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Additive Manufacturing Conference Türkiye – 2025

Proceedings of the Additive Manufacturing Conference Türkiye 2025

April 28 – 30, 2025

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FOREWORD

5th Additive Manufacturing Conference Türkiye was held April 28-30, 2025 at Juju Premier Palace in Antalya, Türkiye.

The event featured a wide array of presentations delivered across multiple technical sessions, including the annual TAMA assembly, bringing together participants from diverse backgrounds. Attendees from Türkiye and various other countries contributed to the growing international reach of the conference. Selected papers from the event are currently under review for possible publication in the *Journal of Additive Manufacturing Technologies* and *Additive Manufacturing Letters*.

A vibrant community of 261 professionals, researchers, and industry experts came together to exchange ideas, explore emerging technologies, and address the pressing challenges and opportunities within the additive manufacturing (AM) landscape. The conference provided an excellent platform for networking and fostering new collaborations.

Additive manufacturing continues to play a transformative role across multiple sectors, offering revolutionary possibilities in product design, production agility, and material innovation. Novel processes, cutting-edge algorithms, and new applications of AM remain focal points of academic and industrial research alike. As the technology matures, its ability to unlock design freedom, enable customization, and promote digitization becomes increasingly vital.

The technical developments and insights shared during the conference—as captured in these proceedings—reflect the high caliber of research and innovation driving the AM field forward. While AMC Turkiye 2025 welcomed international attendees, the strong representation from Türkiye once again emphasized the country's growing investment and leadership in the field of additive manufacturing.

Complementing the technical program, 16 exhibitors and sponsors showcased the latest AM equipment, materials, services, and innovations, contributing to the event's dynamic and comprehensive atmosphere.

We extend our sincere gratitude to all participants, speakers, sponsors, and exhibitors whose efforts and contributions made AMC Turkiye 2025 a resounding success. Special thanks are due to the members of the Conference Committee for their dedication in reviewing and selecting the abstracts presented. Your support continues to shape the future of additive manufacturing in Türkiye and beyond.

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KEYNOTE - WHAT NEUTRON SCATTERING CAN DO FOR ADDITIVE MANUFACTURING?

Prof. Anna Paradowska, The University of Sydney, Australia

The OPAL reactor is a uniquely Australian design which is currently the best of its kind in the world and is the world's first research reactor to use only low enriched uranium fuel and target plates. OPAL is the centre-piece of the facilities offered at ANSTO. Similarly, The Australian Centre for Neutron Scattering is the home of neutron science and engineering in Australia and a leading facility in the Asia Oceania region. It is part of an international network of organisations with neutron sources that delivers world-competitive neutron scattering science for national and international academic and industrial user community. In particular, the instruments have a unique ability to determine critical imperfections, measure internal residual stresses and textures in crystalline 3D printed materials.

These measurements can be carried out on real engineering components, mock-ups, or test samples non-destructively or with minimal preparation. This information provides direct impact into optimization of modern manufacturing processes, improved product reliability, enhanced design performance, reduced production cost, and extended life prediction on significant engineering assets.

This presentation will focus on the challenges and highlights of utilising neutron diffraction and imaging techniques for enhancement of the knowledge of complex additive manufacturing processes.

KEYNOTE - AN INSIDE VIEW: THE UNIQUE SYNERGY OF X-RAY TOMOGRAPHY AND ADDITIVE MANUFACTURING

Anton du Plessis, Stellenbosch University, South Africa

X-ray computed tomography (CT) is a powerful non-destructive testing method for all types of industrial manufacturing applications, giving a full 3D view of the inside of manufactured parts. This is also true for additive manufacturing, where it is often used to check for critical AM-specific defects such as porosity, cracks or major imperfections, especially in high-performance applications where there is low tolerance for such defects. Despite the high cost of CT, it provides unique information that has the potential for large cost savings by process improvements, eliminating costly part failures and allowing a deep understanding of manufacturing conditions. In addition to this, the technology can provide much more information for research and development. In this presentation, the latest capabilities in this context will be highlighted, especially focusing on software developments for CT image enhancement and analysis.

KEYNOTE - ADDITIVE MANUFACTURING OF ELASTOMER, CERAMIC AND METAL MULTI-FUNCTIONAL STRUCTURES

Prof. Eric MacDonald, The University of Texas, USA

3D printing has been historically relegated to fabricating conceptual models and prototypes; however, increasingly, research is now focusing on fabricating functional end-use products. As patents for 3D printing expire, new low-cost desktop systems are being adopted more widely and this trend is leading to a diversity of new products, processes and available materials. However, currently the technology is generally confined to fabricating single material static structures. For additively manufactured products to be economically meaningful, additional functionalities are required to be incorporated in terms of electronic, electromechanical, electromagnetic, thermodynamic, chemical and optical content. By interrupting the 3D printing and employing complementary manufacturing processes, additional functional content can be included in mass-customized structures. This presentation will review work in multi-process 3D printing for creating structures with consumer-anatomy-specific wearable electronics, electromechanical actuation, electromagnetics, energy storage, propulsion, embedded sensors in soft tooling – in polymers, elastomers, metal and ceramic material systems.

KEYNOTE - ACCELERATING ADDITIVE MANUFACTURING STANDARDIZATION

Dr. Alexander Liu, ASTM International, USA

Additive Manufacturing (AM) continues to offer tremendous potential across critical sectors such as aviation, spaceflight, medical, automotive, defense, and construction, experiencing an annual growth rate of 9.1% in 2024, valued at $21.9 billion. Yet, this merely represents 0.15% of the entire world's manufacturing economy estimated to be $12 trillion in 2024. Despite significant technological advances, qualification and certification in AM remains a complex and resource-intensive process. Traditional qualification methods are often incompatible with the unique characteristics of AM, resulting in prolonged timelines, high costs, and uncertain regulatory outcomes. This highlights the urgent need for tailored standards, data-driven frameworks, and agile certification pathways.

Since the establishment of ASTM AM Center of Excellence (AM CoE) in 2018 and the concept of Research to Standards (R2S), ASTM has collected over 200 ideas from more than 100 organizations globally to identify gaps in the standardization ecosystem. The most urgent need revolves around the development of optimized or new test methods, while challenges in data management and inspection/qualification are quickly emerging as critical priorities. Insights from ASTM International Conference on Additive Manufacturing (ICAM) 2024 reinforce these priorities. The top technical focus areas were Design, Modeling & Simulation, Mechanical, and Performance Testing, emphasizing the industry's focus on functional reliability and predictive design. Materials-wise, the metallic AM continues to dominate, with Titanium, Inconel, and Steel being the most frequently discussed.

To date, the R2S initiative has driven to 40+ focused research projects, resulting in many published standards and active work items. The R2S initiative has demonstrated how strategic, standards-oriented R&D can significantly reduce the timeline to standardization, ensure alignment with industry needs, and accelerate the global adoption of AM technologies. As the AM ecosystem continues to grow, integrating innovation with standardization will be essential to building confidence, ensuring quality, and scaling advanced manufacturing capabilities across industries.

KEYNOTE - MIT SHED - ACCELERATING BROAD ACCESS TO ADVANCED TECHNOLOGIES

Dr. Tolga Durak, MIT SHED, USA

The session provides an overview of the Safety, Health, Environmental Discovery Lab (The SHED). First of its' kind at MIT, the SHED serves as a multidisciplinary laboratory dedicated to prototyping, fabrication, and scientific discovery, offering equitable access to advanced technologies for the broader community. By integrating an interdisciplinary framework with domain-specific expertise, the SHED accelerates the progression of education, foundational and applied research, and systematic adoption of emerging technologies while ensuring scientific advancement is both rapid and conducted with the highest standards of safety and efficacy. During the session, information about the mission, core principles and strategic priorities for the SHED is shared along with research projects in the fields of tissue engineering, biofabrication and microfluidics that utilizes varies forms of additive manufacturing are highlighted.

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ABSTRACT

Bone tissue is vital for providing structural support, protecting internal organs, and enabling movement. It also plays a key role in mineral storage and the production of blood cells. In regenerative medicine, the demand for bone tissue is driven by its ability to heal fractures, repair defects, and support implants. Advances in biomaterials focus on replicating bone's mechanical strength and biological functions to enhance regeneration and repair. This study evaluates the mechanical and biological properties of two biomaterial composites: Polycaprolactone (PCL) combined with Bacterial Cellulose (BC) and Polyethylene Terephthalate Glycol (PETG) with BC. Mechanical testing showed that PETG/BC had superior tensile strength and stiffness, while PCL/BC demonstrated greater flexibility and elongation. Biological evaluations, including cytotoxicity and cell proliferation assays, confirmed that both composites were biocompatible, with PETG/BC supporting better cell attachment and growth. These results suggest that PCL/BC is more suitable for flexible, cell-friendly applications, whereas PETG/BC is ideal for mechanically demanding environments.

Keywords: PETG, PCL, Bacterial Cellulose, Additive Manufacturing, Polymers, Tissue Engineering, Bone Tissue Regeneration

ENHANCING SUSTAINABILITY IN METAL ADDITIVE MANUFACTURING: A STUDY ON POWDER REUSABILITY AND MECHANICAL INTEGRITY OF CORROSION RESISTANT STAINLESS STEEL

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ABSTRACT

The sustainability of metal additive manufacturing (AM) is crucial for minimizing environmental impacts and enhancing cost efficiency. This research examines the degradation and reusability of metal powders, specifically corrosion-resistant (CX) stainless steel, within the context of laser powder bed fusion (LPBF) processes. Key parameters such as powder morphology, particle size distribution, and chemical composition are critical to AM sustainability, as they significantly influence powder flowability, packing density, and the mechanical integrity of fabricated components. The study investigates the effects of successive powder reuse cycles (ranging from 1 to 30 prints, employing various reuse strategies) on part quality, including changes in porosity, surface roughness, and the microstructure of as-built samples. Mechanical properties, such as tensile strength, ductility, and impact toughness, are also analyzed for components produced using reused powders. Furthermore, post-process optimization techniques—such as heat treatment and surface finishing—are employed to mitigate the effects of powder degradation. These processes demonstrate potential for restoring part quality and supporting resource-efficient manufacturing practices. The findings reveal that, when carefully managed, powder reuse can maintain the mechanical integrity of AM-fabricated parts. This research contributes to advancing circular economy principles and reducing material waste in AM, emphasizing the importance of sustainable manufacturing practices.

Keywords: CX steel, Laser Powder Bed Fusion, Process-structure-property Relationship, Sustainability, Circular Economy

MECHANICAL PERFORMANCE AND MICROSTRUCTURAL EVALUATION OF MULTI-LATTICE STRUCTURES PRODUCED BY LASER POWDER BED FUSION

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ABSTRACT

In this study, hybrid lattice structures were produced using the Laser Powder Bed Fusion (LPBF) method with AlSi10Mg material. Diamond, Fluorite, and Octet lattice structures were combined in pairs to design hybrid lattices aimed at optimizing structural strength, energy absorption capacity, and lightweight properties. The production process was carried out with fixed laser power and scanning speed parameters, and the effects of these production conditions on the microstructure and mechanical properties were analyzed. AlSi10Mg is widely utilized in various industries, including automotive, aerospace, and defense, due to its lightweight nature, high mechanical strength, and excellent corrosion resistance. This material is particularly favored for manufacturing lightweight components with complex geometries. The biomimicry-inspired hybrid lattice structures demonstrated significant advantages compared to conventional designs, particularly in terms of energy absorption performance and weight reduction potential.

Keywords: Laser Powder Bed Fusion (LPBF), AlSi10Mg, Multi Lattice Structures, Mechanical Properties, Biomimicry-Inspired Design

DEVELOPMENT OF MODEL-BASED THERMAL CONTROL METHODS FOR THE REPRODUCIBLE AM DED-LB GENERATION OF CONSOLIDATED POWDER METAL STRUCTURES

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ABSTRACT

In high powder mass rate laser-driven DED processes (HR DED-LB/P), the stability of the additive melt pool may be compromised by the variation of the parameters determining the thermo-fluiddynamic equilibrium leading to a steady material resolidification in the form of consolidated tracks. The possible lack of diffusion of residual heat from the previously consolidated material layers constitutes in practice a thermal input affecting the balance at the laser-material interaction zone, while the application of an insufficient laser power density affects the appropriate fluiddynamic circulation in the melt pool prior to the final consolidation. An accurate control of the temperature of the laser-material interaction zone is considered as critical to maintain the dynamic viscosity of the liquid metal within the narrow margin in which it can be managed in a stable way. The present work introduces a model in which the different thermal sources and sinks around the laser interaction zone are evaluated, finally assessing the thermal equilibrium conditions for the consolidation process and specifying the appropriate laser energy density input for a correct microstructural buildup. The model serves for the direct feeding to experimental process implementation and parameters specification and can be also fed online for automatic process monitoring and control.

Keywords: DED-LB/P, Thermal modelling, FEM, Laser Power Density, Temperature Control

INFLUENCE OF RECOVERY TEMPERATURE ON THE SHAPE MEMORY BEHAVIOR OF 4D-PRINTED GRAPHENE OXIDE REINFORCED PLLA/PCL NANOCOMPOSITES

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ABSTRACT

This study investigates the influence of recovery temperature on the shape memory behavior of 4D-printed PLA/PCL-GO nanocomposites. The composites were produced via melt blending, utilizing a PLA matrix reinforced with 20% wt% poly(ε-caprolactone) (PCL) and 1 wt% graphene oxide (GO). Specimens were fabricated through Fused Deposition Modeling (FDM) and programmed for shape recovery in a hot water bath, with recovery temperatures of 50°C, 55°C, 60°C, and 65°C. Experimental results demonstrated that recovery temperature significantly affects recovery speed and efficiency. At lower temperatures (50°C), the recovery rate was slower (20 seconds) with a recovery ratio of 83.87%. As the temperature increased to 55°C and 60°C, the recovery time decreased to 15 seconds, with recovery ratios of 85.61% and 87.95%, respectively. At 65°C, the samples exhibited the fastest recovery; however, the high temperature caused deformation in the shape, indicating that this temperature exceeds the optimal range for maintaining shape integrity. These findings underline the importance of recovery temperature in achieving optimal shape memory behavior, providing critical insights for tailoring 4D-printed PLA/PCL-GO composites for applications in biomedical devices, adaptive structures, and smart material systems.

Keywords: Shape memory, PLA/PCL-GO nanocomposites, graphene oxide, 4D printing, recovery temperature

IMPLEMENTING A POST-PROCESSING STRATEGY FOR THE CONSERVATION AND ADVANCEMENT OF ADDITIVE MANUFACTURING FEEDSTOCK

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ABSTRACT

Additive Manufacturing (AM) has emerged as a leading advanced manufacturing technique due to its capability to produce intricate and high-performance parts. However, the increasing adoption of AM raises concerns regarding sustainability, particularly related to feedstock lifecycle and post-Laser Powder Bed Fusion (LPBF) AM possibilities. In response, a recent study undertook a comprehensive experimental effort to enhance sustainability and circularity by extending the lifecycle of its powder feedstock. The study systematically examined varied key disposed-powder pathways, including (i) oversized particles collected post-sieving, (ii) powders retained in the filtration unit of LPBF system, and (iii) powders degraded through oxidation or contamination. Key properties that compromise this feedstock reusability were investigated and strategies for reintegration into the AM process utilizing Directed Energy Deposition (DED) were explored. DED, a more robust AM technique capable of accommodating larger particle size distribution and lower-grade feedstock was leveraged as a means of maintaining powder feedstock within the LCA of powder-based metal AM. Parts printed using DED were characterized down to the microstructural level to assess potential issues such as grain nucleation abnormalities, intermetallic formation, and carbide precipitation, especially in powders sourced from the recirculation chamber of LPBF. This study contributes to advancing the sustainability of AM feedstock by identifying practical reuse pathways for off-grade powders and reducing waste. The findings highlight the potential for integrating LPBF and DED processes to improve resource efficiency, support circular manufacturing practices, and bolster industrial adoption.

Keywords: Laser Powder Bed Fusion, Directed Energy Deposition, Sustainability, Off- grade feedstock

DESIGN FOR MATERIAL JETTING: SURFACE ROUGHNESS CONSIDERATIONS BASED ON EXPERIMENTAL DESIGN

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ABSTRACT

Design for additive manufacturing is very important for successful implementation and usage of different additive manufacturing modalities in different industrial applications. The aim of this study is to investigate the capability of material jetting technology in terms of surface roughness considerations which can be used in design for additive manufacturing studies. For this purpose, 48 specimens with different overhang angles were located along x or y axis of the build platform and produced. Average and maximum surface roughness measurements were performed on upper and lower surfaces of the specimens. The results revealed that lower surfaces have better surface quality than upper surfaces especially for 30o overhang angle threshold value. Locating the part along x or y axis has different effects on surface roughness of upper or lower surfaces. Analysis of variance studies showed that overhang angle has much higher effect on both average and maximum surface roughness of lower and upper surfaces than part location.

Keywords: Material jetting, surface roughness, overhang angle

EFFECTS OF PROCESS PARAMETERS ON THE POROSITY AND CRACK FORMATION OF ADDITIVELY MANUFACTURED NITIHF

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ABSTRACT

Slightly Ni-lean Ni49.9Ti30.1Hf20 cubical parts were fabricated using one of the advanced additive manufacturing techniques, laser powder bed fusion (L-PBF). The primary objective of this study is to explore the influences of process parameters on the formation of pores and cracks and the determination of critical material properties such as the transformation temperature (TTs). Two sets of laser powers of 100 W and 250W with different scanning speeds and, hatch spacings were used to fabricate parts with the energy densities ranging from 33.3 to 77.8J/mm3. One key observation from the study was that the TTs of the L-PBF NiTiHf parts are found to be higher than 200 oC. Additionally, there was a notable reduction in the porosity levels of the fabricated samples as the energy density was increased. This decrease in porosity indicates the improved material density which is a desirable outcome in alloy production. While higher energy density led to reduced porosity, it concurrently resulted in increased crack formation.

Keywords: L-PBF, Shape memory alloys, High Temperature Alloys

EXPERIMENTAL STUDY ON INCREASING THERMAL PERFORMANCE OF PHASE CHANGE MATERIALS USING FINS, METAL FOAMS AND ADDITIVE MANUFACTURED LATTICE STRUCTURES

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ABSTRACT

Phase change materials (PCMs) have earned significant attention in electronic cooling applications due to their exceptional thermal energy storage capabilities. However, their inherently low thermal conductivity (<1 W/mK) limits their effectiveness in rapid heat dissipation. This study aims to enhance the effective thermal conductivity of PCMs by experimentally investigating four different fin structures (1, 4, 9, and 16 fins), three types of metal foams with 90% porosity (10,20,40 PPI), and three additively manufactured lattice structures (Octet, Kelvin, and Body-centered), also with 90% porosity. The experiments are conducted under thermal loads of 3.5 kW/m² and 7 kW/m² to investigate varying heat dissipation demands. The fin structures are evaluated for their ability to increase heat transfer surface area, while the metal foams and lattice structures are analyzed for their potential to provide higher thermal conductivity and uniform heat distribution. The results demonstrate that integrating these advanced structures significantly improves the thermal performance of PCMs, contributing to more efficient and uniform temperature control in electronic devices. This work provides valuable insights for advancing PCM-based thermal management systems in high-performance electronics.

Keywords: Phase Change Materials, Metal Foams, Fins, Lattice Structures, Additive Manufacturing

A COMPARATIVE STUDY OF SINGLE AND DUAL LASER BEAM EFFECTS ON THERMAL GRADIENT AND SOLIDIFICATION RATE IN LB-PBF

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ABSTRACT

Dual-laser systems in laser beam powder bed fusion (LB-PBF) offer promising opportunities for enhanced productivity and optimized processing conditions. However, their impact on key parameters such as temperature gradients (G) and solidification rates (R) requires further investigation to understand potential advantages over single-laser systems. In this study, a transient thermal finite element model was used to simulate the LPBF process, capturing the transient and spatial evolution of G and R. Temperature histories were extracted from the simulations, and detailed analyses of G and R were performed for both single and dual-laser configurations. Unlike prior studies focusing on single tracks, this work analyzes the whole simulation domain, providing more realistic insights into the thermal behavior and microstructural evolution. The results reveal that the dual-laser system alters temperature gradients and solidification rates, offering potential improvements in process efficiency and microstructure control. This comparative study highlights the benefits of dual-laser LB-PBF strategies, advancing the understanding of their impact on metal additive manufacturing.

Keywords: Additive manufacturing, Temperature gradient, Dual-laser beam, Powder Bed Fusion

COLD SPRAY ADDITIVE MANUFACTURING: AN OPERATIONALLY EFFICIENT AND COST-EFFECTIVE ALTERNATIVE TO TRADITIONAL MANUFACTURING APPROACHES

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ABSTRACT

Titomic's cutting edge capabilities redefine industry standards in additive manufacturing by delivering unmatched cost efficiency, accelerated production schedules, and superior performance integrity. Leveraging its proprietary cold spray technology, Titomic's processes enable the fabrication of high-strength, complex components with minimal material waste, reducing production costs while also enhancing sustainability. This innovative process eliminates the need for traditional assembly techniques in a manner that reduces lead times and ensures both precise and repeatable manufacturing outcomes. Engineered for use in any environment, Titomic's provides exceptional physical strength, enhanced corrosion resistance, and superior levels of durability. These characteristics are ideal for applications across the aerospace, defense, maritime, and industrial sectors. Utilizing a broad range of metals and alloys also ensures Titomic's adaptability to the most stringent design and production requirements, enabling manufacturers to meet evolving challenges efficiently and effectively with high confidence. Titomic's unique approach emphasizes enhanced reliability and robust supply chain resilience. Its ability to produce large, integrated structures in a single operation ensures seamless performance while also reducing risks associated with component failure. By combining innovative engineering focused on cost, schedule, and performance, Titomic provides a transformative solution for industries seeking to maintain a competitive edge while delivering excellence in manufacturing applications.

Keywords: Cold Spray, Additive Manufacturing, Metal Manufacturing, Additive Fabrication

THERMAL PERFORMANCE INVESTIGATION OF A COLD PLATE WITH DOUBLE LAYERED HEAT SINK DESIGNED FOR ADDITIVE MANUFACTURING

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ABSTRACT

In this study, a cold plate is designed to cool two-sided heat loads with double-layered straight fins. Additive manufacturing technology is used as the production technique to produce leakage-free and compact products with minimal post-processing work. Since it almost eliminates the joining process, AM technology enables the engineer to design many different alternatives to study on both heat sink and cold plate designs. Heat sink fins are selected as straight types to have as simple a design as possible to reduce any failure due to complexity at the stage of developing this new technology. Four heat sources at each side with 100W/cm2 heat flux values are applied to investigate the thermal performance of double-layered heat sinks. Heat sink designs on each side are made differently to have a close temperature difference between the heat sources and to ensure that electronics function properly. Since there are 4 heat sources on each side, the liquid needs to be distributed equally to bring the microwave chip temperatures close to each other. The fluid is divided into heat sinks using the fractal method approach and applying Hess-Muller rules.

Keywords: Electronic cooling, DMLS, Direct Metal Laser Sintering, Additive manufacturing, High power cooling, Flow branching

3D PRINTED PIPE SEGMENTS WITH BUILT-IN HEATING AND TEMPERATURE SENSING CAPABILITIES

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ABSTRACT

Spacecraft thermal regulation is crucial to ensure survival, optimum operation and lifetime of onboard systems and components by preventing overheating or freezing. To ensure the best control and subsequent performances, thermal management systems such as fluidic ones require temperature sensors and heating elements to be integrated at strategic locations. Nowadays, the integration of those elements involves constraints that limit efficiency. In the framework of the EU project AHEAD led by CSEM, a 316L pipe segment including built-in electrical connector, heating element, temperature sensor and fluidic interfaces was produced thanks to a combination of LPBF, resin casting, conventional machining and Aerosol Jet Printing. The pipe segment is a one-part plug and play device that offers heating power up to 60W and temperature measurement from -65 to +85°C, without the need for integrating external element. In the project, 16 prototypes were manufactured and extensively tested to validate material quality as well as the functionality and performances of the pipe structure, electrical and fluidic interfaces, heating element and temperature sensor. Apart from the sensors whose performances were found below expectations, all requirements were met. This development demonstrates the possibility to produce mechanical parts which comprise advanced electrical functions.

Keywords: DfAM, LPBF, sensor, heating, functionalization

NUMERICAL ANALYSIS OF INNOVATIVE THERMAL MANAGEMENT STRATEGIES IN WIRE ARC ADDITIVE MANUFACTURING FOR ENHANCED PROCESS CONTROL

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ABSTRACT

Wire Arc Additive Manufacturing (WAAM) attracts different industries because of the cost-effective and sustainable production of large volume, complex metal parts using high deposition rates. However, effective thermal management continues to be a critical challenge due to the complexity of the heat transfer process and its impact on the material properties. In this study, numerical analysis using Hexagon's Simufact Welding software is used to create and validate a digital twin of the WAAM process. These simulations are essential for developing advanced thermal management strategies and providing detailed insights into temperature distribution, cooling rates, and thermal history. This enables precise temperature determination to improve component quality, process efficiency, and process control. In this way, process times can be reduced in a targeted manner, or controlled cooling rates can be induced to achieve defined component properties. While the approach excels at predicting thermal behavior for simple structures, challenges remain for highly complex geometries where localized cooling or heating may be more difficult to achieve. This work highlights the importance of integrating simulation-based strategies to advance WAAM technology, paving the way for more reliable, efficient, and environmentally friendly additive manufacturing processes.

Keywords: digital twin, in-situ heat treatment, numerical analysis, thermal process control, Wire Arc Additive Manufacturing

THE STABILITY OF REVERTED AUSTENITE AFTER DIFFERENT DIRECT AGING TREATMENTS OF AN 18NI300 MARAGING STEEL PRODUCED VIA LASER POWDER BED FUSION

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ABSTRACT

Maraging steels are well known for their exceptional combination of high strength and toughness, which is primarily attributed to the precipitation hardening of intermetallic compounds within a low-carbon martensite and to austenite. On the other hand, achieving higher ductility requires consideration of not only the amount of austenite but also of its stability, as these factors play a significant role in enhancing the material's specific performance since ductility is enhanced by the occurrence of Transformation Induced Plasticity (TRIP) effect. Direct aged 18Ni300 maraging steel produced via the Laser Powder Bed Fusion (L-PBF) may contain different amounts of reverted austenite depending on the ageing parameters. This study focuses on investigating the effects of various direct ageing treatments on the amount austenite and its stability in relation to the strain-induced transformation in martensite. True stress and strain hardening rate as a function of true strain were evaluated for all samples to identify the occurrence of a TRIP mechanism. It was also confirmed through X-ray diffraction (XRD) analysis, using the Material Analysis Using Diffraction (MAUD) software with Rietveld refinements to quantify the volume of austenite before and after the tensile test.

Keywords: 18Ni300 Maraging Steel, Laser Powder Bed Fusion, Reverted austenite, Transformation-Induced Plasticity.

TRANSIENT AND SPATIAL EVOLUTION OF TEMPERATURE GRADIENTS AND SOLIDIFICATION RATES IN LASER POWDER BED FUSION

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ABSTRACT

The microstructure plays a critical role in metal additive manufacturing, as it directly influences the mechanical properties, thermal performance, and overall quality of the final product. Therefore, predicting the microstructure is crucial, but it often requires experimental studies or computationally expensive methods, both of which are highly time-consuming. The temperature gradient (G) and solidification rate (R) are two critical parameters that play a key role in determining the microstructure. In this study, a transient thermal finite element model was employed to simulate the laser powder bed fusion (LB-PBF) process, and the transient and spatial evolution of G and R were analyzed to develop a predictive approach for microstructure estimation without the need for any additional method for microstructure estimation. First, our thermal model was validated using data from the literature. Subsequently, temperature gradients and solidification rates were calculated at every time step for each node of the first layer, considering multiple scan tracks. Unlike single-track simulations, our approach provides more detailed and realistic results, capturing complex thermal and solidification dynamics more effectively.

Keywords: Temperature gradients, Solidification rate, Transient thermal analysis

LEVERAGING IN-SITU OPTICAL EMISSION SPECTROSCOPY AND MCT FOR RAPID QUALITY ANALYSIS IN DIRECT METAL DEPOSITION OF AL 7075

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ABSTRACT

This study investigates the use of optical emission spectroscopy (OES) and micro-computed tomography (µCT) for real-time quality analysis in Direct Metal Deposition (DMD) of Al 7075. OES data collected during the DMD process were correlated with µCT images to identify defects. The results showed that OES effectively distinguished between defective and high-quality prints, with 96.7% of signals deviating from the overall process intensities. This approach holds potential for real-time defect detection and corrective actions during the printing process, ensuring better quality in metal additive manufacturing. However, further research is needed to address technical challenges and improve the method's accuracy for real-time applications.

Keywords: Optical Emission Spectra, Micro-CT Scan, Direct Metal Deposition, In-situ Detection, Metal Additive Manufacturing

EFFECT OF DRILLING PROCESS ON THE HOLE QUALITY OF ADDITIVELY MANUFACTURED INCONEL 718 ALLOY

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ABSTRACT

It is a necessity to apply post-processing to parts produced with additive manufacturing. Otherwise, the surface and hole quality of AM parts as well as their dimensional accuracy do not meet the desired conditions. In this study, drilling was applied to improve the hole quality of Inconel 718 alloy manufactured by powder bed fusion-laser beam method. Inconel 718 alloy manufactured under different PBF-LB process parameters was drilled with sharp corner, radius corner and chamfer corner drill bits. The measured outputs were surface quality of drilled hole, surface topography, surface and subsurface microhardness. This study showed that drilling process helps to improve the surface quality of additively manufactured Inconel 718 by reducing the surface roughness. It has been observed that the difference in drill bit geometry improves hole quality by 30% to 90%.

Keywords: Additive manufacturing, Inconel 718, Drilling, Surface quality, Microhardness

COMPARISON OF EXPERIMENTAL AND FINITE ELEMENT SIMULATION STUDIES ON MACHINABILITY OF ADDITIVELY MANUFACTURED AND WROUGHT 316L STAINLESS STEEL

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ABSTRACT

Machining is commonly applied as a post-process to 316L materials manufactured by additive manufacturing (AM) method. AM materials may have different mechanical properties than wrought materials as well as anisotropic microstructures. The reflection of this situation on the machining performance of AM materials should be well understood. In this study, AM and wrought 316L steel materials were machined at different cutting speeds and cutting tool rake angles. Johnson-Cook model was implemented to simulate machining. Cutting responses and surface integrity characteristics were predicted and compared with machining data for both AM and wrought. Predicted outputs show acceptable agreement with experimentally measured data.

Keywords: Additive manufacturing, Stainless steel, Post-process, FEM, Johnson-Cook

PHASE-FIELD SIMULATION OF SOLIDIFICATION IN METAL ADDITIVE MANUFACTURING

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ABSTRACT

The capability of phase-field models for simulating microstructure formation during metal additive manufacturing has been evaluated. Firstly, the coupled phase and orientation field of polycrystalline solidification, known as Warren-Kobayashi-Lobkovsky-Carter (WKLC) model, was applied to simulate the formation of columnar grains with random crystallographic orientations. Secondly, the phase-field crystal model was coupled with heat equation and elastic stress computations, encompassing the entire process, starting from random nucleation within the initial liquid domain to the completion of solidification behind the transient melt pool generated by the heat source.

Keywords: Metal Additive Manufacturing, Phase-field Simulation, Grain Structure, Elastic Stress.

STUDY ON CONTROLLING ANISOTROPY IN HIGH-POWER LASER POWDER BED FUSION OF INCONEL 718 VIA BEAM SPLITTING AND SHAPING TECHNIQUES

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ABSTRACT

Recent advancements in laser-based powder bed fusion of metals (PBF-LB/M), such as laser beam shaping, show the potential to increase volumetric building rates. Recent investigations have shown that the process window can be expanded by adopting alternative beam profiles like ring-shaped lasers with larger beam diameter, instead of traditional Gaussian beams. This may allow higher laser power and faster scanning speeds. Additionally, larger beam diameters may enable increased hatch distances, further boosting the build rate. The as-built microstructure of Inconel 718 (IN718) samples produced with ring-shaped beam profiles often shows high anisotropy, characterized by coarse, elongated grains along the build direction. This issue arises from the formation of wide, shallow melt pools, leading to coarse columnar grains resulting in anisotropic mechanical properties. To tackle this challenge, this study explores a beam-splitting strategy combined with beam-shaping technology. By generating multi-spot laser beams, with Gaussian and Ring intensity distribution, arranged in different configurations, the aim is to reduce anisotropy by affecting solidification behavior and melt pool morphology while maintaining productivity. Comparing samples produced using beam-splitting strategies with those fabricated using state-of-the-art ring-shaped laser beam profiles demonstrates an increase in the building rate by a minimum of 18.4 mm3/s (with Gaussian beam spots) to a maximum of 25 mm3/s (with Ring-shaped), along with the potential to reduce as-built anisotropy in microstructural properties.

Keywords: PBF-LB/M; laser beam shaping; IN718; laser beam splitting; tailoring microstructure; texture; anisotropy

EFFECT OF HYBRID LAYER THICKNESS ON STRENGTH AND PRINTING EFFICIENCY OF 3D-PRINTED PLA

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ABSTRACT

This study investigates the impact of layer thickness on the mechanical properties and performance of 3D-printed polylactic acid (PLA) samples. Different layer thicknesses were employed to explore the trade-offs between mechanical strength and production efficiency. Samples were printed using a Bambu Lab P1S 3D printer, with the printing parameters including a 0.4 mm nozzle diameter, 50 mm/s printing speed, and 220°C nozzle temperature. Tensile and flexural properties were evaluated according to ASTM D638 and 790 standards. The results revealed that medium-layer thickness (0.16 mm) produced the highest flexural modulus and strength. At the same time, thinner or thicker layers exhibited reduced performance due to excessive or insufficient melting during printing. Additionally, increasing layer thickness led to decreased printing time and material consumption, but samples with thicker layers showed higher weight and lower strength. These findings highlight the importance of optimizing layer thickness to balance mechanical properties, material usage, and production efficiency in 3D printing processes.

Keywords: Hybrid layer thickness, material strength, printing efficiency, polylactic acid

IMPACT OF INTERPASS NITROGEN COOLING ON MICROSTRUCTURE AND RESIDUAL STRESSES OF WAAMED 5356 ALUMINUM ALLOY

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ABSTRACT

Wire Arc Additive Manufacturing (WAAM) is a high-deposition rate additive manufacturing (AM) process to build large-scale 3D metal parts with an outstanding buy-to-fly (BTF) ratio. This will contribute to having a sustainable influence on the environment by reducing the metal scrap that is commonly produced by traditional manufacturing processes. As an evolving technology, there are various challenges associated with printing aluminum components using WAAM process; one of these challenges is controlling the heat accumulation during the deposition of subsequent layers. The alternating heating and cooling cycles may result in developing high residual stresses (RS) within WAAMed components that will certainly affect the integrity of the final part. In the present study, an Interlayer-Nitrogen Cooling (INC) is used to reduce the idle time between layers and decrease the distortion that may develop due to heat accumulation, consequently having a stable building process with interpass temperature control. Tensile test and fractography are carried out to observe the mechanical behavior of the different building conditions. The results of porosity formation and residual stresses measurement highlighted an overall improvement in mechanical properties.

Keywords: WAAM, Microstructure Analysis, Aluminum, Residual Stress, cooling

POST-PROCESSING CHALLENGES IN ADDITIVE MANUFACTURING: REDUCING WALL THICKNESS FOR AEROSPACE APPLICATIONS

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ABSTRACT

Additive manufacturing (AM) enables the production of lightweight components for aerospace applications with enhanced fuel efficiency through higher buy-to-fly ratios. This study investigates the post-processing limits of thin-wall structures produced using Laser Powder Bed Fusion from AlSi10Mg alloy. Initial wall thickness of 1 mm was systematically reduced via NC machining to target values of 0.8 mm, 0.5 mm, and 0.3 mm. Results showed successful reduction to 0.5 mm without compromising structural integrity. However, walls below 0.4 mm exhibited rigidity loss and surface damage under machining forces. Penetrant testing confirmed the absence of cracks at 0.5 mm, indicating its suitability for further mechanical testing.

Keywords: Additive manufacturing, thin walls, LPBF, aerospace, AlSi10Mg

THERMAL CONTROL IN WAAM USING INFRARED HEATER TECHNOLOGY

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ABSTRACT

WAAM represents a pioneering technique in the domain of additive manufacturing, offering substantial advancements in large-scale metal component production. This research systematically investigates the intrinsic thermal complexities associated with WAAM, including residual stresses, structural distortions, and surface irregularities. A novel methodological framework integrating active infrared heating is proposed to mitigate these challenges effectively. Experimental results indicate that the infrared-enhanced method reduces residual stresses by approximately 25% and improves dimensional precision by up to 30%. These findings underscore the efficacy of the active heating technique, demonstrating marked improvements in thermal stability and component quality, thus positioning this method as a transformative solution for industrial applications in sectors such as aerospace and automotive engineering.

Keywords: Residual stress, thermal management, infrared heating, dimensional accuracy, microstructural stability

TOWARDS MODELING AND SIMULATION OF MULTI-MATERIAL DIRECTED ENERGY DEPOSITION FOR FUNCTIONALLY GRADED STRUCTURES

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ABSTRACT

As technology advances, materials face increasing demands, especially in the aerospace industry. Metal additive manufacturing (AM), specifically directed energy deposition (DED), addresses these needs by enabling multi-material deposition and in-situ alloying, producing functionally graded materials (FGMs) with tailored properties by combining different materials. Numerical simulations can be used to predict temperature fields and distortions in the DED process, reducing costly trial runs. However, incorporating FGMs in such thermomechanical simulations of DED process requires development of new process models and creation of material models for specific alloy combinations. Using Simufact Welding and extending the capabilities of the software, DED process is modelled, and material compositions are assigned to layers to construct FGMs virtually. Initial process simulations of CuCrZr-IN718 FGM deposition on CuCrZr substrate demonstrate successful modelling of the process. These models correlate well with experimental results, predicting temperature fields and distortions effectively. Future work includes further validation and scaling simulations for industrial applications.

Keywords: Directed energy deposition, functionally graded materials, process simulation, multi material additive manufacturing

DEVELOPMENT OF AN ALGORITHM FOR THE INSPECTION OF MANUFACTURING FAULTS IN LASER POWDER BED FUSION PROCESSES

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ABSTRACT

Additive manufacturing (AM), particularly laser powder bed fusion processes, has revolutionized the production of complex geometries and high-performance components. However, defects such as porosity and incomplete fusion significantly affect the mechanical properties and reliability of manufactured parts. This study presents a novel algorithm to predict porosity in L-PBFP processes by analyzing critical production parameters, including laser power, scan speed, and layer thickness. Unlike traditional machine learning approaches requiring extensive data, the proposed algorithm models porosity mechanisms directly, allowing layer-by-layer prediction without the need for large datasets. Experimental validation was conducted using Ti-6Al-4V samples fabricated under varying process conditions, ensuring comprehensive evaluation. Results demonstrate the algorithm's efficiency in identifying porosity trends and its potential to optimize production parameters. The study emphasizes the importance of pre-production optimization to enhance product quality. This research advances L-PBFP technology by offering a fast, adaptable, and cost-effective method for defect prediction, paving the way for improved quality control in additive manufacturing processes.

Keywords: Porosity Prediction, Laser Powder Bed Fusion, Process Simulation, Additive Manufacturing

CONCRETE MIX DESIGN FOR 3D PRINTING

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ABSTRACT

3D Concreted printing technology brings numerous advantages to the construction sector, such as material optimization, design freedom, minimization of human labor, cost reduction, and is an essential technology in disaster situations. However, it must be considered that the concrete needed in this type of technology must meet different requirements from conventional concrete since a fluid concrete capable of being pumped and extruded is needed, but at the same time, it must meet the conditions of buildability. Due to these conditions, the influence of the materials in the concrete mixes for 3D printing has to be studied. The methodology consisted of searching and collecting data from scientific articles. The selected data focused on material dosages and test results. With this information, an individual statistical analysis is performed to obtain average values of the dosages and properties, and then an overall analysis is performed to obtain a linear relationship between materials and requirements. The results obtained allow us to conclude that there is no common relationship in the design of 3D-printed concrete mixtures.

Keywords: Concrete, mixtures, additive manufacturing, statistician

MACHINING-INDUCED RESIDUAL STRESSES OF ADDITIVELY MANUFACTURED 17-4 PH STEEL UNDER VARIOUS COOLING CONDITIONS

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ABSTRACT

Although emerging additive manufacturing (AM) methods such as laser powder bed fusion (LPBF), can directly produce end components, they still require post-processing to improve material characteristics, geometrical & dimensional accuracy, and surface quality. While various post-processing techniques, like abrasive flow machining or vibratory polishing, can address surface quality improvement, geometrical and dimensional accuracy still need subtractive machining such as turning and milling. Machining of AM parts require utmost care because material removal might result undesirable residual stresses on the component, reducing its service life through early fatigue or failure. Several factors including the heat treatment conditions, cutting parameters or coolant application can influence the so-called machining-induced residual stresses. Considering the previously mentioned machining-induced residual stresses on AM components, this paper offers an extensive experimental study on the 17-4 PH alloy, which is an aerospace-grade steel that can be precipitation hardened. Four distinct cooling techniques were examined in machining of as-built and heat-treated parts produced by LPBF AM. The components were subsequently analyzed for residual stresses and evaluated for surface quality. At first, tensile residual stresses were detected in the as-built state, and the heat treatment transformed them into compressive stresses, which then turned tensile again due to post-machining.

Keywords: 17-4 PH Steel, Laser Powder Bed fusion, Machining, Cooling, Residual Stresses

THE EFFECT OF BUILD PLATFORM TEMPERATURE AND THICKNESS ON AS BUILD DISTORTION IN LASER POWDER BED FUSION PROCESSED OVERHANG PARTS

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ABSTRACT

Controlling, mitigating or minimizing the part distortion in laser powder bed fusion (LPBF) process is very important to obtain high quality end products. Since LPBF is a thermal process, thermally induced residual stresses are the main causes of part distortions. Geometric differences and process parameters influence the part distortion in LPBF process. The aim of this study is to investigate the effect of build platform temperature and thickness, which directly affect the thermal stress formation during build, on distortion in LPBF processed CoCrMo parts. Four different build platform thicknesses (35 mm, 40 mm, 45 mm and 50 mm), four different build platform temperature values (100 oC, 135 oC, 170 oC and 200 oC) and three different specimens with different overhang angles with respect to build platform (45o, 30o and 15o) were used as design variables. The maximum displacement based on numerical simulation studies was used as the design output. The effect of each design variables on design output was evaluated based on Analysis of Variance (ANOVA) studies. It was revealed that build platform temperature is the most important factor (33.65%) on part distortion in LPBF produced overhang parts in the scope of the present study.

Keywords: Laser powder bed fusion, overhang angle, process simulation, build platform temperature, build platform thickness

EFFECTS OF HEXAGONAL OPENING SIZE IN HONEYCOMB STRUCTURES PRODUCED BY SLM ON SATURATED POOL BOILING PERFORMANCE

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ABSTRACT

Advancements in additive manufacturing (AM) technologies over the past decade have shown great potential for improving heat transfer performance through printed surface modifications in electronic cooling systems. This study aimed to observe the effect of the edge length of a hexagonal opening on the pool boiling performance. Three test samples were fabricated via selective laser melting (SLM) using AlSi10Mg powder, with Novec-7100 selected as the working fluid. Pool boiling experiments were conducted under saturated conditions at atmospheric pressure. The experiments yielded several significant findings. Notably, honeycomb structures reduced the boiling incipience superheat and eliminated incipient boiling hysteresis compared to plain surfaces. Additionally, the heat transfer performance of the surface modifications improved with increasing height, attributed to the larger surface area available for nucleation. The surface modifications further enhanced the heat transfer coefficient (HTC) and delayed the onset of the critical heat flux (CHF). These findings provide valuable insights for designing future surface modifications using AM technologies to improve boiling performance. AM offers new opportunities for exploring boiling heat transfer mechanisms and provides a versatile and efficient means of fabricating novel structured surfaces with precisely controllable parameters.

Keywords: Pool Boiling, SLM, Heat Transfer, CHF

INVESTIGATION OF WELDABILITY OF ELECTRON BEAM MELTING MANUFACTURED TI6AL4V PARTS USING COMPREHENSIVE INSPECTION METHODS

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ABSTRACT

This study investigates the weldability of the Electron Beam Melting (EBM) additive-manufactured Ti6Al4V parts using Gas Tungsten Arc Welding (GTAW) manual welding method. EBM is an advanced additive manufacturing technology that enables high-precision fabrication of metal components, but the weldability of the EBM parts has not been thoroughly examined. The evaluation of weld quality investigated using radiographic inspection, metallographic inspections and tensile testing. Radiographic inspection was employed to detect internal defects, while metallographic inspection provided insights into the microstructure and heat-affected zones. Tensile testing was performed to evaluate the mechanical properties of the welded joints. The results reveal critical insights into the weldability of EBM-manufactured parts and highlight the key factors affecting weld quality and part strength. That is, the weldability of the EBM additively manufactured samples was observed and this ability will reshape both of the processes.

Keywords: EBM, GTAW, inspection, Ti6Al4V, weldability

CHARACTERIZATION AND WELDABILITY OF TI-6AL-4V PARTS PRODUCED BY SELECTIVE LASER MELTING

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ABSTRACT

One of the main advantages of additive manufacturing is to eliminate the joining processes and build the complex geometries without any need to post processing. However, size of the build chambers in powder bed systems limits the allowable largest part dimensions. Therefore, welding becomes an inevitable process for large scale part productions. In this study, the weldability of Ti-6Al-4V parts produced by selective laser melting both in as built and HIPped case were investigated. The effect of microstructural changes in weldability was discussed. Laser welding was chosen as welding technique due to its concentrated heat input resulting in a localized heat affected zone. A set of welding parameters (laser power, speed, focal length, head angle, inert gas pressure) were specified and applied to both SLM produced and conventionally produced plates with the same thickness. The resulting melt pool were analyzed and compared with each other.

Keywords: Ti6Al4V, Laser-powder bed fusion, laser welding, HIP

TEMPERATURE EVOLUTION DURING ADDITIVE FRICTION STIR DEPOSITION OF AL6061

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ABSTRACT

Emerging solid-state additive manufacturing (AM) methods have garnered significant interest due to their ability to minimize flaws commonly associated with fusion-based metal AM processes based on sintering or melting. Additive Friction Stir Deposition (AFSD), also known as MELD, is a solid-state AM technique that utilizes frictional heat to plasticize and deposit solid bars. While the AFSD process shows great promise with its high deposition rates and defect-free material characteristics, its limited technology readiness level hinders broader adoption. Optimizing process parameters is thus crucial for achieving successful outcomes, and implementing closed-loop control can further enhance part quality by addressing unexpected issues during the process. This paper advances the state-of-the-art by employing process monitoring by using thermocouples at various locations to monitor the temperature evolution during the AFSD process. Additionally, it evaluates the thermal performance of a specific process parameter set using proportional–integral–derivative (PID) control and explores the impact of closed-loop temperature regulation. The findings compare process parameter adjustments with PID enabled and disabled, highlighting their influence on part quality.

Keywords: Additive friction stir deposition, process parameters, process monitoring and control

ENHANCING PROCESSABILITY OF LASER POWDER DIRECTED ENERGY DEPOSITION OF CUCRZR ALLOY THROUGH NITROGEN-ASSISTED POWDER MODIFICATION

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ABSTRACT

Additive manufacturing (AM) of copper-based alloys has remained challenging due to the high reflectivity and thermal conductivity of copper. The aim of this work is to improve processability and quality of the CuCrZr alloy for the laser directed energy deposition technique. To this goal, nitrogen coating was implemented in order to increase surface roughness of the powder particles and reduce the laser reflectivity of this alloy.

Keywords: Additive manufacturing, powder treatment, copper alloys, microstructure analysis, hardness.

IN-SITU MONITORING OF SINTERING FOR BINDER-JETTED SS316L PARTS

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ABSTRACT

Binder jetting is a multi-step additive manufacturing process that involves forming metal powders into 3D shapes using a binder, followed by sintering. This technique offers superior surface quality and manufacturing speed compared to conventional powder bed fusion methods, all at a reduced cost. However, accurately achieving the desired final geometry is challenging due to anisotropic sintering shrinkage across three axes which significantly impacts process reliability. Relying on trial-and-error methods for each design is inefficient, emphasizing the importance of numerical predictions for sintering behavior. In this study, we performed sintering experiments on binder-jetted SS316L parts using an in-situ camera monitoring system. The sintering behavior was analyzed using parts with different geometries, including cubes, bridges, diamonds, and lattices. Our findings revealed that debinding and sintering are geometry-dependent processes, with each shape responding differently to the same sintering conditions. These results have been utilized to calibrate a numerical sintering model in a separate study.

Keywords: binder jetting, sintering, 316L stainless steel, online monitoring, shrinkage

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EFFECT ON CORROSION RESISTANCE OF CHROMIC ACID ANODIZING OF ADDITIVELY MANUFACTURED ALSI10MG ALLOY

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ABSTRACT

This study investigates the effect of chromic acid anodizing (CAA) on the corrosion resistance of additively manufactured AlSi10Mg alloy, a widely utilized material in aerospace and automotive industries due to its excellent strength-to-weight ratio and thermal conductivity. The alloy was fabricated using the Laser-Powder Bed Fusion (L-PBF) technique, and its unique microstructure and surface characteristics were evaluated for their influence on anodizing behavior. The CAA process parameters were optimized to achieve a uniform oxide layer on the complex geometry inherent to additively manufactured parts. Corrosion performance was assessed through salt spray test in a saline environment. Results demonstrated that the CAA treatment significantly enhanced the corrosion resistance of the AlSi10Mg alloy by forming a dense, protective oxide layer. Microstructural analysis revealed the role of manufacturing-induced defects and residual stresses on anodizing effectiveness. This study underscores the potential of CAA as a surface treatment for improving the durability of additively manufactured AlSi10Mg components in corrosive environments, advancing their applicability in critical industries.

Keywords: L-PBF, chromic acid anodize, corrosion, AlSi10Mg, salt spray

TRANSFORMING WASTE INTO INNOVATION: DEVELOPING PRINTABLE DATE PALM FIBER-REINFORCED LOW-DENSITY POLYETHYLENE COMPOSITES FOR SUSTAINABLE ADDITIVE MANUFACTURING

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ABSTRACT

The rapid growth of additive manufacturing (AM) technologies drives the demand for sustainable materials that address global environmental challenges. This research explores the development of eco-friendly 3D printing filaments by repurposing date palm waste—an abundant, underutilized byproduct in Qatar—combined with recycled low-density polyethylene (LDPE), a material typically unsuitable for 3D printing. By blending these materials, the study aims to produce optimized composites with tailored mechanical and thermal properties for non-structural engineering applications. A robust experimental design is employed to evaluate critical factors, including date palm fiber source (leaflets, midrib), fiber treatment, fiber content (5–20 wt%), and a unique matrix composition, to ensure high-quality filament extrusion and printability. Material characterization includes thermal stability via thermogravimetric analysis (TGA), rheological properties (melt flow index), and mechanical performance through tensile testing on ASTM-standard specimens. Scanning electron microscopy provides insights into fiber morphology and interfacial bonding, while FDM printing tests confirm layer adhesion and consistency, validating the composites' suitability for additive manufacturing. The preliminary findings emphasize the potential of transforming agricultural and plastic waste into high-performance materials, offering a scalable and sustainable solution for various industries. This work exemplifies how Plant-based Fiber Composites (PBFCs) can be leveraged in AM to advance a circular economy, paving the way for innovative, eco-conscious engineering practices and contributing to global sustainability initiatives.

Keywords: Circular Economy, Waste Valorization, Upcycled Waste Composites, Fused Filament Fabrication

CHARACTERIZING DOT-BY-DOT STEEL WAAM BARS USING CT, 3D SCANNING AND MECHANICAL TESTS

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ABSTRACT

This study focuses on the dot-by-dot deposition strategy in Wire Arc Additive Manufacturing (WAAM) technology, which consists of depositing molten metal droplets, creating line-type elements well-suited for large-scale and complex lattice structures. The study analyzes the geometric irregularities and internal defects in bars with varying nominal diameters, build angles (inclination concerning the vertical axis), and printing parameters. It evaluates their impact on mechanical performance via the results of Computed Tomography (CT) and high-resolution 3D scanning. Mechanical tensile tests were performed on the bars to have an idea about the key mechanical parameters, enabling the evaluation of the influence of geometric irregularities on the mechanical performance.

Keywords: Wire arc additive manufacturing, dot-by-dot deposition, porosity analysis, computed tomography

PERFORMANCE EVALUATION OF DOT-BY-DOT WAAM BARS THROUGH GEOMETRIC AND MECHANICAL CHARACTERIZATIONS

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ABSTRACT

This study presents the first results of a comprehensive research effort devoted to characterize the main properties of novel lattice structures composed by steel bars fabricated using the dot-by-dot Wire Arc Additive Manufacturing (WAAM) technique. Conducted as part of the CIRCULAR WELD project (funded by the Italian Ministry of Research under the PRIN program, financed by European Union – Next Generation EU), the final goal of the project is to enhance the quality, reliability, and precision of dot-by-dot WAAM processes and 3D-printed components through the development of an experimentally-validated digital twin model of the entire work-flow. As the first step of the research, different batches of straight steel bars were manufactured varying the main printing parameters in order to cover a range of diameters between 4-8 mm. The bars were then investigated through comprehensive geometric and mechanical characterizations in order to evaluate their printing quality and the key geometrical and material properties.

Keywords: Wire arc additive manufacturing, dot-by-dot deposition, geometrical model, mechanical characterization

UNCERTAINTY QUANTIFICATION OF LATTICE STRUCTURES FABRICATED BY MATERIAL EXTRUSION USING MICRO-CT-BASED SIMULATIONS AND TENSILE TESTS

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ABSTRACT

The effect of geometric uncertainties introduced by the material extrusion additive manufacturing process on the fabricated lattice structures on the tensile properties were investigated in this study. Individual lattice cells with various strut diameters were manufactured by material extrusion from PLA material. Micro-computer tomography (CT) was performed on the manufactured lattice cells. Finite element (FE) models were generated using the micro-CT images to account for the strut geometry variations on the simulations. FE analysis was conducted under tensile test loading conditions. Tensile tests were also performed for the fabricated lattice specimens to evaluate the differences between the micro-CT-based simulations and experimental results. Stiffness values were extracted from the repeated experiments for this purpose. Uncertainties were modeled using probability density functions (PDFs). Bayesian Information Criterion (BIC) was used to identify the most suitable PDF models. The uncertainty prediction potential of the micro-CT-based (FEA) was evaluated compared to the experiments.

Keywords: Lattice structure, material extrusion, finite element analysis, computer tomography, uncertainty

OPTIMIZATION OF BLOCK SUPPORT STRUCTURES WITH FIELD DRIVEN DESIGN METHOD

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ABSTRACT

Optimization of the support structures which used in laser powder bed fusion is important to achieve high quality prints, and to reduce production and post-processing costs and minimize material losses. This optimization is usually carried out manually and creates a workload in job preparations and wastes time. In this study, field driven design method is used to design block supports that are easy to clean and do not result in excessive mass. In the proposed method, the loads that act on the support during manufacturing are analyzed numerically and then applied as fields to optimize the support structures. Using process simulations and implicit design tools, improvements were achieved in terms of performance while keeping manufacturing times similar compared to standard support structure. The efficiency and advantages of the proposed method is demonstrated with numerical and experimental studies. In summary, this study presents an innovative, effortless and efficient support design workflow where process simulations are integrated into the field driven design method.

Keywords: Additive manufacturing, Powder bed fusion, Process simulation, Implicit modeling, Lattice structure

A GRADED-DENSITY DESIGN STRATEGY TO INCREASE NATURAL FREQUENCIES OF LIGHTWEIGHT METAL LATTICE STRUCTURES PRODUCED BY LPBF

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ABSTRACT

This study focuses on the critical role that density gradients play in resonance frequency optimization and the quasi-static performance of metal lattice structures produced by Laser Powder Bed Fusion (LPBF). A simple cubic volume is used to investigate the correlation between FE-based modal analysis and experimentally determined eigenfrequencies as measured by the non-destructive Impulse Excitation Technique (IET). It is shown that an optimized gradient design can lead to a significant increase in the resonance frequencies keeping the mass the same without significantly changing the quasi-static compressive performance.

Keywords: lattice structures, field optimization, modal analysis, quasi-static testing

CRACKING BEHAVIOUR OF AA6061 AL-ALLOY DURING LPBF WITH DIFFERENT BEAM INTENSITY PROFILES

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ABSTRACT

The AA6XXX aluminum alloy series, widely recognized for their outstanding mechanical properties, are prone to significant hot cracking under conditions of rapid solidification, such as those encountered during welding and Laser Powder Bed Fusion (LPBF) processes. This inherent susceptibility presents a critical barrier to their processability in advanced manufacturing applications. While previous efforts to address hot cracking have predominantly focused on altering the alloy's chemical composition to modify its microstructure, a fully effective technological solution for LPBF that avoids changes to the alloy composition remains elusive. In this study, spatial laser beam shaping, employing core and ring intensity configurations, is proposed as an innovative approach to mitigate hot cracking in AA6061 aluminum. A contemporary active fiber laser source featuring multiple cores was utilized to explore novel beam shapes. Single-track deposits were fabricated to evaluate the influence of beam intensity distribution on the generation of cracks. The relationship between laser beam shape, melt pool geometry, and crack length density was systematically analyzed. These findings were further contextualized in the framework of multilayer deposits, highlighting the potential for effective crack suppression through tailored beam shaping strategies.

Keywords: Laser beam shaping, Hot cracking; High strength Al-alloys, Laser powder bed fusion

CHARACTERIZATION OF CUCRZR AUXETIC STRUCTURES MANUFACTURED BY LASER POWDER BED FUSION FOR STRAIN SENSOR APPLICATIONS

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ABSTRACT

This study aims to fabricate copper alloy structures with a negative Poisson's ratio (NPR), specifically auxetic structures, using the laser powder bed fusion (LPBF) technique for sensor applications. The study will involve the production of several re-entrant designs to conduct comprehensive mechanical analysis of these structures and to optimize them for sensor technology applications. The geometrical accuracy of the manufactured samples was assessed using a CMM. The flaws, including porosity, were analyzed using micro-CT. The mechanical qualities were examined by the execution of tensile and compression tests.

Keywords: auxetic geometry, copper alloy, sensor, additive manufacturing

FROM CASTING TO PRINTING: A CASE STUDY ON WAAM AND THE METALLURGY OF A STAINLESS 318 IMPELLER

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ABSTRACT

This study presents a case study of an impeller manufactured using Wire Arc Additive Manufacturing (WAAM) by: 1) comparing it to a cast counterpart through metallurgical tests, including digital radiography, microstructural analysis, and tensile testing; 2) addressing real-world challenges faced by additive manufacturers, such as reverse engineering requirements, raw material procurement, and end-user expectation. The WAAM impeller, made of grade 318 stainless steel, demonstrated superior quality. Digital radiography confirmed that the WAAM part had significantly fewer defects than the cast version. Microstructural analysis revealed micro-porosities up to 0.03 mm in diameter, while tensile testing showed WAAM parts exhibiting greater strength and elongation compared to cast counterpart. Delta ferrite was observed and quantified. Further research is needed to examine the impact of sigma intermetallics and delta ferrite on corrosion resistance. The WAAM process enables the impeller to be printed in just 6 hours and machined in 4, facilitating on-demand production with exceptional efficiency. Its high repairability and extended service life reduce replacement needs, positioning WAAM as a transformative technology capable of reducing long-term costs while delivering robust, reliable, and high-performance large-scale components.

Keywords: WAAM, Stainless, Impeller, Defects

MODELING AND FABRICATION OF HYBRID AUXETIC LATTICE-STRUCTURED TI6AL4V SPINAL CAGE FOR LASER POWDER BED FUSION

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ABSTRACT

Spinal interbody fusion cages are critical in stabilizing the spine and promoting bone fusion in degenerative disc disease treatments. Artificial porous spinal cages are still under investigation to improve high strength and biocompatibility of the implant due to patient-specific demands. This study introduces a novel spinal cage design of Ti6Al4V within combination of auxetic (re-entrant) and diamond unit cell structures for manufacturing with laser powder bed fusion (L-PBF). Firstly, finite element analysis (FEA) was performed on prismatic structures to characterize unit cell dimensions of lattice structures by nTopology software. The results showed that rectangular prism structures (20x20x30mm) with auxetic and diamond unit cells with the stress value of 121 MPa and 266 MPa, displacement of 0.015 mm and 0.026 mm under 1000N load, respectively. Then, unit cells were integrated in a hybrid spinal cage design to use the benefits of both lattice structures for future potential clinical benefits. The hybrid design gave the stress value of 185 MPa, displacement value of 0.0042 mm which was satisfactorily acceptable when compared with cortical bone. Finally, the hybrid design spinal cage was manufactured by L-PBF method to observe the structure visually.

Keywords: Auxetic, lattice, spinal cage, laser powder bed fusion

MICROSTRUCTURAL EVOLUTION OF 17-4 PH STAINLESS STEEL PRODUCED VIA LASER POWDER BED FUSION

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ABSTRACT

Laser Powder Bed Fusion (LPBF) is a widely used metal additive manufacturing technique that enables producing of extremely complex geometries with the advantage of reduced weight and lead time. However, processing martensitic grade stainless steel parts with various LPBF conditions such as material composition, laser mode and type of the protective gas leads to different microstructure. Furthermore, 17-4 PH stainless steels exhibit variations in heat treatment response and mechanical properties. Therefore, this work aims to understand the influence of the layer thickness, protective atmosphere (nitrogen vs. argon) and the laser mode (continuous vs. pulsed) on the as-built microstructure. Moreover, various heat treatments such as solution annealing with two different cooling condition (air cooling and water quenching) and aging were applied on the as-built specimens to understand the microstructural evolution and mechanical behavior of additively manufactured 17-4 PH stainless steels.

Keywords: Laser Powder Bed Fusion, 17-4 PH, Heat Treatment, Microstructure

SELECTIVE LASER POLISHING APPLICATIONS ON ADDITIVELY MANUFACTURED MATERIAL SURFACES

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ABSTRACT

Additive manufacturing (AM) offers exceptional design flexibility, making it possible to create complex shapes that traditional manufacturing methods cannot achieve. However, a major limitation of AM processes lies in their inherently poor surface quality, which is often unsuitable for final applications. Laser polishing (LP) emerges as a promising post-processing method to enhance surface finish by selectively melting a thin surface layer, thereby reducing surface roughness. In this study, the selective laser polishing process was performed on specific geometric shapes identified on the surface, focusing on investigating the surface characteristics of Ti-6Al-4V parts manufactured using the electron-beam-melting (EBM) process. This demonstrates the potential of selective laser polishing to significantly enhance surface quality in additively manufactured components, with a decrease from an initial Sa of 33.805 µm to values between 1 and 3 µm.

Keywords: Additive manufacturing, selective laser polishing, electron beam melting, surface roughness

INVESTIGATING THE EFFECT OF HEAT TREATMENT ON THE MECHANICAL PROPERTIES OF ALSI10MG PARTS PRODUCED BY SELECTIVE LASER MELTING USING NANO-INDENTATION

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ABSTRACT

Selective Laser Melting (SLM) is used to produce complex AlSi10Mg components, with heat treatments improving microstructure and mechanical properties. This study investigates the effects of 12 different heat treatment conditions on the mechanical properties of AlSi10Mg parts produced with SLM. All samples were processed a solutionizing step at 520°C for 2 hours, with only the aging conditions varying. The samples were prepared by mechanically grinding and polishing their surfaces using colloidal silica to achieve a mirror-like finish for nanoindentation testing. Nanoindentation tests were performed using a KLA iMicro Nanoindentation machine, assessing hardness and elastic modulus. The results indicate that aging at 160°C for 4 hours significantly increased hardness due to optimized Si precipitate formation, which hindered dislocation motion. Prolonged aging and insufficient aging times at lower temperatures resulted in decreased hardness. The quenched and as-built samples showed lower hardness due to a lack of precipitate formation. Elastic modulus exhibited less variation, highlighting that it is less sensitive to microstructural changes. Overall, the study confirms that optimized aging conditions improve the mechanical properties of additively manufactured AlSi10Mg components, enhancing strength and durability.

Keywords: Selective Laser Melting, AlSi10Mg, Heat treatment, Nanoindentation

OPTIMIZATION OF LPBF PROCESS PARAMETERS AND HEAT TREATMENT EFFECTS ON THE MICROSTRUCTURE AND MECHANICAL PROPERTIES OF CO-CR ALLOYS

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ABSTRACT

This study examines the impact of Laser Powder Bed Fusion (LPBF) process parameters and annealing temperature on the microstructure and mechanical properties of Co-Cr-Mo alloys. Specimens were fabricated using in-house gas-atomized powder with process parameters optimized through a Design of Experiment (DOE) methodology and three different heat-treatment were applied to the selected four specimens. The results revealed that the highest microhardness was obtained in the as-built sample produced using the highest laser power. Furthermore, as the annealing temperature increased, the precipitate size expanded, leading to a reduction in microhardness attributed to grain growth and precipitate coarsening.

Keywords: Laser Powder Bed Fusion, Co-Cr alloy, heat treatment, microstructure, mechanical properties

INVESTIGATING BUILD PLATE SURFACE PROPERTIES FOR FDM PRINTING

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ABSTRACT

This study investigates the impact of build plate surface characteristics, specifically surface roughness and thermal deformations, on nozzle distance. Achieving high-quality prints in fused deposition modeling (FDM) requires precise control of bead morphology, heavily influenced by the nozzle-to-build plate distance. Using a commercial FDM printer equipped with a spring-back potentiometer for real-time position data, the build plate surface was mapped at ambient temperature and at elevated temperatures (35 °C, 70 °C, and 105 °C). Results reveal significant variations in nozzle distance exceeding 100 µm due to surface roughness and thermal expansion, potentially leading to inconsistencies in the first printing layer. These findings emphasize the importance of monitoring nozzle distance to enhance FDM printing quality, particularly in applications requiring precise layer properties, such as surface coating processes.

Keywords: FDM, Build Plate Roughness, Real-Time Measurement, Topology

IMPROVED SAMPLING TUBE DESIGN FOR ENHANCED RESPIRATORY FUNCTION MONITORING USING 3D BIOPRINTING

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ABSTRACT

Accurate monitoring of respiratory function is essential for effective clinical management of respiratory conditions. This study introduces innovative respiratory gas sampling tubes fabricated through 3D printing, designed to improve gas sampling efficiency and measurement precision. The use of 3D printing enables rapid prototyping, customization of internal geometries, and cost-effective production, making it ideal for developing advanced medical devices. Four tube designs were developed: a traditional flat inner surface tube and three novel cavity-structured tubes with varying cavity depths and widths. Performance was assessed using LM35 temperature sensors and anemometers to measure respiratory rate and exhaled gas volume. Results demonstrated that the Level 3 cavity tube significantly enhanced gas sampling accuracy, achieving volume measurements (486±12 ml) closest to reference values. These findings highlight the potential of advanced 3D-printed designs to optimize respiratory monitoring in clinical applications.

Keywords: 3D bioprinting, Sampling tube design; Respiratory monitoring; Chronic obstructive pulmonary disease (COPD); Biocompatible materials

4D PRINTING OF ELECTRO-ACTIVE CONTINUOUS FIBER REINFORCED AUXETIC STRUCTURES

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ABSTRACT

This study investigates the mechanical performance and shape recovery of 4D-printed electro active carbon fiber-reinforced auxetic structures designed for load-bearing applications. To simulate real-world industrial conditions, the shape memory behavior and mechanical properties were evaluated at room temperature (RT). The shape recovery capability of the 4D-printed structures was assessed using the Joule heating method. The results demonstrated that carbon fiber reinforcement significantly improved mechanical properties of the struc-tures. Moreover, the shape recovery test result showed that the structure can effectively recover more than 90% of applied deformation by Joule heating method. This study's findings demonstrate that 4D-printed fiber-reinforced structures can serve as smart, reusable, load-bearing elements with potential applications in various industries, including biomedical and aerospace.

Keywords: Additive Manufacturing, Smart Materials, Cellular Structures, Shape Recovery, Joule Heating, Electro-active structures

INVESTIGATION OF DEFECT GROWTH IN L-PBF PRINTED ALSI10MG ALLOY

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ABSTRACT

The additive manufacturing (AM), particularly laser powder bed fusion (LPBF) printing of AlSi10Mg alloy is a transformative approach for industries requiring high-performance and lightweight components. However, widespread industrial adoption of LPBF printing of this alloy is hindered by the formation of process-induced defects, such as porosity and lack of fusion, which degrade mechanical performance and reliability. This study examines defect mechanisms in LPBF-fabricated AlSi10Mg alloy under tensile loading, emphasizing their evolution and influence on material behavior. Tensile samples were manufactured using SLM Solutions powders and tested for mechanical properties and defect characteristics. The samples demonstrated a yield strength of 198 MPa, ultimate tensile strength of 318 MPa, and elongation at break of 8.5%. Gas pores, initially contributing to a defect volume of 0.3%, grew under mechanical loading, reaching 0.6% at necking and 1.2% in the fracture region. Defect growth and coalescence were identified as primary mechanisms leading to ductile fracture and limited ductility. These findings highlight the necessity of mitigating defect formation to enhance structural integrity. Future work will explore the effects of stress triaxiality on defect evolution.

Keywords: Laser powder bed fusion, tensile testing, Al-Si10-Mg Alloy, Tomography, Defect

FULFILLING AM'S POTENTIAL: FAST DEVELOPMENT CYCLES, NDT AND QUALITY ASSURANCE USING NONLINEAR RESONANCE

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ABSTRACT

The next generation of AM designs will take advantage of functional optimisation to minimise the material in a part to only where it is required. This will lead to parts with elegant organic designs that have lower mass, reduced raw material cost and faster print times. For this to be feasible, validation that material properties in finished parts match those assumed in structural CAD models would be needed. Additionally, as performance will depend equally on every section of a part, effective Non-Destructive Testing (NDT), for critical applications, like Aerospace and Power Generation, will be indispensable to achieve high volume production but without compromising quality control. Some of the challenges of NDT of AM parts are the detection of flaws such as contact cracks, trapped powder, porosity, and the inspection of dense materials such as copper. This presents a challenge to established NDT methods for critical parts because techniques such as ultrasound and dye penetrant are not effective due to part complexity and surface roughness, and X-CT is not economically viable for production. Non-Linear Resonance technology, which works by exciting components into their resonance modes of vibration and measuring their responses, has been implemented in our product RD1-TT and offers a solution to these challenges. This presentation will showcase case studies conducted on RD1-TT for different AM materials (composites, ceramics, and metals) and complex geometries, showing the capabilities of the technology. Finally, the business use cases of the RD1-TT for AM will be presented including its use as a quality assurance tool for testing AM components at each postprocessing step and its use for R&D as an optimisation tool.

Keywords: Nonlinear Resonance, NDT, Contact Cracks

DESIGNING ECO-FRIENDLY CAST IRON PART FOR FARMING TRACTOR AND PRODUCTION WITH 3D SAND PRINTING TECHNOLOGY

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ABSTRACT

Stiffening ribs are frequently used in castings by commercial vehicle and agricultural tractor manufacturers to enhance overall mechanical performance and reduce weight, particularly in line with current e-mobility and weight reduction trends. In this study, a design was developed for the hinge used in an agricultural tractor's door mechanism in order to simplify the fettling process applied after casting. The new geometry, which can be produced without cores, was evaluated in terms of shrinkage tendency and buckling resistance. While durability analysis was carried out to assess the structural integrity and stiffness of the new ribbed structure, solidification simulations were performed using MAGMASoft to investigate shrinkage tendencies and identify potential casting defects. The rib geometries were examined for their susceptibility to shrinkage and mechanical strength, and were produced through rapid prototyping with 3D sand printing technology. The scrap rate of the existing design is around 10%, whereas the scrap rate of the coreless design is 3%. Owing to the advantages provided by the reduced weight and scrap rate, the carbon footprint was lowered from 935 tons of CO_2e/year to 671 tons of CO_2e/year.

Keywords: casting design, 3D sand printing, MAGMASoft, structural analysis, carbon footprint

THE USE OF 3D SAND PRINTERS IN CAST IRON PARTS' PRODUCTION FOR HEAVY TRUCK, CONSTRUCTION MINING, AGRICULTURAL AND OTHER INDUSTRIES

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ABSTRACT

The use of 3D sand printers in the casting industry represents a revolutionary advancement in manufacturing processes. While traditional casting methods can be time-consuming and costly in terms of mold preparation, 3D printers accelerate this process and deliver more precise results. Sand printers enable the production of complex and detailed geometric shapes with high accuracy. Additionally, they offer significant advantages in areas such as prototype manufacturing, low-volume production, and customized mold designs. The use of this technology reduces material waste, shortens production times, and lowers overall costs. As a result, the integration of 3D sand printers in the casting industry is considered an important step in terms of efficiency, flexibility, and competitiveness.
In this article, complex geometrically shaped cast iron parts produced with the help of 3D sand printers in the casting industry and new trends are discussed.

Keywords: additive manufacturing, 3d sand printer, casting

EXTRACTION OF LAYER DEPOSITION TEMPERATURE DATA FROM LARGE SCALE ADDITIVE MANUFACTURING SETUP USING THERMAL IMAGING AND STATISTICAL ANALYSIS

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ABSTRACT

This study investigates the feasibility of predicting the temperature of the newly deposited layer in large scale composite printing by leveraging the CEAD AM Flexbot E25 and data from a Fluke RSE 600 alongside statistical analysis. A threshold-and-blob-filtering algorithm isolates the temperature data of the top layer, and a half-normal distribution is applied to predict the temperature at the next point of extrusion. The results demonstrate that the predicted temperatures consistently fall within a ±5°C range, indicating a robust and reliable method for simultaneously optimizing layer adhesion and decreasing possible sagging. Potential enhancements include integrating deep machine learning algorithms and incorporating a Kalman Filter to further refine temperature predictions. This study presents a reliable method for accurately predicting the temperature of the recently deposited layer in large-scale composite 3D printing.

Keywords: Large Scale Additive Manufacturing, Composite 3D Printing, Layer Adhesion, Thermal Prediction using Thermal Imaging, In-process Monitoring and Optimization

ENHANCING THE PRODUCTIVITY BY BROADENING THE PARTICLE SIZE DISTRIBUTION AND INCREASING LAYER THICKNESS IN LASER POWDER BED FUSION

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ABSTRACT

In laser powder bed fusion (LPBF), the use of powder with a narrow particle size distribution (PSD) is generally recommended to manufacture parts with high resolution along the build direction, which consequently increases operational costs due to the low yields of feedstock production from the gas atomisation process. To utilise a larger portion of the output from gas atomisation feedstock production, as well as improve manufacturing productivity, this study investigates the feasibility of employing a broader PSD (15–106 µm) and increased layer thickness (90 µm) for processing Ti-6Al-4V. By optimising laser parameters to accommodate a larger particle size distribution and thicker layers, the build rate was significantly increased, while maintaining part density and mechanical performance. Experimental results indicate that builds using a broader PSD and increased layer thickness exhibited comparable densities (≥99.96%) and mechanical properties (yield stress of 943 MPa and elongation of 16%) to those produced with a standard PSD (15–53 µm) and layer thickness (60 µm). Cost analysis showed a potential saving of up to 30% in feedstock costs and a reduction in build time by one-third, highlighting the economic viability of this approach. These findings provide a baseline approach for more sustainable and efficient LPBF practices, making the technology accessible for a wider range of industries.

Keywords: Laser powder bed fusion, particle size distribution, layer thickness, Ti-6Al-4V

DESIGN OPTIMIZATION OF AUXETIC GEOMETRIES FOR STRAIN SENSOR APPLICATIONS

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ABSTRACT

This study involves analyzing the effects of unit cell parameters in re-entrant auxetic lattices for resistive strain sensors. CAD models with varying cell parameters are prepared and their electrical resistance under load are determined using COMSOL Multiphysics. The effects of geometrical parameters on gage factors are discussed.

Keywords: auxetic, sensor, additive manufacturing, copper alloy

TI-5553 ALLOY POWDER MODIFICATION FOR COLD SPRAY ADDITIVE MANUFACTURING THROUGH HEAT TREATMENT

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ABSTRACT

Cold spray additive manufacturing (CSAM) is a solid-state material deposition technique to create new parts and repair components. Ti-5553 powder produced by plasma atomization can exhibit a non-equilibrium state due to rapid cooling. Also, the presence of the ω phase in Ti-5553 powder can hinder dislocation movement, limiting material deformation and impacting the coating performance. Therefore, solution heat treatment of beta titanium powder, Ti-5553, can change and improve the cold sprayability. In this study, for the first time, the effect of powder heat treatment on the microstructural evolution and performance of Ti-5553 alloy for cold spray applications was investigated. The feedstock powder was heat treated in two stages: HT-1 at 900°C for 3 hours with forced air cooling and HT-2 at 665°C for 1 hour with furnace cooling. Transmission Electron Microscopy (TEM) revealed the formation of the ω phase during the HT-1 process. Splat test and deposit manufacturing investigated through Electron Backscatter Diffraction (EBSD) and Electron Channeling Contrast Imaging (ECCI) showed significant differences in deformation behaviour and adhesion between feedstock and heat-treated powders. Coatings produced with HT-2 powder demonstrated reduced porosity (~7%) compared to the feedstock (~14%).

Keywords: Cold Spray Additive Manufacturing, Ti-5553, Heat Treatment, ω phase, TEM

FASTENERS-FREE ADDITIVELY MANUFACTURED “FITTING JOINTS” FOR AIRCRAFT’S PRIMARY FLIGHT STRUCTURES

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ABSTRACT

The innovative joint between additively manufactured metal and composite materials developed within the MIMOSA Project aims to replace traditional rivets and adhesives through mechanical interlocking mechanisms. The aluminum alloy surface (fabricated though L-PBF process with AlSi10Mg alloy) is engineered with 3D-printed anchor structures that mechanically engage the carbon fibers of the composite adherend. This design offers production process optimization, weight reduction, and a minimized environmental footprint. The application of this joint to large-scale aircraft structures, particularly the vertical stabilizer, requires preliminary investigations to assess structural specifications and localized force distributions. This study focuses on the modeling and simulation of fluid-structural interactions acting on the primary flight structure under different operational conditions, including varying rudder deflections (from 0° to 20°) and airspeeds (ranging from 100 to 250 m/s). The analysis leverages finite element method (FEM) and computational fluid dynamics (CFD) techniques to create a comprehensive model. A detailed 3D representation of the vertical stabilizer, incorporating seven distinct materials and more than 300 parts, was developed. The local forces transmitted to the "fittings"—specialized connectors between the tail and fuselage, where the MIMOSA joints are implemented—were computed. Finally, the stress distribution at the multi-material interlocked interface was analyzed to determine the safety factor of the innovative component, ensuring its structural reliability under operational loads.

Keywords: multi-material joint, lightweight, AlSi10Mg, fluid dynamics, aerostructures

MESO-SCALE MODELING OF THE COHESIVE INTERFACES OF INTERLOCKED JOINTS BETWEEN AM-METAL AND COMPOSITE

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ABSTRACT

The challenge of securely joining dissimilar materials, such as metals and carbon fiber-reinforced polymers (CFRP), is a critical issue in advanced engineering. This work presents the MIMOSA joint, an innovative approach that employs additive manufacturing (AM) to create surface modifications on metal substrates with integrated anchor structures. These anchors form a mechanical interlock with CFRP, eliminating adhesives and traditional fasteners, thus simplifying assembly processes and enhancing joint performance. The joint is manufactured through an autoclave curing process, during which CFRP layers are consolidated over the modified metal surface. Numerical analyses were conducted to examine joint behavior under two scenarios: fully bonded and partially bonded configurations. A Representative Volume Element (RVE) methodology was utilized to model fiber movement, resin-rich zones, and interfacial failure using Cohesive Zone Modeling (CZM). The results demonstrate that stress concentrations occur near the anchors due to fiber movement and resin accumulation, potentially initiating failure. While the anchors improve load transfer, stress at their base is a critical factor affecting joint reliability. Microscopic observations confirmed the presence of resin pockets and fiber alignment around the anchors. These findings underscore the importance of optimizing anchor geometry to enhance joint strength and durability, offering valuable insights for lightweight, high-performance structural applications.

Keywords: multi-material joint, lightweight, AlSi10Mg, CZM, FEM

EDM ELECTRODES MANUFACTURED WITH ELECTRICALLY CONDUCTIVE MATERIALS BY AM

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ABSTRACT

This study explores the use of additive manufacturing (AM) technologies for producing electrodes used in Electrical Discharge Machining (EDM). Advanced methods like Atomic Diffusion Additive Manufacturing (ADAM and BMD) and related metal-based systems showcased significant potential in replicating the performance of traditional copper electrodes. While Laser Sintering (LS) electrodes faced durability challenges, metal-based AM systems provided improved erosion resistance and dimensional accuracy. Injection molding validation demonstrated that AM-produced molds delivered precise, consistent parts while reducing production costs and time. These findings underscore AM's transformative role in enhancing manufacturing flexibility and efficiency.

Keywords: Additive Manufacturing, EDM, ADAM Electrodes, Injection Molding, Laser Sintering

EFFECT OF HEAT TREATMENTS AND HIP PROCESSES ON MICROSTRUCTURE AND CORROSION BEHAVIOR OF TI-6AL-4V ALLOY PRODUCED BY E-PBF

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ABSTRACT

This study investigates the effects of heat treatment (HT) and hot isostatic pressing (HIP) on the corrosion behavior of Ti6Al4V alloy fabricated by powder bed fusion using electron beam (E-PBF) technique. Results indicate that thermal processing coarsens the α-lathe compared to the as-built condition. The β phase diminishes with aging and higher HIP temperatures. Open circuit potential (Eocp) measurements reveal that the HIP3 sample exhibits the most positive corrosion potential, attributed to an equiaxed grain structure, coarser α-lathe, and the absence of β phase. Conversely, HIP1 displays inferior corrosion resistance, likely due to galvanic corrosion from a higher β phase content. Overall, the HIP process results in lower corrosion potential than the as-built condition. Microstructural analysis identifies needle-like β phase in HT1 and HIP1 within the corroded areas. EDS line scans detect aluminum oxide at the corrosion edge of HIP1, suggesting an aluminum-based barrier effect. HT1 exhibits superior impedance resistance, linked to coarser α-lathe morphology and a well-defined β phase structure.

Keywords: Powder Bed Fusion Using Electron Beam, Ti6l4V, Corrosion, Thermal Treatment

DESIGN OPTIMIZATION OF A SANDWICH PANEL WITH LATTICE FOR ADDITIVE MANUFACTURING

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ABSTRACT

This study focuses on the design and optimization of a lightweight AlSi10Mg sandwich panel with a Body-Centered Cubic (BCC) lattice core for additive manufacturing. An algorithm for structural shape optimization was formulated based on six parameters that include three diameters of a regional strut, unit cell length, core thickness, as well as face-sheet thickness. The Finite Element Method (FEM) analysis was carried out on Hypermesh and facilitated with MATLAB optimization codes. A two-step optimization process was used, where the primary emphasis was placed on optimizing core thickness and dimensions of the unit cell, other parameters including strut diameters as well as the face-sheet thickness were optimized next. Consequently, honeycomb-core panels were reduced by 29.26% while satisfying structural, mass and natural frequency constraints. This confirms the usability of lattice structures and the application of additive manufacturing in high-performance aerospace parts.

Keywords: Additive Manufacturing, Structural Optimization, Lattice Structures, Sandwich Panels, Selective Laser Melting

NUMERICAL INHERENT STRAIN MODELING FOR RESIDUAL STRESS MANAGEMENT IN LPBF-PRODUCED CO-CR ALLOYS

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ABSTRACT

Numerical modeling of residual stress is crucial in Laser Powder Bed Fusion (LPBF) for ensuring the reliability of critical components. By accurately predicting and managing residual stress, the quality of parts is improved, making additive manufacturing a more viable solution for high-performance applications. This study examines the deflection behavior of Co-Cr-Mo alloy fabricated using (LPBF). The samples were fabricated using two different processing parameter sets, and deflections were measured. The results revealed higher deflection and visible cracks in the samples produced with higher laser power, leading to increased residual stress. Simufact Additive simulations validated the deflection results with less than 1% error, and inherent strain values were obtained for both samples. Ongoing tests and XRD analysis will further clarify residual stress behavior, contributing to the successful manufacturing of complex engine parts.

Keywords: Laser Powder Bed Fusion, Co-Cr alloy, residual stress analysis, computational model

DESIGN AND LIFECYCLE OPTIMIZATION OF THE ADDITIVELY MANUFACTURED FOOT OF THE QUADRUPED ROBOT

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ABSTRACT

This study explores the design optimization of additively manufactured robotic feet for quadruped robots used in protection and surveillance missions. Additive Manufacturing (AM) brings design freedom and enhances functional performance while eliminating molding costs and keeping project timelines. The robotic foot, made from Elastic 50A, a hyperelastic material, undergoes significant elastic deformation and recovers its original shape when the applied forces are removed. The robotic foot is optimized through finite element analysis (FEA) and experimental testing to meet design requirements for strength and extended operational life under cyclic compressive loading conditions. The study also compares the economic feasibility of AM with traditional manufacturing methods. The FEA results, validated through compression tests, successfully predict the material's compressive behavior. Additionally, operational lifecycle tests simulate real-world conditions to evaluate the durability and long-term performance of the robotic foot. This work provides valuable insights into the design and manufacturing of advanced robotic feet, enhancing their performance while ensuring cost-effective and time-efficient production.

Keywords: Additive Manufacturing, Robotic Foot, Design Optimization, Elastic 50A, Operational Lifecycle

THE IMPACT OF ENERGY DENSITY AND PARAMETERS ON SURFACE ROUGHNESS OF CONSOLIDATED DESIGNED PARTS FOR ELECTRON BEAM MELTING

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ABSTRACT

Additive manufacturing technology enables the production of consolidated parts, lattice components and complex geometries, providing substantial benefits for industrial applications. One of the key advantages is the ability to manufacture multi-component structures as a consolidated part, which can enhance performance and reduce assembly requirements. However, current additive manufacturing technologies still face challenges in fully meeting industrial standards for surface roughness, dimensional accuracy, and the minimum gap tolerances required for consolidated production. To address these limitations, this study focuses on optimizing the design and production strategies for consolidated parts manufactured using the electron beam melting (EBM) method. The research aims to establish suitable parameter sets for EBM and to identify production strategies tailored for consolidated part design. In this context, experiments were conducted using various combinations of key EBM parameters, including current, scanning speed, and line offset, which influence energy density. The surface roughness and hardness of the produced parts were measured, and the minimum energy density required to melt Ti6Al4V powder was calculated and experimentally validated. By aligning the study's objectives with the needs of consolidated part design, the findings are expected to contribute to the development of optimized EBM parameters and production strategies that address industrial requirements more effectively.

Keywords: Additive Manufacturing, Energy Density, Parameter Optimization, Surface Roughness

NUMERICAL MODELING OF SINTERING DYNAMICS IN BINDER-JETTED SS316L COMPONENTS

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ABSTRACT

Binder Jet Additive Manufacturing (BJAM) offers advantages like cost efficiency and faster production but faces challenges in achieving near-full density and dimensional accuracy during the sintering process. This study addresses these challenges by developing a finite element modeling (FEM) framework for simulating the sintering of binder-jetted SS316L parts. Incorporating experimental data, the model captures densification behavior, and gravity-induced distortions considering variables such as viscosity, sintering stress, and grain growth. Calibrated with in-situ shrinkage and density monitoring, the model employs ANSYS 2024 R2 and OPTISLANG for parameter optimization, achieving close alignment with experimental results. Validations using cube and bridge geometries demonstrated less than 5% error in shrinkage predictions and 3% error in relative density estimates. The calibrated model was further applied to complex geometries, confirming its effectiveness in predicting shrinkage and deformation. This work advances the reliability of BJAM by optimizing sintering parameters and minimizing distortions, laying the foundation for enhanced industrial scalability.

Keywords: binder jetting, sintering, 316L, numerical modeling, shrinkage

Acknowledgements: The authors gratefully acknowledge the Scientific and Technological Research Council of Türkiye (TUBITAK) under Grant Number 221M200 for their financial support.

ADAPTING ADDITIVE MANUFACTURING TECHNOLOGY THROUGH DOCUMENTATION & STANDARDIZATION

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ABSTRACT

The research on documentation and standardization for additive manufacturing remains limited in the literature. It is crucial to ensure that information from the design phase is accurately translated into the final product. Moreover, they also provide standard steps for production and quality control of the output product. Post process optimization should also be included in the documentation as well. In this study, we've tried to implement an approach for the documentation and standardization of AM parts.

Keywords: Standardization, Documentation, Quality Control, Process Control, MBD

DESIGN AND VALIDATION OF LATTICE-INTEGRATED HEATSINKS USING ADDITIVE MANUFACTURING

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ABSTRACT

Advances in additive manufacturing have simplified and reduced the cost of producing parts that are challenging and expensive to make using traditional methods. This technology allows for the creation of consolidated parts, lattice structures, and complex geometries, offering significant advantages for various industries. Heatsinks are components that dissipate heat using fin structures to increase surface area and improve heat transfer efficiency. Fin designs can include various geometries such as rectangular, triangular, wavy, slotted, perforated, and striped plate types. This study aims to share the results and evaluations obtained from the design, analysis, and testing processes for developing an innovative fin design using lattice structures. Traditional fin designs can be insufficient for some cases in terms of heat dissipation. To address this issue, a lattice fin design was developed using additive manufacturing. Through the application of lattice structures, the heat dissipation efficiency can be enhanced by increasing the surface area. Time-dependent thermal analyses were performed on fin patterns designed with various types lattice structures and gyroid was selected as the optimal lattice type for the design. Testing of the prototype manufactured by AlSi10Mg using Selective Laser Melting (SLM), revealed consistent performance improvements in heat dissipation, aligned with the analysis results.

Keywords: Heatsink, lattice, gyroid, fin structures, Selective Laser Melting

OPTIMIZING LASER POWDER BED FUSION PROCESS PARAMETERS FOR ENHANCING IMPACT STRENGTH OF H13 TOOL STEEL

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ABSTRACT

This study was focused on the optimization of Laser Powder Bed Fusion (L-PBF) process parameters for manufacturing H13 tool steel parts. Key objectives included enhancing mechanical properties, production efficiency, and reducing costs through the systematic adjustment of laser power, scanning speed, and build orientation with three different levels. Impact tests and scanning electron microscope (SEM) analysis were applied on to the three replicate samples for determining optimal process parameter set. The results demonstrated that impact strength of the samples was highly affected by different parameter sets.

Keywords: H13 Tool Steel, Laser Powder Bed Fusion, Mechanical Properties, Impact Test, Parameter Optimization

Acknowledgements: This work has been supported by Yildiz Technical University Scientific Research Projects Coordination Unit under project number FYL-2024-6246.

COMPARISON OF MICROSTRUCTURE AND HARDNESS OF AD730 LASER POWDER BED FUSION AND UDIMET720LI FORGING ALLOYS

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ABSTRACT

Nickel based superalloys are widespread materials which are utilized for high temperature applications such as gas turbine engines due to their high-performance characteristics such as fatigue, creep, tensile properties at both room and elevated temperature and excellent corrosion resistance. Additive manufacturing is an advanced manufacturing method which offers design freedom advantage over conventional manufacturing methods for near net shape modelling of engineering designs. However, it is still a question mark that the performance of the additively manufacturing parts against the conventional methods. In this study, high pressure turbine disks were manufactured by laser powder bed fusion (L-PBF) and close die forging methods. Moreover, their mechanical and metallurgical characteristics were examined via part cut-up and witness samples. According to the grain size measurements, it was observed that the disk produced by L-PBF had coarser grains than forged disk.

Keywords: Nickel based superalloys, Laser Powder Bed Fusion, Close die forging, Additive Manufacturing

PREPARATION OF GRAPHENE REINFORCED POLYMER COMPOSITE USING 3D PRINTING TECHNOLOGY AND INVESTIGATION OF MECHANICAL PROPERTIES

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ABSTRACT

Three-dimensional (3D) printing is an additive manufacturing technology that enables the rapid, precise, customized, and efficient production of components with complex structures directly from a digital 3D CAD model to a physical model without the need for molds, as an alternative to traditional manufacturing methods. Programmable Photopolymerization (P3) based on Digital light processing (DLP) – is a 3D printing technique that uses a light projector to cure photopolymers layer by layer with high surface quality and dimensional resolution. It allows for precise process control and optimization for light projector-curable polymers and nanocomposites with reinforced graphene nanoparticles. In this study, light projector-curable polymer nanocomposites were prepared with the addition of different contents of graphene via the P3 technique for use in additive manufacturing, and ideal dispersion methods were investigated to prepare reinforced resin suitable for production in P3 technology. The effect of graphene addition on the curing of the resin and the mechanical properties of the nanocomposite specimens were investigated. Recent developments in printable materials, device properties, and printed structures of typical 3D printing techniques for graphene and graphene/polymer composites are discussed. Despite significant advances in 3D printed graphene and polymer composites, innovative work is still needed to fully realize their inherent capabilities.

Keywords: 3D Printing, Graphene, Nanocomposite, Mechanical Properties, Programmable Photopolymerization (P3)

PRELIMINARY INVESTIGATION OF 3D-EXTREME HIGH-SPEED LASER METAL DEPOSITION (3D-EHLA) FOR PRINTING TI6AL4V WITH LOCALIZED INERT ATMOSPHERE

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ABSTRACT

The 3D Extreme High-Speed Laser Metal Deposition (3D-EHLA) process, also known as High-Speed Directed Energy Deposition (HS-DED), is a versatile solution for both coating and additive manufacturing. Rapid cooling and solidification rates typical of this process result in a fine microstructure, enhancing mechanical properties, such as tensile strength, hardness or fatigue resistance. Titanium alloys, with their high strength-to-weight ratio and corrosion resistance, are vital in the Aerospace and Oil & Gas industries. However, their reactivity at high temperatures poses contamination risks when processed with high-power lasers. This study explores the processability of Ti6Al4V using the 3D-EHLA process with Ponticon's pE3D system, coupled with specialized nozzles from Nidec. These nozzles deliver high shielding gas flow rates around the molten pool, creating a localized inert atmosphere that prevents oxidation. Based on the testing procedures, it was found that the resulting deposits are dense, with an average porosity of around 0.1%. Additionally, the microstructural analysis revealed the presence of a martensitic phase. This preliminary research advances the understanding of Titanium alloy processing with 3D-EHLA, optimizing microstructural control and enhancing the quality of additively manufactured components in critical industries.

Keywords: 3D-EHLA, Titanium alloys, Additive Manufacturing, Microstructural control, Oxidation prevention

ON CORRELATION BETWEEN PROCESS PARAMETERS AND PLASTIC STRAIN-HARDENING MODEL IN LPBF ADDITIVE MANUFACTURING USING INTELLIGENT ALGORITHMS

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ABSTRACT

Additive manufacturing (AM) process parameters significantly affect the mechanical behaviour of printed materials under uniaxial tension. Therefore, it is essential to find the relationship between these parameters and material behaviour to enhance AM performance. This study focuses on predicting the strain-hardening behaviour of AM materials, specifically 316L stainless steel and Inconel 625, using the Hollomon and other models to describe the plastic zone during tensile testing. Since neural networks excel at capturing more complex interactions by applying algorithms like neural networks, we aim to uncover the relationship between key process parameters—such as layer thickness, printing speed, building orientation, printing power, and laser diameter—and material deformation. Experimental validation and comparative analysis of the developed models underscore their effectiveness and highlight the potential of intelligent algorithms in advancing AM research.

Keywords: LPBF Additive Manufacturing, Process Parameters, Intelligent Algorithms, Tensile Test Plastic Region, Hollomon Strain-Hardening Model

CRITICAL MECHANICAL PERFORMANCE EVALUATION OF AN ARMORED VEHICLE PART FABRICATED VIA WIRE ARC ADDITIVE MANUFACTURING

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ABSTRACT

Wire Arc Additive Manufacturing (WAAM) is one of the Directed Energy Deposition (DED) technologies in Additive Manufacturing. WAAM offers fabrication of large scale, dense and structural parts with high material efficiency, shorter lead times and less buy-to-fly (BTF) ratios. This research work aims to investigate the critical mechanical performances of a connection component for armored vehicles, fabricated by WAAM technology. WAAM was chosen for its ability to reduce material waste, support rapid production capability through design flexibility, and deliver dense, reliable material properties. Firstly, coupon-based tests were conducted and optimized parameters were determined. After the fabrication, the part was machined to meet geometric tolerances identical to traditionally manufactured counterparts. The standard tests results with the mechanical and metallurgical reliability of the WAAM-fabricated part with no critical failures. Challenges included achieving dimensional accuracy within target tolerances and optimizing production time by adjusting wait periods without compromising build quality. Despite these challenges, the process provided consistent results, validating WAAM's suitability for such applications.

Keywords: Wire Arc Additive Manufacturing (WAAM), Armored Vehicle Components, Rapid Prototyping, Dimensional Accuracy

DEFORMATION BEHAVIOR ANALYSIS OF COMMERCIALLY PURE TITANIUM AND TI6AL4V GYROID LATTICES THROUGH TIMOSHENKO BEAM THEORY, THE GIBSON-ASHBY MODEL AND EXPERIMENTAL METHODS FOR BONE IMPLANTS

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ABSTRACT

Gyroid lattice structures enhance osseointegration by facilitating cell migration through interconnected channels while mitigating the stress-shielding effect. This study investigates the mechanical performance of gyroid lattices fabricated from commercially pure titanium (Cp-Ti) and Ti-6Al-4V using laser powder bed fusion (L-PBF) technology. Compression testing revealed that Cp-Ti demonstrated superior ductility with smooth deformation, whereas Ti-6Al-4V exhibited 45° shear band formation under full deformation. Despite similar elastic modulus values, Ti-6Al-4V showed significantly higher yield strength. Higher porosity levels were associated with increased ductility, particularly in thinner-walled designs (0.3 mm). The Timoshenko beam theory provided a closer correlation with experimental data compared to the Gibson-Ashby model. These results indicate that Cp-Ti gyroid structures are ideal for non-load-bearing implants because of their outstanding ductility, whereas Ti-6Al-4V is better suited for load-bearing applications due to its higher strength. Future research should focus on refining post-processing methods to minimize surface defects and improve the mechanical performance of gyroid lattice structures.

Keywords: Titanium, Gyroid, Laser Powder Bed Fusion, Compression

JOINING OF ADDITIVE MANUFACTURED 316L STAINLESS STEEL COMPONENTS VIA ROTARY FRICTION WELDING TECHNOLOGY

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ABSTRACT

The study creates a hybrid process utilizing Rotational Friction Welding (RFW) with Laser Powder Bed Fusion (L-PBF) to join 316L stainless steel (SS) components. RFW produces high-strength joints below melting temperature in a low environmentally-impactful manner, while L-PBF enables the fabrication of precise and intricate geometries. This research aims to leverage their synergy, manufacturing hybrid tensile specimens (dog bones) and evaluating their properties towards different applications. The proposed process used L-PBF to fabricate tensile specimen half dog bones and joined them via RFW with optimized parameters. The welded zone was investigated undergoing metallographic, XRD, and EDX analyses. Mechanical tests, including tensile testing and hardness measurements, were conducted to evaluate performance compared to fully L-PBF specimens. Hybrid specimens exhibited higher tensile and yield strengths than fully 3D printed equivalents, yet with a lower elastic modulus, highlighting tunable flexibility. XRD and EDX confirmed the austenitic phase without intermetallic phase formations. Microstructural observations aligned with the literature, showing grain refinement in the weld zone and coarser structures in base metals. The study demonstrated that RFW and L-PBF effectively combine to create defect-free, high-strength joints in 316L SS, with potential in, among others, energy absorption applications.

Keywords: Rotational Friction Welding, Laser-Powder Bed Fusion, 316L Stainless Steel, Hybrid Manufacturing

CLOSED-LOOP CONTROL OF WELD BEAD PROFILE IN WIRE ARC ADDITIVE MANUFACTURING USING LASER SCANNERS

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ABSTRACT

Wire Arc Additive Manufacturing (WAAM) is typically conducted without integrated sensor systems for weld bead monitoring, potentially compromising manufacturing quality. High-precision fabrication, however, necessitates closed-loop process control strategies enabled by real-time measurement of bead geometry. In this study, we implemented a closed-loop control system by integrating two laser scanners onto the end effector of an industrial robot performing arc welding. These scanners were utilized to dynamically adjust the robot's trajectory, which was initially pre-generated using Grasshopper3D. The system compensates for deviations by modifying the toolpath in pseudo-real time, ensuring adequate layer count when the measured bead height falls below the planned dimensions. It can also handle cases where the bead geometry exceeds the expected height. The performance of this sensor-based approach will be benchmarked against a traditional open-loop WAAM process. The evaluation involved fabricating vertical walls composed of single weld beads, with comparisons regarding geometric accuracy, density, hardness, tensile strength, and microstructural characteristics. The results overview the potential of sensor-integrated closed-loop systems to enhance the reliability and precision of robotic WAAM processes.

Keywords: wire arc additive manufacturing, laser scanner, closed-loop control, path planning

AN INTEGRATED PARAMETRIC APPROACH TO TOOLPATH AND PROCESS MANAGEMENT IN ROBOTIC WIRE ARC ADDITIVE MANUFACTURING

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ABSTRACT

Wire arc additive manufacturing (WAAM) is a fabrication method where metal wire is utilized as the feedstock, and arc energy, based on gas metal arc welding (GMAW), is employed to enable production [1]. This process is distinct from other additive manufacturing techniques due to its affordability, efficient use of materials, and rapid deposition capabilities, making it particularly suited for constructing large components [2]. The WAAM workflow involves several interconnected steps, beginning with the creation of a 3D model, slicing it into distinct layers, generating a toolpath, simulating the production process, converting the toolpath into machine-readable instructions, and concluding with the actual manufacturing. While various software applications are available to execute specific steps within this workflow, the use of separate tools often introduces inefficiencies, higher error rates, and longer production times. This research introduces an integrated framework for robotic WAAM that consolidates all these stages into a unified system. A parametric modeling approach was adopted to tackle the critical phase of toolpath generation, allowing for the development of a highly optimized deposition strategy. Within the proposed methodology, a parametric 3D model was created and sliced into layers. The toolpath was designed for maximum material density, and the process was simulated in a virtual environment. The generated toolpath was subsequently translated into machine code for execution by an ABB robotic arm. Finally, experimental validation was performed through physical production trials, both with and without the use of a two-axis positioner. The results of this study underline the potential of this streamlined approach to significantly enhance design flexibility, optimize production planning, reduce development cycles, and simplify process management, thereby advancing the efficiency of robotic WAAM applications.

Keywords: Wire arc additive manufacturing, Parametric modeling, Process simulation, Toolpath development

MICROSTRUCTURAL EVOLUTION AND MECHANICAL ANISOTROPY IN LPBF-PROCESSED 18NI300 STEEL

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ABSTRACT

Additive manufacturing (AM) has gained significant importance in modern engineering due to its ability to create complex geometries, reduce material waste, and enable case specific manufacturing. Among AM advanced materials, 18Ni300-maraging steel stands out for its exceptional mechanical properties, including high strength, toughness, and excellent machinability. Due to its superior materials properties, which comes from its ultra-low carbon content and precipitation hardening mechanism, make it a preferred choice in demanding applications especially for aerospace, automotive, defense industries. The AM of 18Ni300 steel is possible by varied methodologies. Laser powder Bed Fusion is one of them and stands out as a precision-oriented method that utilizes a high-intensity laser beam to selectively melt metal powder layer by layer, creating detailed and high-performance components. However due to the rapidly fluctuating heat flow rates with different orientations, which directly impact the microstructural and mechanical properties of the fabricated parts. There is a critical need for research to understand complex interactions between process parameters and material behavior. In this experimental study, microstructural observation and hardness tests were performed to evaluate the LPBFed 18Ni300 steel's homogeneity and mechanical properties with different orientations. The results highlight how optimized LPBF processes can produce high-performance, durable 18Ni300 steel structures with superior mechanical properties, further expanding its potential in critical industrial applications.

Keywords: 18Ni300, L-PBF, Orientation Effect, Homogeinty Anistropy

THE ROLE OF BUILD ORIENTATION IN CONTROLLING MICROSTRUCTURE AND HARDNESS OF LPBF-PRODUCED 316L STEEL

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ABSTRACT

316L stainless steel are widely recognized material with their exceptional corrosion resistance, mechanical reliability, and durability especially in aviation industry for components requiring high performance in demanding environments. Additive Manufacturing (AM), especially Laser Powder Bed Fusion (LPBF), stands out as an innovative method that enables the manufacturing complex geometries and minimizes material waste of 316L. Due to the nature of LPBF high heat inputs are enters to he materials which strongly effect thermal gradients and directional solidification patterns and material. Especially for 316L this complex thermal gradients strongly regulates the material properties. From this point of view there is still a need for further investigation to understand orientation-specific mechanical performance of 316L. This experimental study unravels the relationship between build orientation and the microstructural behavior of LPBF-fabricated 316L stainless steel. Detailed investigations were conducted through microstructural analysis, hardness testing, with specific attention given to the orientation-dependent wear mechanisms.

Keywords: 316L Stainless Steel, Additive Manufacturing, LPBF, Residual Stress, Mechanical Anisotropy

ENHANCING PRODUCTIVITY AND POWDER REUSE EFFICIENCY IN LASER POWDER BED FUSION OF ALUMINIUM ALLOYS

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ABSTRACT

The advancement of aluminium alloys in Laser Powder Bed Fusion (L-PBF) is critical for enabling lightweight, high-performance applications in aerospace, automotive, and energy sectors. This study addresses two critical aspects to increase the adoption of this technology as a cost-effective solution enhancing productivity and ensuring powder use efficiency. First, the implementation of multi-laser strategies for AlSi10Mg is explored, showcasing optimized laser parameters that achieve high build rates while maintaining precision and mechanical properties. A special emphasis is placed on achieving enhanced fatigue life, which is critical for structural components in high-stress environments. These advancements demonstrate the feasibility of scaling up L-PBF without compromising part integrity while using multiple lasers for enhanced productivity. Moreover, this study evaluates efficient reuse of Scalmalloy©, focusing on its reuse up to 40 cycles while preserving key material properties. By addressing challenges related to material performance degradation during recycling, the research ensures sustainable practices in additive manufacturing. By combining insights from AlSi10Mg and Scalmalloy©, this paper provides a comprehensive understanding of advancing aluminium alloys in L-PBF, bridging the gap between industrial scalability and material sustainability.

Keywords: Laser powder bed fusion, Powder reuse, Multiple lasers, Productivity.

NUMERICAL AND EXPERIMENTAL INVESTIGATION OF MECHANICAL PROPERTIES OF CARBON FIBER REINFORCED PARTS

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ABSTRACT

This work investigates Continuous Fiber Fabrication (CFF) in additive manufacturing, a special material extrusion technique that enables the production of lightweight parts with complex geometries. CFF, developed by Markforged, combines fiber reinforcement and material extrusion processes and becomes an alternative composite production technique. A major challenge in CFF is accurately assessing the mechanical performance of parts, as traditional testing may not always be feasible due to time and economic reasons. Thus, Finite Element Analysis (FEA) is proposed as an alternative for evaluating mechanical responses. However, discrepancies in FEA results from existing studies highlight the need for improved modeling techniques. The authors developed and validated a finite element modeling approach for CFF parts to address this. The study begins with material characterization, followed by the design and fabrication of specimens subjected to tensile, bending, and eccentric loads. These tests are then compared with the FEA simulations, which focus on the force and displacement for elastic behavior. Results show good agreement for small displacements, but discrepancies arise for larger, plastic deformations. The work also explores the sources of these errors and suggests improvements for future modeling strategies.

Keywords: Additive Manufacturing, Continuous Filament Fabrication, Composite Materials, Finite Element Analysis, Material Characterization

FABRICATION OF COPPER HEAT EXCHANGERS VIA WIRE ARC ADDITIVE MANUFACTURING: PROCESS OPTIMIZATION AND NON-DESTRUCTIVE ANALYSIS

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ABSTRACT

This study explores the fabrication of pure copper using the Wire Arc Additive Manufacturing (WAAM) method, focusing on its application for heat exchangers. Copper's high thermal and electrical conductivity makes it ideal for critical applications; however, its high reflectivity and thermal conductivity pose challenges in additive manufacturing (AM) processes. Specifically, powder-based methods often result in pores and defects due to inadequate material melting. To address these issues, WAAM, which uses an electric arc to deposit metal wire layer by layer, was employed. Experimentally found parameters using the Metal Inert Gas (MIG) method were optimized in this study, and the results demonstrate the potential of WAAM to produce dense, non-porous copper structures suitable for industrial applications like heat exchangers.

Keywords: Wire Arc Additive Manufacturing (WAAM), copper, heat exchanger, toolpath generation, Non-Destructive Testing (NDT)

POWDER PRODUCTION, PROCESS OPTIMIZATION, AND ADDITIVE MANUFACTURING OF IRON ALUMINIDE ALLOYS USING LASER-DIRECTED ENERGY DEPOSITION

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ABSTRACT

With a combination of desirable properties such as low density, high specific yield strength, low material cost, and excellent oxidation and corrosion resistance, iron aluminide (Fe-Al) has shown considerable potential to be a useful alternative to high-alloy chromium steels and in some cases even nickel-based superalloys, in high-temperature applications. Due to these features, it is especially suitable for the aerospace and automobile sectors. Recent advancements indicate an increasing interest in Fe-Al within the additive manufacturing industry, particularly in directed energy deposition processes. Despite this progress, there is a lack of knowledge for the further processing of Fe-Al materials using the laser-directed energy deposition (L-DED) process. In this study, Fe-Al powder material was produced from a commercial Al rod encased in a commercial Fe tube by a plasma-based ultrasonic atomization for the L-DED system. Using these powders, the effects of a given range of L-DED parameters on the weld geometry were analyzed and modeled with the response surface method. Afterward, an additively manufactured sample was produced according to this model. The sample was investigated in terms of microstructure, chemical composition, and phase structure by SEM/EDX, XRD, and EBSD analyses.

Keywords: Iron Aluminides, Optimization, L-DED, Ultrasonic Atomization, Intermetallic phase

AN ASSESSMENT ON FAILURE MODES AND SOLUTION STRATEGIES FOR 3D PRINTED POLYMER PARTS

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ABSTRACT

The aerospace industry requires stable, robust, cost-effective solutions regarding its strict regulation and standardization requirements. The polymer additive machine manufacturers present and continuously improve their high-end solutions in the market. Achieving the sustainable quality of printed products is highly affected by preprocessing and in situ process conditions. The most crucial obstacle is achieving the same quality for each batch, especially for serial part production. In industries such as aerospace, where production volumes are low and part diversity is high, the complete elimination of errors remains unattainable, even when optimal manufacturing parameters are meticulously applied. Therefore, repair and post-processing procedures should be implemented within a defined set of rules to prevent parts from becoming scrap. The study includes an FMEA analysis of the printed parts on the FFF (Fused Filament Fabrication) system, which consists of 16 different error parameters within the systematic approach. Results indicate that the most effective defect parameters are excess material inclusion, stabilizer wall penetration, contour, and raster intersection fillet. This study proposes different post-process options for the industrial use case of 3d printed parts, especially within the frame of aerospace.

Keywords: Polymer Printing, Post-process, Repairing

PRODUCTION AND CHARACTERIZATION OF DOT-BY-DOT WIRE ARC ADDITIVE MANUFACTURING STEEL RODS

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ABSTRACT

This study investigates the fabrication of steel rods by using the dot-by-dot Wire Arc Additive Manufacturing (WAAM) method. Two deposition strategies, single-point and three-point deposition, are employed to produce three different steel rods with varying process parameters to evaluate their influence on the final structure. Characterization was conducted using non-destructive testing methods, optical and scanning electron microscopy, and Vickers hardness measurements to evaluate microstructural and mechanical properties. The results suggest that increasing gas post-flow increases the size of the weld pool, whereas promotes the porosity formation due to inadequate protection of the shielding gas. Furthermore, heat accumulation and rapid cooling in the upper layers enable phase transformations, increasing hardness. These findings highlight the significant role of deposition strategies in controlling microstructural homogeneity, defect formation, and mechanical performance in WAAM-fabricated components.

Keywords: Wire Arc Additive Manufacturing (WAAM), Directed Energy Deposition (DED), Dot-by-dot, Non-Destructive Testing (NDT), Low alloy steel

AUTOMATIC MASS MODEL GENERATOR FOR ADDITIVE MANUFACTURING

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ABSTRACT

Real-life systems and geometries must be tested many times before the finalization, and since manufacturing of these systems takes time and have valuable components that could be damaged during the tests, this study introduces two different algorithms on generating the mass model of any geometry that could be used for these tests instead of the original system. The aim of both algorithms is to create a model that is easier to manufacture, but has the same outer geometry, mass, center of gravity and moment of inertia values with the original geometry. One of the algorithms is specially designed to generate models that are suitable to manufacture with Additive Manufacturing (AM), and the other algorithm generates models that is expected to be fabricated with both conventional and AM techniques. Since the most important criteria in the design of the algorithms is the ease of production, a rough final geometry is decided as a first checkpoint. Then, the mass value and the center of gravity position are calculated for the estimated final geometry, and two models for two different products have been manufactured using Fused Filament Fabrication (FFF) and Stereolithography (SLA). For future works, the geometries are planned to be slightly changed to additionally have the same moment of inertia with the original geometry, and final fabrications will be made both with FFF and conventional methods.

Keywords: mass model, fused filament fabrication, stereolithography

INVESTIGATION OF THE EFFECT OF MANUFACTURING ORIENTATION ON POST-THERMAL PROCESS PERFORMANCE OF PP PARTS: L-PBF VS. MEX

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ABSTRACT

Polypropylene (PP) is widely preferred in chemical environment applications due to its low density, high chemical resistance, ductility, and media isolation properties. Additionally, it serves as an alternative to Polyamide in the Laser Powder Bed Fusion (L-PBF) method due to its acceptable mechanical properties and low cost. PP is also among the ideal materials for material extrusion-based additive manufacturing (MEX). As a semi-crystalline thermoplastic, PP is known to undergo changes in mechanical properties when subjected to post-thermal processes. In this study, PP samples were produced using the L-PBF method with different orientations, and the effects of post-thermal processes on their mechanical properties were analyzed. Additionally, single-layer samples were produced under ideal conditions using the MEX method, and the impact of post-thermal processes was compared between the two manufacturing techniques. The study revealed that the orientation angle during manufacturing significantly influences the mechanical performance of post-thermal processes. However, when the thermal process is applied at cryogenic temperatures, the reduction in impact resistance values reaches similar levels across all orientations.

Keywords: Polypropylene, Laser-Based Powder Bed Fusion, Material Extrusion, Orientation Angle, Post Thermal Processing

PRODUCTION OF FE-MN-SI SHAPE MEMORY ALLOY BY LASER POWDER BED FUSION AND INVESTIGATION OF ITS SHAPE MEMORY PROPERTIES

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ABSTRACT

Fe–30Mn–6Si (wt%) shape memory alloy (SMA) exhibits both shape memory and biodegradable properties. In this study, ternary alloy samples were fabricated using the Laser Powder Bed Fusion (LPBF) technique. Initial single-track experiments were conducted to optimize the process parameters. A laser power of 260 W was selected, and the influence of the hatch distance was assessed through an evaluation of the samples' transformation temperatures and shape recovery performance.

Keywords: Fe-Mn-Si, shape memory alloys, laser powder bed fusion, shape memory effect

CHARPY IMPACT STUDY ON ADDITIVELY MANUFACTURED CONTINOUS-FIBER REINFORCED COMPOSITE PARTS

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ABSTRACT

This study investigates the effects of key printing parameters on the Charpy impact resistance of additively manufactured continuous-fiber reinforced composite parts. The parameters examined include infill rate, the number of concentric fiber rings, fill pattern type, and isotropic carbon fiber angles. All samples were fabricated using a Markforged Mark-2 printer and analyzed via radiographic inspection to identify potential delaminations or gaps between carbon fibers. Subsequently, Charpy impact testing was conducted, with energy absorption and weight measurements recorded. The results were used to evaluate impact resistance-to-weight ratios for different parameter settings. This study aims to provide insights that help designers develop more cost-efficient and lightweight impact-resistant products.

Keywords: additive manufacturing, Charpy impact test, impact energy, continuous fiber-reinforced composites, radiographic inspection

CHARACTERIZATION OF COPPER-REINFORCED PA 12 COMPOSITES VIA ULTRASONIC TESTING

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ABSTRACT

This study investigates the effects of energy densities and rate of copper (Cu) addition and type on the mechanical properties of copper-reinforced Polyamide 12 (PA 12) parts produced via Selective Laser Sintering. It is novel to examine the effect of a wide range of copper percentages on the elastic modulus of PA 12-Cu composite structures. Using Ultrasonic Testing and Resonant Ultrasound Spectroscopy Background Theory, modulus are determined. Results demonstrate that the percent addition of copper is crucial as well as the type of the added copper. Dendritic copper addition results in superior properties over spherical copper addition cases in general. When copper addition rates are considered, samples containing 15% Cu have a lower modulus, and those with 5% and 10% Cu have approximately the same elastic modulus. When the effect of energy density is examined, it is observed that the change in energy density has a significant effect on the elastic modulus.

Keywords: Keywords: SLS, Ultrasonic Testing, PA 12, Elastic Modulus, Copper

EFFECT OF SLIDING DISTANCE ON THE WEAR BEHAVIOR OF SLS-PRINTED PA12

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ABSTRACT

Selective Laser Sintering (SLS) method, which is one of the Laser Powder Bed Fusion (LPBF) additive manufacturing methods, is one of the most preferred methods in industry. One of the most critical points of the SLS method is the determination of the process parameters and the physical, mechanical, and tribological direct change of the final product with the appropriate parameters. In this study, the wear behavior of PA12 material produced by the SLS method was investigated. The process parameter was kept constant at 0.25 mm hatch distance and 0.300 J/mm3 energy density value. In order to examine the effect of sliding distance on the wear behavior of the material, wear test load and sliding velocity values were kept constant at 5 N and 100 mm/s. The total sliding distance was applied as 100 m (short distance) and 500 m (long distance) parallel to the production direction. As a result of the tests, the wear behavior, specific wear rate, coefficient of friction, and 3D wear surface topographies were examined and compared. As a result of the test, the wear resistance at a sliding distance of 500 m exhibited approximately 20% better than the wear resistance at sliding distance of 100 m.

Keywords: PA12, SLS, dry sliding wear, 3D surface, sliding distance.

MECHANICAL AND THERMAL RESPONSES OF MEX-MANUFACTURED ABS PARTS TO POST-THERMAL TREATMENTS: THE ROLE OF LAYER THICKNESS

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ABSTRACT

ABS is one of the most commonly used polymers in MEX production. Although it offers advantageous mechanical properties, shrinkage and warping issues negatively affect the dimensional stability of ABS parts. Additionally, thermal effects are known to play a significant role in the mechanical properties of ABS. This study examines the effects of layer thickness to mechanical and thermal properties of MEX-manufactured ABS specimens after different post-thermal treatments. Samples were manufactured with different layer thickness values and treated at -80°C and -20°C. Tensile, Charpy impact, and DSC tests were conducted following ASTM standards. Results show no significant UTS changes, but -80°C treatment induced physical aging. The glass transition temperature remained stable, while mechanical effects varied with testing speed and orientation.

Keywords: Material extrusion, Acrylonitrile butadiene styrene (ABS), Layer thickness, Post-thermal treatment, Mechanical stability

INVESTIGATING THE EFFECT OF HEAT TREATMENT PROCESS ON MICRO-STRUCTURAL AND MACRO-MECHANICAL PROPERTIES OF 17-4 PH MATERIAL PRODUCED BY SELECTIVE LASER MELTING PROCESS

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ABSTRACT

In this contribution, the effect of heat treatment operations on SLM processed 17-4 PH material was deeply investigated. For that purpose, the micro-structural and macro-mechanical properties were analyzed in terms of phase compositions, hardness and impact toughness. Due to the substantial modifications on the micro-structure, the macro-mechanical properties severely altered which indicated that a proper phase composition is compulsory to achieve an optimum point for harness-toughness conflict. The result of direct aging trial provided pretty good results which emphasize that this method may assess potential use in industrial applications. The elimination of solution treatment definitely reduces the cost of production which would be an invaluable outcome for serial production. The phenomena of reverted austinite especially its link with the direct aging process will be discussed as a future work study.

Keywords: 17-4 PH, SLM, solution treatment, direct aging, retained austenite

CRYOGENIC TREATMENT PERFORMANCE OF MEX-MANUFACTURED PARTS

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ABSTRACT

Polypropylene (PP) is widely preferred in chemical environment applications due to its mechanical properties, such as the ability to endure high stress and strain, as well as its high chemical resistance. Additionally, it is among the ideal materials for material extrusion-based additive manufacturing (MEX). Moreover, it is well known that the mechanical properties of polymers change after exposure to different cryogenic and thermal treatments. This study examines the mechanical and thermal behavior of MEX-manufactured PP under post thermal treatment condition. Tensile tests showed the highest UTS at 0.1 mm layer thickness, with as-built specimens outperforming those conditioned at -80°C. DSC analysis revealed physical aging effects in -80°C specimens.

Keywords: Material Extrusion, Polypropylene, Post-thermal treatment, Mechanical performance, Physical aging

INVESTIGATION OF MECHANICAL PROPERTIES AND ENERGY ABSORPTION OF GYROID TPMS LATTICE STRUCTURES FABRICATED VIA SELECTIVE LASER MELTING

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ABSTRACT

The development of metal additive manufacturing (AM) technology have enabled the production of parts with complex designs and smaller sizes, realizing intricate topologies that are unachievable through conventional manufacturing techniques. Among these, Triply Periodic Minimal Surface (TPMS) structures have emerged as a to prominence owing to their superior structural properties, lightweight nature, and high energy absorption capabilities. TPMS-based lattice structures have gained significant research interest due to their continuous curvature, high surface area, and tuneable mechanical performance. These structures derive their unique characteristics from their structural topology, offering extensive parameterization possibilities while presenting challenges in behaviour prediction. Lattice structures based on TPMS have been widely explored for their exceptional mechanical properties and enhanced energy absorption but the possibilities are still not fully explored for many parameters and materials. This study investigates the mechanical properties of Gyroid-based TPMS lattice structures with variable packing density fabricated using Selective Laser Melting (SLM) with AlMgSi10 alloy. Gyroid lattice structures with variable relative densities will be designed and manufactured to evaluate their mechanical response under compressive loading. Experimental testing will be conducted to identify deformation mechanisms, categorizing them as bending-dominated, stretching-dominated, or mixed behaviour. Using experimental data, the effective Young's modulus, yield strength, and specific energy absorption will be estimated for different relative densities. The results will provide insights into the influence of packing density variations on mechanical performance,. This study aims to optimize TPMS-based structures for enhanced mechanical efficiency and energy absorption, contributing to their potential applications in lightweight engineering systems.

Keywords: Gyroid-based Triply Periodic Minimal Surface (TPMS), Selective Laser Melting (SLM), Energy Absorption

COMPRESSION BEHAVIOR OF DIGITAL LIGHT PROCESSING PRINTED SANDWICH PANEL CORES

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ABSTRACT

This study investigates the mechanical behavior of sandwich panel cores fabricated using Digital Light Processing (DLP) 3D printing technology. Honeycomb and auxetic (reentrant) core geometries were selected due to their exceptional strength-to-weight ratio and unique deformation properties. These structures have diverse applications in aerospace, automotive, and civil engineering industries, such as aircraft flooring, automotive crash absorbers, and protective equipment. The core geometries had relative densities of 30%, 40%, and 50%, and were fabricated using DLP Printer. Mechanical performance was evaluated through static compression tests using an Instron universal testing machine. The results demonstrated the significant influence of geometry and relative density on the stress-strain behavior and failure modes. Honeycomb and auxetic patterns showed superior load-bearing capacity, while showing enhanced energy absorption. This work highlights the potential of 3D-printed cellular cores in optimizing mechanical performance for engineering applications.

Keywords: Sandwich panel cores, Additive manufacturing, Vat photopolymerization, Auxetic structure, Honeycomb

EFFECT OF ULTRAONIC VIBRATION ON THE MICROSTRUCTURE AND HARDNESS OF WAAM-PRODUCED AISI 316LSI3 STAINLESS STEEL

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ABSTRACT

Wire Arc Additive Manufacturing (WAAM) is an advanced manufacturing method that enables the production of large metallic structures with high material efficiency. However, the inherent thermal gradients in WAAM lead to directional grain growth and anisotropic mechanical properties. This study investigates the effects of ultrasonic vibration applied to the build platform on the microstructure and hardness of AISI 316LSi3 austenitic stainless steel. Samples were fabricated under two conditions: with and without ultrasonic vibration. Optical microscopy revealed that ultrasonic vibration refined the dendritic structure and promoted a more equiaxed grain morphology. Vickers hardness measurements indicated an increase in hardness values and a more homogeneous distribution across the samples produced with vibration. These findings suggest that ultrasonic vibration in WAAM can enhance microstructural uniformity and mechanical properties, making it a promising technique for high-performance applications.

Keywords: WAAM, AISI 316LSi3, ultrasonic vibration, microstructure, hardness.

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MICROSTRUCTURE AND MECHANICAL PROPERTIES OF WAAM-FABRICATED INCONEL 625 PART

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ABSTRACT

Wire Arc Additive Manufacturing (WAAM) is receiving growing interest in the development of large-size metallic parts, yet its anisotropic microstructure is still a limitation to structural use. In the present study, the directional sensitivities in WAAM-fabricated Inconel 625 microstructure and mechanical properties are studied. Microstructural examination shows columnar grain development along the perpendicular direction from building (Z-axis) and non-homogeneous grain distributions over the transverse (X) and longitudinal (Y) axes. Microhardness characterization indicates that the orientation of the build is microhardness-dependent, thus maximum values appearing in the Z-axis due to rapid solidification and smaller grain structure. Density measurements also indicate near-zero porosity, confirming the high-quality deposition process. The results give important information on the mechanical and microstructural properties of Inconel 625 fabricated via WAAM with a strong recommendation for high-end applications such as aerospace and marine engineering.

Keywords: Wire Arc Additive Manufacturing (WAAM), Inconel 625, Microstructure, Mechanical Properties, Microhardness

ADDITIVE MANUFACTURING OF ALUMINIUM BY MOLTEN METAL DEPOSITION: PREDICTION OF BUILD QUALITY

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ABSTRACT

Molten Metal Deposition (MMD) is an innovative additive manufacturing (AM) technique that deposits molten metal using metal wire feedstock, with focus on aluminium alloys. As in many AM technologies the occurrence of porosity is a common defect mechanism This study investigates the link between formation of the porosities, interlayer bonding and energy input during the printing process for MMD fabricating aluminum 4043 alloy specimen. The energy input is mainly determined by the process parameters print speed, deposition rate, interlayer time, nozzle- and substrate temperature. A two-dimensional thermal model was developed to analyze temperature distributions during single-layer and multi-layer builds. Key process parameters—nozzle temperature, substrate temperature, and printing speed—were examined to assess their effects on thermal gradients, porosity and surface waviness as a result for the interlayer bonding quality. Results indicate high energy input tend to have increased porosity density while the surface waviness was reduced, indicating good interlayer bonding. The opposite was observed for low energy inputs. Concretely, maintaining a substrate temperature of ~470°C minimizes porosity, while a nozzle temperature of 900°C and a printing speed of 180 mm/min ensure high interlayer temperatures, improving the interlayer bonding. The findings contribute to understanding MMD process control and optimizing material properties for improved AM performance.

Keywords: Molten Metal Deposition, Aluminium Alloys, Additive Manufacturing, Porosity Defects

A PRACTICAL PARAMETER OPTIMIZATION APPROACH FOR LASER POWDER BED FUSION OF COCR POWDERS

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ABSTRACT

This study presents a practical approach to optimizing laser parameters in Laser Powder Bed Fusion (LPBF) of CoCr powders. A 200 W prototype LPBF system was used to conduct single bead laser sintering experiments, varying laser power and scanning speed to analyze melt pool characteristics. The employed sectioning, polishing, and annealing techniques in the process provided high-contrast melt pool profiles for evaluation. Resulting optimized parameters successfully yielded dense and high-quality 3D parts, confirming the effectiveness of this approach.

Keywords: LPBF, CoCr, laser parameters, melt pool characteristics, optimization.

SNAP-FIT CAP DESIGN OF AN INFLATABLE BUOY

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ABSTRACT

This study focuses on the detailed design and production of snap fit cap of an inflatable buoy which is able to be opened by considerable force while inflation of buoy. This snap-fit cap will be using an underwater unit that has negative buoyancy. In addition, this underwater unit is single-use only, so it will be lost in underwater after its functional operation; so that testing operations or training operations for this unit costs expensive. Hence, a buoy system has been designed to rescue the test unit from being lost underwater and this design has no connection elements for example bolts and nuts.

Keywords: snap-fit, cantilever snap-joint, tough-2000, SLA, DfAM

MECHANICAL CHARACTERIZATION OF 3D PRINTED PLA: INFLUENCE OF STRAIN OFFSET - YIELD STRESS VALUES ACROSS DIFFERENT INFILL ORIENTATION IN TENSILE TESTING AND FINITE ELEMENT ANALYSIS MODELING

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ABSTRACT

3D printing is the most promising and rapid prototyping technology for various applications, as it offers many benefits. However, the quality and performance of 3D printing parts depend on 3D printer manufacturing parameters; therefore, it is important to study the material properties. As printed polylactic acid (PLA) is widely used for 3D printed material, it was selected for this study to understand its mechanical behavior and optimize its application in additive manufacturing. Computational mechanical is one of the techniques used to predict and optimize material behaviors and structural performance. However, modeling a complex material model and achieving an accurate response in finite element analysis (FEA) will always remain a challenge. This study investigates the mechanical material properties of 3D-printed PLA by integrating tensile testing and FEA to optimize material behavior. To achieve a thorough comparison, tensile testing was conducted on three different raster orientations, i.e., 0°, 45°, and 90°. The resultant stress-strain data were used to calibrate FEA simulations. For FEA non-linear material modeling, isotropic elasticity combined with a multilinear plasticity model was used, where the yield stress values were determined by using the strain offset method. Six different strain offset values, i.e., 0%, 0.007%, 0.01%, 0.02%, 0,05%, and 0,2%, were analyzed to evaluate their impact on the accuracy of FEA results against experimental results. The results highlight a significant influence of strain offset selection on the plastic region estimation and overall accuracy. Where the widely used 0.2% strain offset method (commonly used in material modeling) led to overestimating the plastic region, 0% strain offset provides the most accurate simulation response with an absolute relative error of 0.1-0.2% compared to the experimental response. These results highlight the importance of selecting the correct yield stress value for 3D-printed nonlinear material molding in FEA simulations. This paper provides a technique to improve the accuracy of numerical models for polymer-based 3D printing, especially for PLA, for better prediction of printing parameters and parts.

Keywords: Additive manufacturing, Finite element analysis (FEA), Non-linear material modeling, Polylactic Acid (PLA), Strain offset method

OPTIMIZATION OF PARAMETERS FOR COPPER DEPOSITION ON STEEL USING DED-ARC/M

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ABSTRACT

This study explores multi-material directed energy deposition arc for metals (DED-arc/M) by optimizing copper (Cu1897) deposition on mild steel (S235JR) using response surface methodology (RSM). Key parameters—arc length correction (ALC), pulse correction (PC), and gas flow rate (GFR)—were optimized for maximum bead penetration. Experimental results confirm enhanced penetration, minimal porosity, and a balanced hardness transition, highlighting WAAM's potential for fabricating functional bimetal components.

Keywords: Additive manufacturing, Directed energy deposition, Multi-material, Wire arc additive manufacturing

ARTIFICIAL INTELLIGENCE AND AUTOMATIZATION IN ADDITIVE MANUFACTURING FOR 3D PRINTING BIG CERAMIC PARTS AND BIG SERIES OF PARTS

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ABSTRACT

The integration of artificial intelligence (AI) and full-process automatization in additive manufacturing (AM) represents a transformative paradigm to reach the new era of manufacturing. By addressing key challenges such as design complexity, printing parameters optimization, and production scalability, AI-driven solutions enable real-time decision making and predictive analytics across the entire AM workflow. Automatization enhances production efficiency through seamless coordination of pre-production, insitu monitoring, and post-processing, reducing waste and improving product quality. Together, these advancements position AM as a pivotal solution for manufacturers, offering unprecedented flexibility, cost-effectiveness, and sustainability. The adoption of AI and automation in AM not only accelerates innovation but also bridges the gap between traditional manufacturing and the digital era, making it an indispensable tool for the future of production systems.

Keywords: Artificial intelligence, Automatization, AI-driven solutions, AM

INVESTIGATION OF LOCAL STRAIN FIELDS IN EBM-ADDITIVE MANUFACTURED NITI PARTS USING DIGITAL IMAGE CORRELATION

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ABSTRACT

Digital Image Correlation (DIC) is a non-contact, full-field optical measurement technique that has become widely recognized for its effectiveness in analyzing strain and displacement in materials subjected to mechanical loading. By tracking the deformation of a stochastic speckle pattern applied to the specimen surface, DIC enables high-resolution, spatially resolved analysis of local deformation behavior throughout the testing process. This study presents the application of DIC to assess the mechanical performance of Nickel-Titanium (NiTi) shape memory alloy component fabricated using Electron Beam Melting (EBM), an additive manufacturing technique known for producing complex geometries and tailored microstructures. Tensile specimens were extracted from EBM-fabricated NiTi parts and subjected to uniaxial tensile loading to investigate their local strain response. Preliminary findings reveal significant insights into the deformation characteristics and mechanical integrity of EBM-produced NiTi part. The results underscore the efficiency of DIC as a diagnostic tool for capturing local strain evolution, particularly in heterogeneous and anisotropic microstructures resulting from additive manufacturing processes.

Keywords: Digital Image Correlation (DIC), NiTi SMA, EBM, Additive Manufacturing

MECHANICAL PERFORMANCE OF 3D PRINTED FIBER-REINFORCED POLYMER COMPOSITES

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ABSTRACT

3D printing of Continuous Fiber Reinforced Polymer Composites (CFRPCs) offers great potential for manufacturing high-performance composite structures utilized in several industries. Mechanical performance of CFRPCs is crucial to their industrial applications. This study aims to evaluate the mechanical properties of 3D printed glass fiber-nylon composites with various designs of gripping areas and fiber configurations using mechanical testing and microstructure characterization. Dogbone specimens are manufactured using two different procedures: a) Directly 3D printing the final geometry; b) 3D printing a plate and then cutting out the final geometry of the dogbone specimens. Micrography of specimens' cross-sections is carried out to analyze their microstructure and quantify their polymer, fiber, and porosity phases. Mechanical stiffness and strength of directly printed and cut-out specimens are measured using mechanical tensile tests and the results are compared for the two specimen types with varying gripping designs and fiber configurations. The results indicate that cut-out specimens show higher stiffness, but lower tensile strength compared to one-step directly printed ones. This study provides insights into the manufacturing quality, and mechanical properties of 3D printed CFRPCs, facilitating their application in high-performance load-bearing structures.

Keywords: 3D Printing, Continuous Fiber Composites, Mechanical performance