected application are printed implants with elastic modulus closer to human bone. Three powder mixtures were prepared in the drum mixer: Ti15Mo consists of 85 wt% of a cp-TiGd2 mixed with 15 wt% of Mo, and 90 and 85% Ti6Al4V with 10 and 15 wt% Mo, respectively. Additionally, influence of printing orientation and different surface treatments on surface topography and fatigue behaviour is investigated and discussed.

Speaker Country:

Austria

Powder for MAM / 49

Producing Light Structures through Additive Manufacturing and Using Upcycled Feedstocks

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Weight reduction is crucial for transport industries (like aerospace), it is possible to achieve through topological optimization or by implementing lattice structures. This objective can be obtained by additive manufacturing processes. Besides, sustainability concerns are important and the use of upcycled powder feedstocks can be noteworthy. In the current study, we present an upcycling approach to produce metallic feedstock powders for additive manufacturing purposes. The construction of light structures is evaluated using two methodologies: 1) applying the Parametric Identification Process (PIP) as a computational method to evaluate the impact of density on the mechanical behaviour of printed materials; 2) implementing lattice structures to produce strong shallow walls.
Input materials used for this study involved commercial powders (AISI 316L and AlSi10Mg) and upcycled ones. Regarding the latter type, metallic chips received as machining by-products were transformed into powder feedstock by applying mechanical milling. It is a fusion-less solid-state process that uses less energy than the melting process. This upcycling method adds more value to MCs than downgrading. Powder characteristics are essential, which means, particle size distribution of 20 to 63 µm and 50 to 150 µm for direct energy deposition and powder bed fusion processes, respectively. However, the success of using a broader range (38 to 212 µm) with irregular-shaped particles was already evaluated for the former process in our previous studies. Moreover, particle shape (as rounded as possible) and flowability are essential as well. Selective laser melting was used for printing samples with different densities and direct energy deposition was used for printing upcycled feedstocks. Powder analyses were loose and tap densities measurements accompanied by a flow test. Characterizations of bulk materials involved density measurements, microstructural observations (using optical and scanning electron microscopy) and mechanical properties such as hardness and tensile tests. This study has been supported by New Space Portugal PR192303 and LAETA-DOI: 10.54499/UIDB/50022/2020.

Speaker Country:

Portugal

Opening & Plenary Talk RWTH Aachen / 50

From Science to Industry - Sustainable Innovation in a High Tech Eco System

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Speaker Country:

Plenary Talk / 51

The world's first emission-free steel powder for additive manufacturing

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Speaker Country:

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Hidden Life Cycle Impacts of Metal AM in Regulated Industries

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Additive Manufacturing (AM) has become increasingly popular in recent years due to its capability for rapid and on-demand production of parts, prototypes, and spare parts. It is often hailed as a "Green technology" due to lesser material usage compared to traditional manufacturing methods and possibilities for lightweighting the design. Many studies have focused on Life Cycle Assessments (LCAs) in AM and the important factors throughout the use phase of the product to be considered. However, an often neglected aspect in the life cycle is the R&D and certification phase. In regulated industries, such as oil and gas, aerospace or the medical sector, specific standard requirements need to be met for AM parts, leading to extensive and sometimes destructive testing and the production of additional parts for certification. These additional steps are often overlooked in LCAs, because their impact is negligible in conventional mass fabrication. However, in one-of-a-kind manufacturing, these steps can significantly impact the overall LCA results. This research aims to qualitatively assess the impact of "digital quality assurance" versus "conventional quality assurance" in the context of metal additive manufacturing. By examining these methods, the study seeks to reveal the hidden LCA impacts and provide insights into how digital quality assurance can enhance the sustainability of AM in regulated industries.

Speaker Country:

Denmark