AMC 2026
Additive Manufacturing Conference

ABSTRACT BOOK

Additive Manufacturing Conference 2026
April 13-15, 2026
Antalya Turkiye

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Proceedings of the Additive Manufacturing Conference Türkiye 2026

April 13-15, 2026

Complied by

Yusuf KAYNAK

Marmara University

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FOREWORD

6th Additive Manufacturing Conference Türkiye was held April 13-15, 2026 at Juju Premier Palace in Antalya, Türkiye.

The event featured a wide array of presentations delivered accross many technical sessions, bringing together participants from diverse backgrounds. Attendees from Türkiye and various other countries contributed to the growing international reach of the conference. Our renowed four keynote and three invited speakers also contribute to AMC 2026 a lot. Selected papers are currently under review for possible publication in the Journal of Additive Manufacturing Technologies.

During the conference, 104 papers in 40 sessions are being presented including special HIP sessions.

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 2026 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, 20 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 2026 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.

On behalf of the Organizing Committee
Prof. Yusuf KAYNAK
Chair of AMC 2026

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KEYNOTE - A DIGITAL TWIN FOR ADDITIVE MANUFACTURING AND FATIGUE

Prof. A.D. (Tony) Rollett, Carnegie Mellon University, USA

A recent project entitled "Development of an Ecosystem for Qualification of Additive Manufacturing Processes and Materials in Aviation" demonstrated the inverse dependence of fatigue on pore number density in AM Ti-6Al-4V. The fatigue-based process window was much narrower than typically reported but explainable in terms of observed variations based on spatter rates and intermittent lack of melt pool overlap. A current "Institute for Model-Based Qualification & Certification of Additive Manufacturing (IMQCAM)" focuses on creating a numerical digital twin (DT) for predicting fatigue as a function of process parameters. We report on recent developments in modeling microstructure, texture and pores along with variations in heat treatment. We conclude that establishing a qualified materials process is feasible via an efficient survey of a limited domain of process space. In terms of predictability of fatigue, the limited data suggests that the scatter in life is smallest in the long crack (Paris Law) regime, intermediate for short cracks and largest for crack nucleation. This provides an important background for Uncertainty Quantification (UQ), which is a major focus for the IMQCAM team and which has already revealed a significant sensitivity to compositional variations, for example. Ultimately, we aim to create a probabilistic model of fatigue that connects the initiation, short-crack and long-crack phases. Support for this approach to fatigue is justified by analysis of experimental measurements of the three separate stages and its stress scaling.

KEYNOTE- VOXEL BASED MATERIAL DESIGN BY ELECTRON BEAM ADDITIVE MANUFACTURING

Prof. Carolin Körner, Friedrich-Alexander University, Germany

The layer-by-layer approach of metal powder bed based additive manufacturing opens a fully new design freedom in manufacturing: Voxel based material design, i.e., the control and adaption of the local material properties as needed. The microstructure can be adjusted via the solidification conditions and the local composition. In addition, the layer-by-layer process also enables the components to be inspected during the build. The electron beam can be used in a variety of ways, as an energy source to maintain the building temperature, to solidify the material and also, similar to the scanning electron microscope, for process observation.

As part of this talk, additive manufacturing with the electron beam will be introduced and its specific properties will be discussed. The challenges and opportunities in electron-optical process observation are presented. Two examples for material design are shown. The first example demonstrates how mastering local selective evaporation can locally change the composition, microstructure and ultimately properties of titanium aluminides. The second example shows how the texture and grain size of nickel-based superalloys can be mastered.

KEYNOTE - SOLID-STATE ADDITIVE MANUFACTURING: TECHNOLOGICAL CHALLENGESAND NEW OPPORTUNITIES FOR NEXT GENERATION MANUFACTURING

Prof. I.S. Jawahir, University of Kentucky, USA

Additive manufacturing (AM) processes continue to offer unique functional capabilities for diverse applications in industry. Over the last three decades, the most commonly known Fusion based Additive Manufacturing (FBAM) methods such as Powder Bed Fusion (PBF) and Directed Energy Diffusion (DED) have continued to grow with significant innovations and applications. Almost all FBAM processes continue to suffer poor energy/resource efficiency, increased waste generation, reduced reusability of materials, and inconsistent and undesirable sub-surface quality, thus demonstrating poor process sustainability and product quality.

In recent years, solid-state additive manufacturing (SSAM) technologies have emerged as effective alternative to traditional FBAM processes. In SSAM, the additive feedstock material undergoes plastic deformation at temperatures below its melting point, avoiding many of the inherent challenges associated with FBAM, including complex melt-pool dynamics and microstructure control, undesirable residual stresses, internal defects, part distortion, build rate and volume limitations, etc. SSAM enables producing functionally superior components from single and multi-materials systems. SSAM enables manufacturing of large components that would otherwise be manufactured by casting or forging (which are highly energy-intensive, time consuming, and costly processes), while providing repair opportunities for large-scale legacy components and structures (e.g., bridges) and revitalizing aging infrastructure. SSAM processes show significantly improved energy/resource efficiency with material reuse capabilities and offer consistent sub-surface quality for improved functional performance of manufactured components, thus offering significant sustainability benefits.

This presentation will demonstrate the significant benefits of SSAM with recent findings from the two major SSAM processes: (a) Additive Friction Stir Deposition (AFSD); and (b) Cold Spray AM (CSAM). These processes offer enhanced process sustainability through reduced energy consumption and material wastes, with more effective material utilization, while potentially utilizing scrap waste as material feedstock (offering a “waste-to-value” proposition) with significant closed-loop circular economy benefits in sustainable manufacturing. A recently developed novel, metrics-based sustainability evaluation method will also be shown for quantitative assessment of additive manufacturing processes leading to product/process innovations in additive manufacturing. This presentation will include technological challenges involved in modeling and optimization of SSAM with innovations in tooling and cooling, showing new opportunities for SSAM for next generation manufacturing.

KEYNOTE - MATERIAL-STRUCTURE-PERFORMANCE INTEGRATED ADDITIVE MANUFACTURING OF ADVANCED CERAMICS

Prof. Zhangwei Chen, Shenzhen University, China

Advanced ceramic components possess excellent chemical stability and superior physical properties, and have been widely applied in fields such as mechanical electronics, energy and environmental protection, aerospace, etc. This report first reviews the principles, advantages, and disadvantages of various ceramic 3D printing technologies, and discusses the performance of printed parts. It also reports the latest progress in material-structure-performance integrated additive manufacturing of advanced ceramics at the Additive Manufacturing Institute of Shenzhen University (AMI-SZU), highlighting application research explorations in energy fields such as lithium batteries, fuel cells, and nuclear fusion energy, as well as in environmental fields such as catalytic carriers, using techniques including vat photopolymerization, inkjet printing, and direct ink writing 3D printing. Furthermore, an integrated shaping and material-creating ceramic additive manufacturing approach based on organic/inorganic precursors is proposed, which has achieved promising research results.

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CHARACTERIZATION AND OPTIMIZATION OF LIQUID ROPE COILING FOR MECHANICAL METAMATERIALS VIA VISCOUS THREAD INSTABILITY

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ABSTRACT

This paper presents a method for the characterization and optimization of Liquid Rope Coiling (LRC) as a computationally efficient alternative to explicit lattice structures for programming the stiffness of flexible 3D-printed components. While traditional lattice generation is computationally intensive, LRC leverages viscous thread instability to create implicit foam-like structures directly from simple toolpath vectors. Using Grasshopper for direct G-code generation, nozzle drop height (HH), coiling ratio (β) and layer height (Δzz) were systematically varied on a standard FDM platform (Bambu A1 Mini) with TPU 85A. To ensure process stability, a constant-pressure extrusion strategy was implemented by modulating print speed rather than volumetric flow rate, thereby avoiding extruder grinding. Results demonstrate that loop morphology is primarily driven by HH, while structural density is controlled by β with Δzz serving as the primary vertical compaction parameter. A multiple linear regression model (R2 = 0.992) is derived, to predict characteristic loop diameter ($DD(HH, \beta)$) which is subsequently used to calculate the optimal toolpath step-over (λ) via a material-specific overlap factor (kk). Finally, a dimensionless Squish Parameter ($\mathcal{SS}$) is proposed to quantify mechanical impedance, proving that LRC allows for precise, localized tuning of mechanical metamaterials. This approach significantly reduces data weight and manufacturing time compared to explicit lattice modeling.

Keywords: Liquid Rope Coiling, Viscous Thread Instability, Mechanical Metamaterials, Programmable Stiffness, Implicit Structuring.

DESIGN OPTIMIZATION AND ADDITIVE MANUFACTURING OF ISOTROPIC LATTICE MATERIALS

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ABSTRACT

Isotropic lattice materials offer advantages such as low weight and uniform mechanical performance under multi-axial loading, making them attractive for advanced engineering applications. However, conventional lattice structures generally exhibit anisotropic behavior due to their porous and direction-dependent architecture. In this study, isotropic elastic behavior is achieved by combining different lattice unit cells and optimizing individual strut diameters. The Nelder–Mead simplex method is employed to efficiently identify fully isotropic lattice designs through a systematic, derivative-free optimization framework, without requiring gradient information or manual parameter tuning. Among the optimized designs, a lattice configuration compatible with additive manufacturing is selected, fabricated using fused filament fabrication, and validated through numerical analyses and experimental compression tests.

Keywords: Lattice Materials, Additive Manufacturing, Finite Element Analysis, Optimization, Homogenization

INFLUENCE OF POST-HEAT TREATMENT ON MECHANICAL AND THERMAL PROPERTIES OF AlSi10Mg ALLOY FABRICATED BY SELECTIVE LASER MELTING

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ABSTRACT

Recent advances in Additive Manufacturing (AM) have increased the use of Selective Laser Melting (SLM) for producing aluminum alloy components with complex geometries. AlSi10Mg is one of the most used alloys in SLM due to its mechanical properties and thermal performance. However, the nature of the process leads to microstructural anisotropy and residual stresses, making post-heat treatment essential. Unlike many previous studies focusing on mechanical performance, this work evaluates the trade-off between strength and thermal conductivity under different post-heat treatment conditions and build orientations. Specimens were produced using AlSi10Mg powder and manufactured in three orientations (X, Y, and Z). Four conditions were examined: as-built, low-temperature annealing (130 °C for 4 h), high-temperature annealing (295 °C for 2 h), and T6 heat treatment. Mechanical properties were evaluated by tensile and microhardness testing, while thermal conductivity was determined using Laser Flash Analysis. Results show that as-built condition provides high strength, limited ductility and relatively low thermal conductivity, whereas T6 improves thermal conductivity at the expense of mechanical strength. Lowtemperature annealing causes minor changes. Among four conditions, high temperature annealing offers a balanced combination of strength and thermal conductivity. Also, post-heat treatment tends to reduce orientation-dependent properties, leading to more isotropic material response.

Keywords: AlSi10Mg, mechanical properties, post-heat treatment, Selective Laser Melting, thermal conductivity

ABRASIVE FLOW MACHINING OF ADDITIVELY MANUFACTURED COMPLEX CONFORMAL COOLING CHANNEL COMPONENTS

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ABSTRACT

There are not many post-processing methods available to improve the poor inner surface quality of complex conformal cooling channels manufactured by additive manufacturing. Abrasive Flow Machining (AFM) stands out among these methods in terms of penetration into the inner channels. In this study, the inner channel surfaces of components manufactured by powder bed fusion-laser beam were improved using the AFM method. The effects of media concentration, cycle number, and abrasive grain size on surface quality were investigated as AFM process parameters. This study showed that the AFM process helps to improve the inner surface quality of AM components by reducing the surface roughness. It was observed that the AFM process improved the channel quality by 97%.

Keywords: Abrasive flow machining, conformal cooling, roughness, surface integrity.

COMBINED RATIOMETRIC AND ILLUMINATED IMAGING FOR COOLING RATE MEASUREMENT IN LASER POWDER BED FUSION

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ABSTRACT

In this work, we present a technique for simultaneous ratiometric and illuminated imaging of the laser powder bed fusion (L-PBF) process using a single RGB color camera and a blue laser illumination source. Thermal data are collected via ratiometric temperature measurement and morphological data such as melt pool length and width are segmented from illuminated image frames. By tracking the evolution of these features over time and combining them to calculate temperature gradients, we demonstrate the feasibility of accurately estimating cooling rates directly from RGB video data. Travel direction cooling rates in 316L stainless steel melt pools are measured to be between 1.7×105 to 3.0×106 K/s and show an inverse relationship with increasing linear energy density. Cooling rates measured with the blue laser illuminated imaging technique are found to be lower than previous experimental values, and primary cellular arm spacings (PCAS) from printed single tracks are measured and linked to material cooling rate via a power law correlation with an R squared value of 0.958. Reasonably high correlations (R squared of 0.72-0.84) are also seen between cooling rates and individual camera channel signals, paving the way for partscale cooling rate monitoring.

Keywords: Laser Powder Bed Fusion, Melt Pool Physics, High-Speed Imaging, Process Monitoring

THE EFFECT OF TIC CONTENT AND PARTICLE SIZE ON MECHANICAL PERFORMANCE IN LPBF-PROCESSED IN625 COMPOSITES

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ABSTRACT

This study presents a comprehensive evaluation of Inconel625 (In625) metal matrix composites (MMCs) fabricated via Laser Powder Bed Fusion (L-PBF). The primary objective is to enhance the mechanical performance of In625 by systematically investigating the distinct and synergistic influences of Titanium Carbide (TiC) reinforcement size nano (20–50 nm) versus micro (1–10 μm) and weight fractions (0.5 wt.% and 2 wt.%) relative to the unreinforced baseline. Composite powders were homogenized using Resonant Acoustic Mixing (RAM) to preserve spherical morphology and ensure uniform distribution. Mechanical assessments, focusing on microhardness and tensile behavior at room (25°C) and elevated temperatures (600°C), reveal that TiC integration significantly alters the performance profile of the alloy. High-concentration micro-TiC (2 wt.%) yielded the most substantial microhardness increase, up to 54% in the XY direction. Conversely, tensile results indicate that while reinforcements slightly reduce ductility at ambient temperatures, they provide critical thermal stability at 600°C. Notably, the 2 wt.% nano-TiC variant exhibited superior high-temperature strengthening, achieving a 25% increase in yield strength and a 26% increase in ultimate tensile strength compared to pure In625. These findings establish a correlation between reinforcement parameters and mechanical integrity, offering a pathway for optimizing additively manufactured superalloys for extreme service conditions

Keywords: Laser powder bed fusion, In625, Nano-TiC reinforcement, Micro-TiC reinforcement, Metal matrix composites

FLEXURAL PERFORMANCE OF GYROID-INFILLED CP-TI MAXILLOFACIAL MINI-PLATES FABRICATED VIA LASER POWDER BED FUSION

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ABSTRACT

Orthopedic implants made of CP-Ti or Ti6Al4V are widely used for bone repair due to their lower elastic modulus compared to stainless steel or cobalt-chrome. However, their modulus still exceeds that of natural bone, causing the stress-shielding effect, which hinders full bone densification. To mitigate this, porous designs manufactured via Laser Powder Bed Fusion (PBF-LB) are employed, particularly Triply Periodic Minimal Surface (TPMS) structures. While literature focuses largely on compressive and tensile properties, this study investigates the flexural strength of CP-Ti maxillofacial mini-plates produced by PBF-LB. The bending performance of a conventional mini-plate was compared with TPMS-designed counterparts. Results demonstrate that the strength of porous mini-plates converges with natural bone strength values reported in the literature, offering a promising solution for biomechanical compatibility.

Keywords: Commercially pure titanium, Laser powder bed fusion additive manufacturing, Miniplates, Triple periodic minimal surfaces, Bending strength

DESIGN AND EVALUATION OF A MOBILE CONCRETE EXTRUSION SYSTEM FOR ADDITIVE MANUFACTURING IN CONSTRUCTION

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ABSTRACT

The United Kingdom faces a persistent housing affordability crisis driven by rising construction costs, labor shortages, and insufficient build rates. Additive manufacturing (AM) has emerged as a potential solution, offering automation, reduced material waste, and rapid deployment. However, existing construction-scale concrete printing systems are limited by high transportation and setup costs, restricting their use in low-cost housing. This study investigates a low-cost, mobile AM approach through the design and experimental evaluation of a concrete extrusion demonstrator. The system combines a peristaltic pumping mechanism driven by a NEMA 23 stepper motor with a compact omnidirectional wheeled chassis to reduce setup time and improve on-site maneuverability. Experimental testing assessed extrusion massflow control, material retractability, and chassis positioning accuracy using a viscous concrete analogue. Results show a controllable relationship between pump speed and mass flow rate (4.23–6.85 g/s), reliable material retraction without residual extrusion, and precise chassis motion with no measurable positional error. Despite limitations such as flow pulsation and material substitution, the findings demonstrate that mobile, low-cost AM systems can achieve the control and accuracy required for constructionscale printing, supporting AM as a scalable pathway for affordable housing.

Keywords: Additive manufacturing, 3D concrete printing, affordable housing, peristaltic pump, construction automation

ADVANCEMENTS IN HYBRID MANUFACTURING: LEVERAGING POLYMORPHIC FIXTURES FOR PRECISION MACHINING OF PBF-LB COMPONENTS

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ABSTRACT

Components manufactured using laser powder bed fusion (PBF-LB) offer significant advantages but also present several challenges; foremost among these is the stair stepping effect. Surface quality issues can be addressed through techniques such as sandblasting, vibratory finishing for external surfaces, and abrasive flow machining (AFM) for internal geometries. However, conventional machining remains a common method to achieve critical geometric tolerances like flatness, cylindricity, and concentricity. Among these, the machining process poses its own set of difficulties, particularly in securing PBF-LB parts with lattice structures and thin-walled geometries. For complex PBF-LB components, custom fixtures are of high demand in terms of time and logistics. Polymorphic fixtures have emerged as an innovative solution to overcome these constraints. These tools utilize several thousands of miniature pins to automatically reconfigure themselves based on computer-aided design (CAD) models. Given the potential of this promising method, further research is necessary. This paper examines work holding a complex and slender bracket component produced via PBF-LB with two distinct lattice structures using polymorphic fixtures. The critical assembly surfaces of these components were machined using polymorphic fixturing. The results are discussed in terms of their applicability and benchmarked regarding the achieved surface quality measurements.

Keywords: Laser powder bed fusion, machining, polymorphic fixturing, surface quality

ENHANCEMENT OF SURFACE INTEGRITY IN EBM-MANUFACTURED Ti-6Al-4V COMPONENTS VIA A DUAL-PASS SELECTIVE LASER POLISHING STRATEGY

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ABSTRACT

The industrial adoption of Ti-6Al-4V components produced by Electron Beam Melting (EBM) is often limited by their inherently high surface roughness. This study investigates the optimization of surface integrity through a Selective Laser Polishing (LP) process, governed by a systematic control of Energy Density (ED). Recognizing that surface quality and thermal effects are directly dependent on laser-material interaction, a pulsed laser system was employed to execute a specific dual-pass scanning strategy. This approach incorporated an initial pre-heating pass (low energy density) to mitigate thermal gradients, followed by a primary polishing pass (high energy density) to induce controlled remelting. Experimental studies were conducted using varying process parameters (laser power, scanning speed, and pulse frequency) to calculate and optimize the total Energy Density (ED). Morphological analyses revealed that the application of this staged thermal input significantly reduced surface irregularities. The areal surface roughness (Sa), initially measuring between 30–40 µm in the as-built state, was successfully reduced to a range of 2–3 µm. Thermal analysis confirmed that the pre-heating step played a crucial role in stabilizing the melt pool dynamics and preventing defect formation during rapid solidification. These findings demonstrate that a tailored, multi-pass LP strategy based on precise ED control is essential for achieving superior surface finishes in additively manufactured complex parts.

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

CHARACTERIZATION OF COLD-SPRAYED C103 ALLOY AND THE EFFECT OF STRESS-RELIEF HEAT TREATMENT

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ABSTRACT

Cold Spray Additive Manufacturing (CSAM) is a solid-state additive manufacturing method in which highvelocity solid particles are deposited and bond to the substrate through impact-driven mechanisms. Since the process does not involve melting and solidification of the material, heat-input-related risks such as oxidation, phase transformation, and thermal distortion are minimized. Although the process does not generate melting– solidification-related residual stresses, it inherently develops complex residual stress fields due to high-velocity particle impact, severe plastic deformation, and layer-buildup mechanisms. This ongoing study focuses on the systematic characterization of the microstructural features, residual stress state and mechanical properties of coldsprayed C103 alloy in the as-sprayed and stress-relieved conditions. Mechanical evaluations include tensile strength, yield strength, and hardness. Furthermore, microstructures of the as-sprayed and stress-relieved C-103 are examined and compared. Subsequently, residual stress measurements using X-ray diffraction (XRD) are being carried out as part of this study.

Keywords: Cold Spray Additive Manufacturing (CSAM), C-103 Alloy, Mechanical Properties, Residual Stress, X-ray Diffraction (XRD), Stress Relief,

COLD METAL FUSION (CMF): AN ECONOMICAL PATH TO METAL ADDITIVE MANUFACTURING VIA GREEN PART POST-PROCESSING

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ABSTRACT

Cold Metal Fusion (CMF) technology provides an economical entry into metal additive manufacturing (AM) by combining specialized expertise with industrial reliability. By utilizing an SLS system at low process temperatures between 30°C and 50°C, the technology produces high-strength "green parts". These parts allow for efficient machining and surface treatments prior to sintering, significantly reducing the total cost of ownership compared to traditional metal AM. This study examines hardware optimizations for metallic powders and the surface quality improvements achieved through green part post-processing. Results from industrial showcases, such as titanium pumps and impellers, demonstrate that CMF achieves material properties comparable to Metal Injection Molding (MIM) while enabling complex geometries without support structures.

Keywords: Cold Metal Fusion, SLS, Titanium Ti64, Green Part, Metal Additive Manufacturing

ASSESSING THE LIMITS OF IN-SITU BACK-SCATTER ELECTRON IMAGING IN NARROW ELECTRON BEAM POWDER BED FUSION PROCESS WINDOWS USING X-RAY CT

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ABSTRACT

In-situ process monitoring via Back-Scattered Electron (BSE) imaging is emerging as a promising approach for Quality Assurance in Electron Beam Powder Bed Fusion (PBF-EB). Current research primarily investigates this technique using wide process windows and primitive geometries, where intentional, gross defects are easily distinguishable from the background signal. However, industrial applications demand the fabrication of more complex geometries within narrow process margins. Therefore, this study quantitatively assesses the detection limits of layer-wise BSE monitoring for such intricate structures produced within narrow process windows, benchmarked against volumetric X-Ray Computed Tomography (X-Ray CT) data.

Keywords: Electron beam powder bed fusion, Back-scatter electron imaging, X-Ray CT

LOW ANGLE OVERHANG MANUFACTURABILITY IN Ti-6Al-4V LASER POWDER BED FUSION

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ABSTRACT

Support structures impose major cost and productivity penalties in laser powder bed fusion (PBF-LB) of Ti-6Al4V, especially for low-angle down-facing features typically supported below ~45°. This study quantifies the supportless overhang limit at 60 μm layer thickness on a quad-laser Renishaw RenAM 500Q and identifies a stable down-skin process window. Cantilever artefacts spanning 5-40° established the baseline limit, followed by fixed 15° artefacts to evaluate geometric and build-location sensitivity, and down-skin trials supported by in-situ meltpool emission monitoring. Standard bulk settings (VED ≈ 37.4 J/mm^3) failed at ≤20°. With full-area down-skin activation, repeatable 15° overhangs were achieved using reduced power (200-240 W at 1500 mm/s) or increased scan speed (320 W at 2500–3000 mm/s), corresponding to VED ≈ 20–28 J/mm^3 and relative density of 99.80– 99.96% in the overhang region. Build stability was sensitive to build-plate gas-flow asymmetry and reduced interlayer cooling time in multi-laser operation.

Keywords: Laser Powder Bed Fusion, Ti-6Al-4V, overhangs, down-skin parameters, supportless manufacturing.

REPRESENTATIVE QUALITY INDICATORS (RQIS) FOR LARGE-SCALE ADDITIVE MANUFACTURING: PATHWAY TO INDUSTRIAL QUALIFICATION

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ABSTRACT

This work addresses key limitations constraining the industrial adoption of Additive Manufacturing (AM): the lack of robust quality assurance protocols and statistically meaningful qualification data. A central barrier is the absence of reliable, repeatable flawed components, or Representative Quality Indicators (RQIs), necessary for validating Non-Destructive Evaluation (NDE) methods. This study introduces advances by Theta Technologies and partners in developing a controlled flaw-generation methodology using a resonance-based technique to seed realistic "contact cracks"—extremely fine, partially closed defects relevant to industrial AM processes—into both test coupons and full-geometry parts. The resulting RQIs, with separation between crack surfaces beyond the resolution limits of X-CT, can be used to compare and evaluate NDE technologies. They were tested using Nonlinear Resonance (NLR) proving the capability of the technique as an effective for high-rate technique that could be used in production. In the UK, the AMSCALE ATI project is leveraging this approach to refine the methodology, develop a robust crack-seeding platform, and conduct essential Probability of Detection (PoD) studies required for aerospace certification, supported by industrial partners including Rolls-Royce and GKN Aerospace. This research establishes a critical pathway for the reliable, traceable qualification of large-scale AM components, advancing the readiness level of nonlinear resonance NDE for widespread industry adoption.

Keywords: Nonlinear Resonance, NDT, Contact Cracks.

DEVELOPMENT OF A RAPID VERIFICATION LAYOUT TO CHECK THE SENSITIVITY OF IN-SITU MONITORING FOR L-PBF SYSTEMS

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ABSTRACT

In-situ monitoring (ISM) plays an increasingly important role in ensuring process stability and part quality in Laser Powder Bed Fusion (L-PBF) systems. Currently there is a need for fast and standardized methods to verify whether ISM reliably detects process deviations during printing process. This work presents a rapid verification layout developed to assess ISM sensitivity in a time and cost efficient manner. The layout contains a compact set of features designed to induce controlled variations in melt behavior, thermal gradients, and local process parameters. These intentionally created deviations generate characteristic signal responses that can be used to evaluate ISM performance without requiring specialized hardware or nonstandard parameter sets. Validated across multiple L-PBF systems, the layout consistently produced reproducible ISM signatures that correlated with the induced anomalies. This enables the establishment of baseline machine responses as well as quick identification of deviations that may arise from maintenance activities, optical adjustments, or general system drift. By enabling verification within a build time of under one hour, the proposed layout supports frequent monitoring checks and contributes to more reliable quality assurance workflows. Future work will focus on automated signal assessment and extensions for multi-laser platforms.

Keywords: Additive Manufacturing, In-situ monitoring, qualification

COMPUTED TOMOGRAPHY-DRIVEN GEOMETRY COMPENSATION OF ADDITIVELY MANUFACTURED CERAMIC CORES FOR TURBINE BLADE INVESTMENT CASTING

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ABSTRACT

Ceramic cores are used in turbine blade investment casting to form internal cooling channels, where dimensional accuracy of the core directly affects channel integrity and casting quality, thus part performance. Digital Light Processing (DLP) is a vat-photopolymerization based additive manufacturing process that enables fabrication of ceramic cores. However, due to the inherent nature of the DLP process and its required post-process steps such as debinding and sintering, geometrical shrinkage and dimensional deviations may occur during those ceramic core manufacturing steps. This study aims to manufacture ceramic cores by DLP within the required dimensional tolerances by applying a computed tomography (CT) driven geometry compensation workflow. After the initial production, the geometry was captured by CT and evaluated in VGSTUDIO MAX software to determine deviation fields against the nominal model. A compensation model was generated using CT-derived deviations; to enable controlled corrections. CT results of the compensated build confirmed improved conformity to the nominal geometry on critical features. To enable reporting without revealing sensitive geometry data, warpage improvement was also quantified at five predefined reference points and presented as percentage change. Overall, CT-driven compensation provides an effective route to satisfy dimensional requirements for DLP-manufactured ceramic cores used in turbine blade casting.

Keywords: Ceramic Cores, Digital Light Processing (DLP), X-ray computed tomography (CT) measurement, geometry compensation

A NEW ERA IN DENTAL CROWN–BRIDGE RESTORATIONS: SLM-MANUFACTURED TINB-BASED ALLOY WITH OPTIMIZED PORCELAIN BONDING AND FAVORABLE MECHANICAL AND BIOLOGICAL PROPERTIES

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ABSTRACT

The need for new metallic material should be considered in this era, as most alternative biocompatible materials have been optimized for industrial applications. From this perspective, this study focuses on dental crown–bridge restorations and demonstrates how a new titanium-based alloy meets the requirements for dental applications. Initially, the aim was to create an alloy composition that presents a β phase even after Selective Laser Melting production, which generally leads to α-phase formation. Heat treatment was selected to obtain a fully β-phase microstructure and to eliminate residual thermal stress. Process parameter optimization for this material was performed on a BLT 160 machine, with the development of both in-skin and border parameters for thin-walled structures required for crown–bridge restorations. Ultimately, mechanical behavior and biological responses were the main criteria used to determine the acceptance of the TiNbZrSn alloy in its final form. ISO standards and their threshold values were considered for acceptance, together with comparisons to commonly used metallic materials. Favorable results obtained from tensile testing, de-bonding crack initiation (3-point bending) test, and chewing simulator tests, along with biocompatibility and cytotoxicity results, provide strong evidence supporting the potential of this material to change perspectives on new material development in the dental field.

Keywords: titanium-based alloys, dental, SLM, metal-porcelain bonding, biocompatibility

COMPARATIVE EVALUATION OF TI6AL4V AND COMMERCIALLY PURE TITANIUM TPMS LATTICE STRUCTURES FOR ORTHOPEDIC IMPLANTS

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ABSTRACT

Ti6Al4V and commercially pure titanium (CP-Ti) are widely used in additive manufacturing for medical applications. In the study, the success of these two materials in orthopedic implants was evaluated. TPMS (Triply Periodic Minimal Surface) lattices produced from Ti6Al4V and CP-Ti were examined comparatively in terms of manufacturability, production accuracy, and mechanical properties. The literature indicates that TPMS lattices enhance cell migration and osseointegration, and that they offer advantages in load-bearing applications due to their energy absorption, mechanical strength, load distribution, and deformation characteristics. The lattice structures were designed in accordance with the ISO 13314 standard. A Python script was written to design the sample geometry. The optimum process parameters for both materials were determined by analyzing density, design accuracy, overhangs, and internal structural analysis. Compression tests were performed. Behavior of the geometries was evaluated comparatively, considering the differences between Ti6Al4V and CP-Ti and the effects of different TPMS structures. Biocompatibility and osseointegration behaviors will be discussed further considering the data obtained.

Keywords: TPMS, lattice, orthopedic implant, Ti6Al4V, Pure Ti

INNOVATIVE CASSETTE-TYPE HYBRID BUILD PLATE DESIGN FOR IMPROVED MACHINABILITY AND COST REDUCTION IN DENTAL AM IMPLANTS

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ABSTRACT

Additive Manufacturing (AM) has grown rapidly and become an established production technology, driving extensive research and industrial adoption. Among AM methods, Laser Powder Bed Fusion (LPBF) remains a major research focus due to its process complexity, material flexibility, and post-processing requirements. While substantial effort has been devoted to process parameters, materials, and heat treatments, build plate design and functionality remain relatively under-studied despite their significant influence on part quality, process reliability, and production cost. In LPBF, build plates are typically required to match the part material, resulting in high costs when processing titanium alloys. In addition, build plate design directly affects post-processing operations, particularly CNC machining of small, high-precision components. This study proposes a cost-effective, machinability-oriented hybrid build plate design for titanium dental implant production. The build plate features a localized titanium region limited to the build area, while the remaining structure is manufactured from stainless steel. The titanium region is implemented as a removable cassette to enable high-precision machining. By replacing non-functional titanium regions with stainless steel, the proposed design significantly reduces cost while improving machinability. The results demonstrate that the hybrid build plate offers an economical and practical solution for LPBF-based titanium implant production.

Keywords: Hybrid Build Plate, Titanium, Additive Manufacturing, LPBF, Dental Implant

4D PRINTING OF SHAPE-MEMORY ARTIFICIAL VESSEL WITH IMPROVED MECHANICAL PROPERTIES

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ABSTRACT

The 4D printing technology is a method in which shape-memory materials are produced using 3D printing. In this study, resin formulations with different compositions were developed for use in a DLP 3D printer, and a shapememory cycle was applied to the formulation that yielded mechanical properties closest to those of natural vessels. The ideal resin provided an elastic modulus of 13 MPa and a tensile strength of 5.4 MPa. Using this resin, an arterial vessel model with an inner diameter of 4 mm was 3D printed. The vessel model, which has a glass transition temperature of 38 °C, endowed with shape-memory capability, achieving a 100% recovery rate. The developed artificial vessel model exhibits mechanical performance values within the range of natural vessels. Performance tests on the model are still ongoing, and this study shows promise for future surgical applications.

Keywords: 4D printing, photo-polymerization, shape memory, vessel model

NUMERICAL MODAL ANALYSIS OF ADDITIVELY MANUFACTURED CELLULAR/LATTICE STRUCTURES: EFFECTS OF UNIT-CELL TOPOLOGY, RELATIVE DENSITY AND ORIENTATION ON NATURAL FREQUENCIES AND MODE SHAPES

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ABSTRACT

Cellular and lattice architectures enabled by additive manufacturing (AM) are increasingly adopted in aerospace and lightweight engineering to achieve tailored stiffness-to-mass ratios and vibration performance. This study presents a fully numerical framework to quantify how unit-cell topology (honeycomb, re-entrant/auxetic and strutbased lattice families), relative density and orientation affect natural frequencies and mode shapes of thin lattice panels. The work targets lattice/cellular design and AM-oriented simulation needs by providing an early-stage, fabrication-free decision support tool for design-for-AM (DfAM). A parametric finite element modal analysis is conducted under consistent boundary conditions, and mode-shape correlation is assessed using the Modal Assurance Criterion (MAC). Results indicate that (i) increasing relative density produces a monotonic rise in eigenfrequencies due to enhanced effective stiffness; (ii) topology governs the dominant deformation mechanisms (stretch- vs bending-dominated response), leading to distinct modal families; and (iii) orientation introduces measurable anisotropy, causing mode swapping and frequency splitting in higher modes. The proposed methodology establishes a reproducible route to screen AM cellular designs for vibration-sensitive applications before committing to build trials or certification testing.

Keywords: additive manufacturing, lattices and cellular structures, design for AM (DfAM), modal analysis, natural frequency, finite element method, MAC

TOPOLOGY OPTIMIZATION AND PART CONSOLIDATION OF A BRAKE SYSTEM FOR PRINT-IN-PLACE ADDITIVE MANUFACTURING

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ABSTRACT

The scope of this study is to optimize a bicycle brake caliper with an additively manufactured actuation mechanism. The study utilizes compliance-based Topology Optimization (TO) for lightweighting. For the design domain, a conventional mechanical caliper was reverse-engineered. The novel contribution of this design is the part consolidation through a print-in-place ball-and-ramp brake actuation mechanism that significantly reduces part count. The new design uses the AlSi10Mg alloy and achieves a 47% weight reduction and reduces total part count from 19 to just 9. The design has been manufactured using SLM with AlSi10Mg powder and validated through a test assembly. The metal part has been inspected with radiographic inspection. A revised geometry addressing bicycle interface compatibility has been validated by FFF prototyping. Future work includes physical testing on a real bicycle to evaluate braking performance.

Keywords: Topology Optimization, Design for Additive Manufacturing, Cycling, Part Consolidation, Print-inplace

RADAR ABSORPTION PERFORMANCE OF ADDITIVELY MANUFACTURED RE-ENTRANT METAMATERIAL STRUCTURES

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ABSTRACT

Reducing the radar cross section (RCS) is a key requirement in aerospace applications, and metamaterial-based structural designs offer a promising approach to achieving this objective. In this study, the electromagnetic absorption behavior of a re-entrant metamaterial unit cell was investigated. Electromagnetic simulations were conducted over the X-band frequency range (8–12 GHz), and absorption performance was evaluated using the reflection coefficient (S11). The unit cell geometry was optimized by varying the base length (L), the inward inclination angle of the side arms (θ) at constant wall thickness. Following the optimization, radar absorption tests were performed on the re-entrant structure fabricated from AlSi10Mg via additive manufacturing. The findings show that the re-entrant metamaterial provides satisfactory absorption performance. When the experimental and analytical results were compared, a similar overall behavior was observed; however, a deviation was noted in the absorption levels. For future studies, this discrepancy could be reduced by further optimising the additive manufacturing conditions, considering the influence of surface roughness, porosity effect and conducting the measurements using more precise anechoic chamber setups.

Keywords: Metamaterial, Re-entrant structure, Radar absorbing , X-band, Additive manufacturing

THERMODYNAMICALLY ENGINEERED GRAIN REFINEMENT IN Ti-6Al-4V VIA CALPHAD-ASSISTED ALLOYING

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ABSTRACT

Wire Arc Additive Manufacturing (WAAM) of Ti-6Al-4V produces coarse columnar prior-β grains due to directional solidification and repeated thermal cycling, resulting in microstructural anisotropy. This study proposes a computational alloy design strategy to reduce anisotropy by modifying solidification behavior through minor alloying additions. CALPHAD-based analysis were correlated with experimental grain morphology obtained from arc-melted alloys. Key solidification parameters were identified and linked to grain refinement behavior. The results demonstrate that thermodynamic metrics can guide alloy design to achieve reduced grain size and aspect ratios approaching unity, providing a predictive framework for WAAM alloy optimization.

Keywords: Alloy Design, Ti-6Al-4V, Computational Material Science, Solidificaiton Control, Microstructure Engineering

FUNCTIONALLY GRADED Ti-6Al-4V BY LPBF: MICROSTRUCTURE, INTERFACES, AND MECHANICAL PROPERTIES

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ABSTRACT

This study investigates the fabrication of functionally graded (FG) structures using the Laser Powder Bed Fusion (LPBF) technique by systematically varying process parameters across multiple layers. Twelve process parameter sets were defined and grouped into four different graded manufacturing strategies to fabricate the multilayer and graded parts. Compression tests revealed clear differences in mechanical response among the FG samples, with certain parameter combinations exhibiting enhanced yield strength and overall performance. The results demonstrate that LPBF is a viable approach for producing functionally graded structures with tailored mechanical properties through controlled process parameter variation. Future work will focus on detailed on dynamic compression behavior, microstructural characterization, hardness mapping, and interlayer bonding.

Keywords: Functional Graded Materials, LPBF, Ti6Al4V

CALPHAD-BASED PHASE STABILITY AND NON-EQUILIBRIUM SOLIDIFICATION ANALYSIS OF SS316L–IN718 FUNCTIONALLY GRADED MATERIALS

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ABSTRACT

Laser-directed energy deposition (L-DED) is a versatile additive manufacturing technique that enables the fabrication of functionally graded materials (FGMs) with continuous compositional gradients, allowing localized tailoring of material properties. FGMs, by combining at least two different materials, offer significant potential for extreme applications such as aviation, space, and energy applications. However, phase stability and nonequilibrium solidification behavior across the compositional gradient are critical challenges. In this study, an FGM system consisting of eleven distinct local alloy compositions with 10 wt.% compositional increments from SS316L to IN718 was designed. CALPHAD-based thermodynamic analyses were used to examine phase stability and solidification behavior of FGM using Thermo-Calc software. The results show that phase evolution across the FGM is strongly dependent on composition. Equilibrium calculations revealed the progressive stability of Laves, γ', and γ'' phases with increasing IN718 concentration. Scheil simulations showed significant Nb-driven micro segregation and late-stage precipitation of Nb-rich phases like NbC and Laves. Critical locations with increased segregation susceptibility were found in intermediate compositions, especially in the range of 20–30 wt.% IN718. The combined equilibrium and non-equilibrium analyses provide a thermodynamic framework for understanding phase evolution and guide for FGM design in additive manufacturing applications.

Keywords: Functionally graded materials, CALPHAD, Thermo-Calc, Scheil solidification, SS316L–IN718

ACOUSTIC NON-DESTRUCTIVE TESTING OF AM MEDICAL DEVICES

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ABSTRACT

The next generation of AM medical devices is using functional optimisation to place material only where it is structurally required and to create surface features that promote bone growth, resulting in lightweight components with organic, elegant geometries. Achieving this reliably at high production volumes requires effective Non-Destructive Testing (NDT) to validate part quality and to monitor critical processes such as powder removal and heat treatment without compromising throughput. However, inspecting AM parts presents significant challenges. Defects such as trapped powder and porosity can lead to contact cracks during fatigue, yet established NDT methods often struggle with these flaw types. Material properties obtained with tensile testing do not represent the behaviour of complex device geometries, X-CT is costly and typically limited to end-of-process inspection, and optical methods detect only surface-breaking flaws and are influenced by operator variability. Non-Linear Resonance technology, which excites components in their natural resonance modes and measures their vibrational response, offers a promising alternative. It addresses several of these limitations. This presentation will showcase studies on AM medical devices using Nonlinear Resonance NDT, including measurements on tensile coupons seeded with contact cracks, and demonstrate how the method can be applied as a quality-control tool for special processes such as powder removal and heat treatment.

Keywords: Nonlinear Resonance, NDT, AM Medical Devices.

PHYSICAL AND SPECTRAL CHARACTERISTICS OF THE VAPOR PLUME IN LASER POWDER BED FUSION

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ABSTRACT

The high temperatures reached in laser powder bed fusion (LPBF) vaporize material from the melt pool and form a plume above it. This vapor plume can obscure optical process monitoring and attenuate light from the process laser beam, as well as emit its own radiation. In this work, we explore the physical and spectral characteristics of the vapor plume produced when printing with Ti-64 material with spectrometry and multispectral imaging data. Temporally averaged spectrometry data is used to determine line emission peaks from the high-temperature vapor atoms and imaging in multiple wavelength bands is further employed to elucidate the spatial presence of line emission. Spectral plume attenuation is also captured by measuring spatial transmission through the plume at different wavelengths. We find the plume to be composed of two distinct regions; A dense, hot emitting region where emission is dominated by bound-bound electronic transitions, and a cooler extinction region, where atoms nucleate into Ti-64 nanoparticles and scattering and absorption of light are dominant. We do not see significant ionization at the processing conditions tested. These data show that the plume can significantly attenuate the laser beam and imaging wavelengths, demonstrating the importance of resilient process monitoring and control approaches.

Keywords: Laser Powder Bed Fusion, Vapor Plume, Melt Pool Physics, High-Speed Imaging, Process Monitoring

COUPON LEVEL EXPERIMENTAL ASSESSMENT OF ADDITIVELY MANUFACTURED FUNCTIONALLY GRADED LATTICE CORES FOR CFRP SANDWICH STRUCTURES

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ABSTRACT

Lightweight CFRP sandwich structures require core architectures that provide high compressive efficiency and vibration resistance. This study benchmarks coupon-level performance of additively manufactured lattice cores with uniform and ramp-type functional grading for composite sandwich concepts. Five topologies (Diamond, FCC, Fluorite, Kelvin Cell, and Octet) were designed in nTopology and printed from PLA+ by material extrusion (MEX). Grading was implemented as a linear Z-direction thickness variation (1.75–2.50 mm; uniform 2.125 mm) in 50×50×50 mm coupons. Quasi-static compression (Instron 5967, 5 mm/min, 0–20 mm, n=3) quantified peak load, energy absorption (EA), and crushing force efficiency (CFE). Topology dominated strength: Octet reached the highest peak load (~30 kN) and EA (~423 J), followed by Fluorite and FCC. Grading did not uniformly raise peak load but typically reduced post-peak load drops and enabled more progressive crushing. CFRP face-sheet integration of graded cores increased EA and mean crushing force. An impacthammer test on a graded Octet-core sandwich showed a shifted first-mode response and a broader resonance peak than a monolithic CFRP plate, indicating higher effective damping.

Keywords: Additive manufacturing, functionally graded lattice, CFRP sandwich, material extrusion, vibration

TEMPERATURE AND DWELL-TIME-DRIVEN EVOLUTION OF TI6AL4V POWDER MORPHOLOGY DURING DIODE-LASER PREHEATING FOR POWDER BED FUSION

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ABSTRACT

Powder bed preheating is employed in additive manufacturing to mitigate thermal gradients and residual stresses; however, excessive thermal exposure may degrade powder morphology and recyclability. This study investigates the effects of laser-based preheating temperature and dwell time on the morphological, chemical, and crystallographic evolution of gas-atomised Ti6Al4V Grade 23 powder using a homogenised defocused diode-laser system. Powders were heated from room temperature to 1500 °C with a 10 s dwell time, with an additional 1 min dwell applied at 1200 °C. Characterisation was conducted using SEM-EDS, X-ray diffraction, and quantitative morphology analysis, including sphericity, roundness, convexity, solidity, and particle size distribution. Process implications were validated via multi-layer fabrication using Diode Point Melting with in-situ dynamic laser heating. Increasing temperature induced particle necking and agglomeration, reducing sphericity and roundness. Preferential aluminium vaporisation was observed above 800 °C, while extended dwell time promoted partial α→β phase transformation. Prolonged laser–powder interaction governed powder degradation more strongly than temperature alone.

Keywords: Laser preheating; Ti6Al4V; Powder morphology; Diode laser

EVALUATION OF POWDER ANALYSIS FOR Ti6Al4V

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ABSTRACT

In Metal Additive Manufacturing (MAM) processes, raw material quality is one of the most critical determinants affecting final part performance. The objective of this study is to conduct a time- and environment-dependent investigation of the dimensional and morphological analyses of industrially produced Ti6Al4V alloy powder carried out at three distinct time points: T0 (immediately after production), T1 (after 2 months of storage in vacuum packaging), and T2 (12 hours after T1 under atmospheric conditions) using Dynamic Image Analysis (DIA) methods (Litesizer and Camsizer X2). The findings reveal that (unlike the Al alloy powders) the Ti6Al4V powders undergo cycles of agglomeration and de-agglomeration depending on vacuum and atmospheric transitions. This may be caused by the triboelectric electrostatic charging of the powder during atomization and storage.

Keywords: Ti6Al4V metal powder, Particle size distribution (PSD), morphology, shelf-life

HIGH-PERFORMANCE SOFT MAGNETIC INDUCTORS VIA BINDER JETTING OF FE–50NI

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ABSTRACT

This study examines binder jetting of Fe–50Ni soft magnetic alloys for transformer, inductor, and motor cores, enabling complex geometries, and focuses on density and magnetic performance in bulk and toroidal designs. Two powders with different particle size distributions were sintered under atmospheric and vacuum conditions: ~1360 °C achieved near-full density, while 1335 °C preserved complex geometries at ~80% density suitable for toroidal inductors. Bulk toroids reached saturation flux density comparable to a commercial reference at 50 Hz but showed wider hysteresis due to eddy-current losses. Complex design cores improved AC behavior, with concentric square-ring designs delivering the highest permeability and inductance up to ~7 kHz, demonstrating geometry-driven loss reduction for advanced electrical applications.

Keywords: Binder jetting, Soft magnetic material, Additive manufacturing, magnetic properties, Fe-50Ni

ANISOTROPIC INVERSE DESIGN OF SMOOTH PERIODIC LATTICES USING VARIATIONAL AUTOENCODER-BASED NEURAL NETWORKS

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ABSTRACT

Lattice structures of various types are widely used in additive manufacturing to optimize the tradeoff between weight and various target properties such as strength, heat conductivity and shock absorption. While the type and design definition of different lattice types vary, it is common in industry to achieve desired properties by trial and error of design parameters, validating via numerical methods. Moreover, it is not common to change lattice geometry or topology for various tasks (apart from changing thickness and cell size), therefore fine-tuning of multiple/anisotropic objectives are not achievable. This study proposes a new generative model, leveraging conditional β-Variational Autoencoders (β-VAE) running on continuous data in the form of signed distance fields (SDF). With the definition of a new method of analytical anisotropy for otherwise anisotropic triply periodic minimal surface (TPMS) lattices, proposed methodology is shown to be capable of achieving <15% mean absolute percentage errors (MAPE) for an inverse design target space composed of relative density (ρ) and 2 elastic moduli values of different directions (Ex, Ey). Moreover, these results are shown to be valid on 70% of the convex target space, indicating a highly structured latent space, also demonstrated in dimensional reduction analysis as well as 3-point latent space interpolations.

Keywords: TPMS, Anisotropy, VAE, Inverse Design, Lattice

COMPARATIVE ANALYSIS OF SHEAR DEFORMATION THEORIES FOR SANDWICH BEAMS WITH ADDITIVELY MANUFACTURED LATTICE CORES UNDER SINUSOIDAL LOADING

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ABSTRACT

Sandwich beams with additively manufactured lattice cores are increasingly used in lightweight structural applications due to their high stiffness-to-weight ratio and design flexibility. Accurate prediction of their mechanical response requires appropriate shear deformation theories, particularly when transverse shear effects become dominant. In this study, the mechanical behavior of simply supported sandwich beams subjected to a sinusoidal distributed transverse load is investigated using analytical and numerical approaches. First-Order Shear Deformation Theory (FSDT), Third-Order Shear Deformation Theory (TSDT), and Refined Zigzag Theory (RZT) are formulated and compared with three-dimensional finite element (3D-FEM) simulations. The sandwich beams consist of composite and additively manufactured AlSi10Mg facesheets combined with additively manufactured lattice cores, which are also represented by homogenized equivalent models. Parametric analyses are conducted to investigate the impact of core stiffness and geometric ratios on displacement and stress distributions. The results demonstrate that RZT provides the most accurate displacement predictions and shows excellent agreement with FEM results across all investigated cases. While FSDT and TSDT capture stress trends reasonably well, they exhibit notable deviations in deflection responses. The findings underscore the significance of advanced shear deformation theories for the reliable analysis and design of lattice-core sandwich beams under sinusoidal loading conditions.

Keywords: Additive manufacturing, composite sandwich structures, lattice cores, higher-order theories

STRESS DRIVEN TOPOLOGY AND LATTICE BASED LIGHTWEIGHT DESIGN OF A GEARBOX HOUSING WITH VARIABLE SHELL AND LATTICE THICKNESSES FOR SLM 3D PRINTING

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ABSTRACT

An aluminum gearbox housing used within FNSS was redesigned for Selective Laser Melting (SLM) on the basis of design for additive manufacturing (DfAM) concept with the aim of reducing the total weight while preserving structural performance. The original geometry, without topology optimization or lattice structures, was taken as the reference design. Topology optimization was applied to the entire part; however, the results were not directly adopted as the final design, and only the structurally efficient and manufacturable features in the flange regions were selected. The Von Mises stress field obtained from structural analysis (linear-elastic analysis) of the topology-optimized flanged housing was mapped to shell and lattice thicknesses using ramp functions, enabling thicknesses to increase in high-stress regions and decrease geometrically and continuously in low-stress regions. Based on the comparison of different lattice topologies, the Split-P lattice structure demonstrated a more balanced weight– mechanical performance, achieving approximately 38% mass reduction compared to the original geometry.

Keywords: Selective Laser Melting (SLM); Stress-driven design; Variable shell and lattice thickness; Topology optimization; Gearbox housing

MODAL TOPOLOGY OPTIMIZATION AND ADDITIVE MANUFACTURING OF INCONEL 718 COMPONENTS

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ABSTRACT

The practical adoption of diverse topology optimization methods, developed over several decades, has proliferated across industry and academia, driven by the capability of additive manufacturing (AM). Based fundamentally on numerical analysis and material removal according to mathematical algorithms, this method has led to the development of dedicated finite element method (FEM) software packages. Thanks to both additive manufacturing and successfully implemented FEM, numerous sectors—primarily aerospace—are now benefiting from this method, leveraging it to lightweight components particularly operating under static loads. Nevertheless, the implementation of this method for components with critical dynamic properties is limited in comparison to static applications. There is a clear need for research involving dynamic optimization to further the development of this established field. Aiming to fill this gap, this study optimizes a bracket component for its first three natural modes using Ansys software, achieving weight reduction while simultaneously increasing the frequency values for each mode. As a result of the optimization, the first mode frequency of the bracket increased by 13%, while its weight was reduced by 40%. The practical feasibility of the design was validated through Laser Powder Bed Fusion (PBFLB) manufacturing using Inconel 718 material and subsequent 3-dimensional (3D) metrological measurements.

Keywords: Topology optimization, natural frequency, laser powder bed fusion, Inconel 718

PREPARATION OF GRAPHENE-REINFORCED COPPER FEEDSTOCKS FOR BINDER JET ADDITIVE MANUFACTURING: EFFECTS OF MIXING STRATEGY ON MORPHOLOGY AND FLOWABILITY

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ABSTRACT

This study investigates powder preparation strategies for graphene-reinforced copper feedstocks tailored to binder jet additive manufacturing (BJAM). Cu–rGO composite powders were produced via planetary ball milling by varying reinforcement ratio, milling speed (250–500 rpm), time (0.5–3 h), and strategy (simultaneous vs. sequential rGO pre-milling followed by co-milling with Cu). Powder morphology and graphene dispersion were evaluated by SEM. To align with BJAM requirements, additional low-shear blends (0.25–1 wt% rGO) were prepared and characterized using standardized flow metrics. Simultaneous high-concentration milling with 500 rpm caused severe plastic deformation of Cu, reducing sphericity and increasing irregular particles, which can degrade recoating stability and green density uniformity. In contrast, sequential milling at 250 rpm improved dispersion while better preserving near-spherical Cu morphology and showed good reproducibility.

Keywords: Binder Jetting, Graphene, Thermal conductivity, powder preparation, composite powder

POWDER REUSE BEHAVIOUR OF STANDARD AND EXPANDED TI-6AL-4V FEEDSTOCKS IN LASER POWDER BED FUSION

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ABSTRACT

Expanded particle size distributions (PSDs) have been proposed to improve material utilisation and reduce the cost of Ti-6Al-4V feedstock for laser powder bed fusion (PBF-LB), yet their behaviour under repeated processing remains poorly understood. This study compares a standard PSD (15-53 μm) and an expanded PSD (15-106 μm) processed on an industrial PBF-LB system. Powder state was assessed using PSD analysis, spatter morphology, powder chemistry (O, N, H), flowability and apparent density. Over three processing cycles, the expanded PSD exhibited a shift towards finer particle sizes, indicating early-stage refinement rather than coarsening. Coarse spatter particles were observed at the chamber periphery but were not incorporated into the powder bed in sufficient quantities to influence PSD. Oxygen content increased for both powders; however, when normalised by PSDderived specific surface area, the expanded PSD showed a lower oxygen increase per unit surface area than the standard PSD. Both powders exhibited improved flowability and apparent density with continued cycling, with the expanded PSD consistently exhibiting lower Hall flow times and higher apparent density. These results demonstrate that expanded PSD feedstocks can retain stable particle size characteristics and bulk powder behaviour while supporting more sustainable PBF-LB operation.

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

INDUSTRIAL-SCALE CLEANING OF AEROSPACE-GRADE TITANIUM AND HIGH-STRENGTH ALUMINUM MACHINING SWARFS FOR HIGH-VALUE ADDITIVE MANUFACTURING FEEDSTOCK

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ABSTRACT

The aerospace industry generates substantial quantities of high-value Titanium and Aluminum alloy machining chips during subtractive manufacturing. Due to contamination from machining fluids, carbonaceous residues, and oxidation, these high-grade materials are frequently downgraded as waste, limiting circular economy potential. While laboratory-scale cleaning studies have demonstrated feasibility, industrial implementation requires substantial process adaptation. Based on previous laboratory-scale cleaning studies conducted within a TÜBİTAK 1004 project, one of the aims of the Horizon project (REPAM), to transfer the process to an industrial scale using a solvent-based cleaning system capable of dissolving complex machining oils. This transition required extensive optimization of washing parameters and the development of process methodologies. The primary challenge was not washing efficiency but controlled drying, as residual solvent led to elevated organic carbon signals in ONH/C analyses. Therefore, both process parameters and analytical methodology were optimized to distinguish carbon originating from cutting fluids and solvent residues. Through drying optimization ensuring complete solvent evaporation before discharge, contamination levels were reduced to acceptable recycling thresholds for advanced aerospace applications. The study demonstrates that industrial-scale solvent-based chip cleaning is feasible when supported by integrated process and analytical optimization, enabling high-value alloys to remain within a sustainable production cycle.

Keywords: Recycling, Additive Manufacturing, Feedstock, Recycling of Swarf, Cleaning

EFFECTS OF PRE-DEFORMATION PARAMETERS ON GEOMETRICAL ACCURACY IN METAL POWDER BED FUSION PROCESS

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ABSTRACT

In Laser Powder Bed Fusion, Rapid heating and cooling cycles induce non-uniform thermal expansion and contraction, resulting in part warpage and reduced dimensional accuracy. To mitigate warpage, compensation strategies such as pre-deformation are employed, whereby the 3D model is intentionally deformed opposite to the predicted distortion prior to manufacturing. This approach requires deformation data obtained from numerical simulations. In this study, the effects of mesh size and deformation scale on the effectiveness of the predeformation method are experimentally investigated using a 100 mm long part built in a horizontally inclined orientation. The results demonstrate that pre-deformation improves geometric accuracy across all mesh sizes and deformation scales, with finer meshes yielding superior accuracy. Optimal performance is achieved for deformation scales between 0.85× and 1×. The flatness of the main datum improves from 0.337 mm in the original part to 0.0889 mm in the best case. However, circular features show reduced dimensional accuracy in pre-deformed geometries and therefore require post-machining considerations.

Keywords: Laser Powder Bed Fusion, Warpage, Residual Stress, Process Simulation, Pre-deformation

AUTOMATED POWDER REMOVAL AND RECOVERY PLATFORM FOR METAL ADDITIVE MANUFACTURING

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ABSTRACT

Efficient removal of residual powder from complex internal channels is a critical step in metal additive manufacturing, especially for SLM and EBM processes where trapped powder causes quality, reliability, and safety concerns. In this study, a Powder Removal and Recovery Platform (PRRP) was developed to automate the cleaning and recovery of metal powder from lattice structures, internal channels, and support regions. The system integrates a sealed inert-gas chamber, a dual-axis rotational mechanism enabling controlled part orientation, vibration-assisted motion, filtration and collection unit, and a localized blasting module for difficult regions. To support this hardware, a parallelized path-planning algorithm was developed to analyze the internal geometry of the part and generate an optimized motion sequence in real time. This sequence is transmitted to motor drivers in real time, enabling the part to be aligned with gravity along its longest powder-flow paths. Additional inertia-based micro-motions were introduced to improve powder mobility inside narrow or complex channels. Experimental validation was performed using transparent polymer mock-ups, granule media, and SLM-produced Ti-6Al-4V components. The PRRP achieved 91.1–99.1% powder removal efficiency depending on geometry and relative density. Compared to manual cleaning, the system reduced operator effort and cycle time by up to 95%. These results demonstrate that the developed PRRP provides a highly repeatable, efficient, and automation-ready postprocessing solution for metal AM applications.

Keywords: Metal Additive Manufacturing, Automated Depowdering, Post-processing

FABRICATION OF FE/B_4C CORED COMPOSITE WIRES FOR WIRE ARC ADDITIVE MANUFACTURING

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ABSTRACT

This study investigates the fabrication of cored wires for metal matrix composite production in wire arc additive manufacturing (WAAM) processes. Currently, WAAM technology predominantly relies on commercially available standard welding wires. However, a review of the literature indicates that such standard wires are insufficient to meet the increasing functional requirements of advanced applications. In this context, the use of Fe/B_4C cored wires represents a novel and previously unreported approach for metal matrix composite fabrication via wire arc additive manufacturing. The cored wires were fabricated using the powder-in-tube technique. Low-carbon steel tubes with inner diameters of 4 mm, 5 mm, and 6 mm were filled with Fe/B_4C powder mixtures containing 5%, 10%, 15%, 50% and 100% B_4C by volume and subsequently processed into wires by wire drawing. As a result of employing these wires in wire arc additive manufacturing, the in-situ formation of Fe_2B eutectic phases as hard reinforcements within the iron matrix is anticipated.

Keywords: Wire arc additive manufacturing, metal matrix composites, cored-wire, in-situ reaction.

COMPARISON OF X-RAY COMPUTED TOMOGRAPHY AND IMPULSE EXCITATION TECHNIQUE RESULTS ON ELECTRON BEAM MELTED TI-6AL-4V SAMPLES

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ABSTRACT

EBM is an Additive Manufacturing technique producing functional metal components and is widely used in aerospace, automotive, and biomedical applications. Despite being conducted under a controlled atmosphere, manufacturing-induced porosity can occur, affecting the mechanical performance and fatigue life of Ti-6Al-4V components. This study investigated the internal structure of Ti-6Al-4V fatigue samples produced by EBM by correlating results from X-ray computed tomography (CT) and the impulse excitation technique (IET). Three untested samples and three tested but unfractured samples were analyzed. A clear correlation was observed between the pore volume fraction (%) detected by CT and the loss rate and damping values obtained by IET. Samples with higher porosity exhibited increased energy dissipation, reflected in higher loss rate and damping values. The study also highlighted the influence of measurement parameters and sample geometry on reproducibility, indicating that, although the correlation between CT and IET is significant, achieving perfectly reproducible results remains challenging.

Keywords: AM, EBM, X-ray computed tomography, Impulse excitation technique, Ti-6Al-4V

DEVELOPMENT OF AN HIGHLY-CUSTOMIZABLE ARCHITECTURE SLICER FOR ELECTRON BEAM MELTING (EBM)

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ABSTRACT

This study details the development of a specialized slicing software for Electron Beam Melting (EBM) additive manufacturing. The software addresses the critical need for customizable scan strategies in EBM by integrating high-level geometric processing with low-level machine instruction generation. Utilizing a multi-threaded Python architecture, the slicer converts STL geometries into machine-readable OpenBeamProtocol (OBP) [1] instructions. Key features include a modular parameter generation system and a visualization interface developed with PySide6. The study demonstrates the software's ability to manage complex regional and linear fill strategies while optimizing beam parameters for precision and speed. The architecture ensures high customizability by allowing the seamless integration of parameters derived from previously observed [2] or detected scan strategies; this includes the ability to easily implement new experimental strategies by adjusting variables related to line length, return-point effects during beam reversals, and specific regional geometric characteristics.

Keywords: EBM, Slicing Software, Island Hatching, Additive Manufacturing, OpenMelt

DESIGN CRITERIA TO REDUCE THE WARPAGE IN LASER POWDER BED FUSION

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ABSTRACT

Warpage is a significant challenge in Laser Powder Bed Fusion due to rapid thermal cycling and non-uniform heat distribution, which result in unbalanced shrinkage and geometric inaccuracies. In this study, a set of design rules is derived from the literature and practical experience, and their effectiveness in controlling warpage and ensuring dimensional accuracy is evaluated through both numerical simulations and experimental measurements. The results indicate that warpage mitigation should be addressed throughout the entire manufacturing workflow, from the part design stage to post-processing. Furthermore, the findings demonstrate that adherence to these design rules enables to minimize distortions, reduce warpage effectively, optimize the use of support structures, and improve geometric accuracy through the application of process simulations.

Keywords: Additive Manufacturing, Laser Powder Bed Fusion, Warpage, Residual Stress, Design for Additive Manufacturing

INVESTIGATING THE ROLE OF SCANNING STRATEGIES ON POROSITY FORMATION AND MITIGATION IN STITCH REGIONS VIA THERMAL MODELING AND X-RAY CT

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ABSTRACT

Overlapping regions in Laser-Beam Powder Bed Fusion (PBF-LB) are prone to porosity formation. This study introduces a continuous parametric scanning strategy specifically designed to minimize porosity in these zones. Utilizing a unified parametric modelling framework, the proposed approach integrates adaptive scan-path generation with thermal simulation. The strategy was evaluated using transient thermal analysis and validated by multi-scale X-ray CT. Results demonstrate that enhancing cooling-rate uniformity effectively reduces porosity, while different scanning strategies yield distinct pore morphologies characterized by variations in size, shape, and distribution.

Keywords: Scanning strategies, Laser beam powder bed fusion, Porosity, X-Ray CT, Transient thermal analysis

HIGH-PERFORMANCE THERMOPLASTICS OBTAINED BY FUSED FILAMENT FABRICATION FOR POWER TRANSFORMERS INSULATING COMPONENTS: ESTER COMPATIBILITY AND DIELECTRIC BREAKDOWN ASSESSMENT

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ABSTRACT

Additive manufacturing has emerged as a promising approach for producing customized insulating components for power transformers. This study investigates the suitability of high-performance polymers for power transformer insulation components, with a focus on ester compatibility and dielectric strength. Six materials (PEKK-C, PPSU, PSU, PEI, and two grades of TPI) were printed using fused filament fabrication under optimized printing parameters. Samples were aged in natural ester to evaluate polymer–ester compatibility through physical, chemical, and dissolved gas analyses. Dielectric breakdown strength was subsequently assessed. Apart from PEKK-C and TPI2, the polymers showed some properties that suggest they may have some effect on the ester. Variations in water content, acidity, and disruptive tension were observed depending on the material. Dielectric breakdown results exceeded 19 kV/mm for all polymers, meeting the requirements for distribution transformers. Meanwhile, one TPI grade achieved nearly 40 kV/mm, approaching the requirements of shell-type transformers. The results demonstrate the potential of additively manufactured high-performance polymers for transformer insulation, while highlighting the importance of material selection and process optimization for high-voltage applications.

Keywords: Additive Manufacturing, Fused Filament Fabrication, Ester compatibility, Dielectric Breakdown, Power Transformers

MICROSTRUCTURAL AND MECHANICAL CONTROL OF TI6AL4V VIA INTEGRATED DIODE POINT MELTING AND DYNAMIC LASER ASSISTED HEATING

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ABSTRACT

Laser Powder Bed Fusion (LPBF) of Ti6Al4V is inherently limited by steep thermal gradients, leading to martensitic microstructures, residual stresses, and anisotropic mechanical behaviour. To address these limitations, this study investigates the integration of Diode Point Melting (DPM) with Dynamic Laser Assisted Heating (DLAH) in laser powder bed fusion, with a focus on thermal management, microstructural evolution, and mechanical response. A multi-laser system employing low-power 450 nm diode emitters was utilised, where DPM enabled localised melting while DLAH provided controlled in-situ pre- and post-heating during layer deposition. Multi-layer Ti6Al4V specimens were fabricated under varying laser heating temperatures, and their relative density, surface roughness, grain morphology, and mechanical properties. The results demonstrate that the introduction of DLAH significantly enhances process stability in multi-layer builds, achieving relative densities exceeding 99.5% while reducing surface roughness compared to non-heated DPM conditions. Mechanical characterisation shows a balanced improvement in ductility and elastic modulus with only a marginal reduction in ultimate tensile strength, indicating effective mitigation of excessive martensitic hardening.

Keywords: Diode Point Melting (DPM); Dynamic Laser Assisted Heating (DLAH); Ti6Al4V; Thermal gradient control

STRUCTURAL OPTIMIZATION FOR AM IN PRESENCE OF INTERMITTENT LOADS IN MULTIPLE APPLICATION POINTS

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ABSTRACT

This study develops a redesign methodology for a shaft of sequential gearboxes, comparing multiple loading scenarios through topology optimization (TO) followed by parametric refinement and multi-objective analysis. The mechanism transforms rotational input from the shifter into axial displacement across sixteen uncoupled shifting sequences (six speed configuration including neutral/reverse and locking states), making the single critical load-case optimization impractical due to position-dependent stress distributions. A multi-step finite element model with sixteen load increments simulates these conditions, applying forces with respect to each step of the simulation, aiming to maximize the structural stiffness under a 60% mass target with 17-4PH steel suited for additive manufacturing (AM). The emergent topology, characterized by cyclically symmetric crossing-rod "X" junctions, informs a further parametric reconstruction employing helical bands (thickness range 0.5-2.5 mm). Script-driven grid-search finite element automation assesses torsional stiffness under 100 Nm loading. Optimized variants realize 21-39% mass savings relative to the 0.898 kg original, attaining 8721 Nm/rad stiffness at 0.705 kg, achieving the established lightweight benchmark.

Keywords: lightweight design, automotive, additive manufacturing, multi-objective optimization, ecodesign.

SUSTAINABLE SOLUTIONS FOR TITANIUM SUPPLY IN ADDITIVE MANUFACTURING

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ABSTRACT

The value chain of additive manufacturing is a long path from product design to end-user, where supply of raw materials is critical since they are usually extracted in specific countries or regions, and the production processes are extremely energy dependent with a high level of carbon footprint. Titanium is one of the most popular metals recently being used in AM. It is widely used in industries such as aerospace, defense, medical and nuclear in the form of alloys, mainly because of its outstanding corrosion resistance and strength-to-density ratio, the highest of any metallic element. Since standard Titanium manufacturing schemes require the use of carbon as a reducing agent in significant volumes, the development and demonstration of carbon-free titanium production technologies is an urgent issue. Thus, scientific research into the processes of reduction of Titanium raw materials contributes to the choice of effective technological solutions in the development and on-site implementation of appropriate industrial processes. This presentation will be an overlook on the current status of Titanium powder supply chain for AM industry in Euro zone, together with emerging solutions in terms of alternative extraction, processing as well as recycling. Discussions will be based on the outcomes and findings of an EU funded multinational project REPTiS, with a global objective of offering a sustainable and energy efficient solution for responsible extraction and processing of Titanium together with other Primary Raw Materials from strategic partner country Ukraine to supply EU industrial value chains and strategic sectors with a net zero-waste approach within 3 main steps: Ilmenite mining, Titanium & By-products Processing by Velta-Ti Process and Sustainable Product Design.

Keywords: Additive Manufacturing, Critical Raw Materials, Titanium supply,

DESIGNING PROCESS STEPS USING ADDITIVE MANUFACTURING TECHNOLOGIES FOR THE DEVELOPMENT OF DIESEL AND HYDROGEN ENGINE BLOCKS AND CYLINDER HEADS

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ABSTRACT

While electric vehicles are rapidly becoming widespread in passenger cars, it is expected that this trend will continue as quickly in trucks and buses, with diesel engines still being used in these sectors for some time. Although research on electric trucks has been ongoing for many years, and some are slowly moving towards mass production, other countries are working on this technology, and some are even developing and improving other significant advancements in electric engines through their subcontractors. In hydrogen-powered engines, since all parts except cooling systems and coupling systems remain the same, companies prefer this expansion with lower investment. In this study, the development processes of all production steps—starting from the design phase of engine blocks and cylinder heads manufactured from lamellar graphite cast iron, currently operating with diesel fuel and adaptable for future hydrogen applications—will be comprehensively presented. These steps include completing the required analyses, producing prototype castings using 3D sand printers, employing 3D sand printing technologies in pre-series manufacturing, and defining the pathways leading toward mass production. Throughout this journey, Magmasoft filling and solidification simulations will be utilized, residual stresses in the components will be evaluated both virtually and experimentally using the sectioning method, and all remaining process stages will be systematically defined.

Keywords: additive manufacturing, 3d sand printer, casting, engine block, cylinder head

OPTIMIZATION OF LASER POWDER BED FUSION (LPBF) PROCESS PARAMETERS FOR CUCRZR ALLOY USING IN-SITU OPTICAL TOMOGRAPHY DATA

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ABSTRACT

This study aimed to determine the optimum production parameters and characterize the process for CuCrZr alloy parts produced via Laser Powder Bed Fusion (L-PBF). Experimental productions were conducted on an EOS M290 machine equipped with a 400 W laser, using PURESPHERE 11410 CuCrZr powder, 15-45 µm, produced by Sentes-Bir as the feedstock. A total of 29 different parameter sets were tested to manufacture cubic samples with dimensions of 20x20x20 mm. The manufacturing process was simultaneously recorded using the EOS Optical Tomography (OT) system. The densities of the samples were determined by the Archimedes method, and their microstructural and mechanical properties were examined in detail. As a result of the analyses and evaluation of OT data, the optimum parameters yielding a sample with 99.5% relative density were successfully identified. Thus, the effectiveness of in-situ monitoring data in producing high-density CuCrZr parts was demonstrated.

Keywords: LPBF, in-situ monitoring, process optimization, CuCrZr, relative density.

IMPACT OF SLM SCANNING STRATEGIES ON MECHANICAL PERFORMANCE, MACHINABILITY, AND ENVIRONMENTAL FOOTPRINT OF SS316L COMPONENTS

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ABSTRACT

This study unveils how different scanning strategies and orientations in Selective Laser Melting (SLM) dramatically affect the mechanical properties, machinability, and sustainability of stainless-steel components. Using perspectives such as Unidirectional, Island, and Strip patterns at various layer rotations (0°, 45°, 90°), nine samples were fabricated, revealing a notable strain in Ultimate Tensile Strength (400 MPa to 650 MPa) despite identical materials. These variations influence the wear of carbide cutting tools during CNC milling, thereby affecting energy consumption, CO_2 emissions, and the environmental footprint. To evaluate these effects holistically, a cradle-to-gate life cycle assessment was conducted, encompassing SLM fabrication, part removal, and CNC machining with Minimum Quantity Lubrication (MQL). The results offer a comprehensive framework for analyzing surface roughness, tool wear, energy use, and emissions across processing steps, emphasizing how additive manufacturing parameters shape the environmental impact of subsequent subtractive processes. Despite limitations such as the laboratory-scale setting and reliance on secondary data, this research provides vital insights into hybrid manufacturing systems. It highlights the importance of integrating sustainability considerations from design through post-processing to foster more sustainable, high-performance manufacturing solutions.

Keywords: Additive manufacturing, CNC milling, scanning strategies, energy consumption, and carbon emission

LIGHTWEIGHT STRUCTURAL AND END-OF-ARM TOOLING DESIGN FOR HIGH-SPEED IN-MOLD LABELING ROBOTS USING AI-BASED GENERATIVE DESIGN

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ABSTRACT

In Mold Labeling (IML) automation demands robotic systems capable of operating at very high speeds while maintaining precision, repeatability, and reliability. The structural components and end-of-arm tooling (EOAT) of IML robots are critical contributors to system dynamics, cycle time, and overall production efficiency. Conventional designs, typically manufactured by CNC machining, are often constrained by manufacturability considerations rather than optimal functional performance, leading to excessive mass, high inertia, and long cycle times for redesign. This study presents a unified and extended framework that combines artificial-intelligence-powered generative design, finite element–based structural optimization, and hybrid manufacturing strategies for both structural robot components (X–Y axis parts) and IML gripper systems. Two previously independent case studies were merged into a single coherent methodology. Structural parts were optimized through generative design and validated via modal and harmonic analyses. EOAT grippers were redesigned using topology optimization with integrated vacuum channels and manufactured using additive manufacturing–compatible materials. The results demonstrate weight reductions of 20–55%, improved dynamic characteristics, shortened production times, and significant cost savings. The proposed approach highlights the potential of AI driven design and hybrid manufacturing as scalable solutions for next-generation high-speed industrial IML robotics.

Keywords: In Mold Labeling (IML), generative design, additive manufacturing, hybrid manufacturing, robot structural optimization, EOAT

MODELA - A DECISION FRAMEWORK FOR MODULAR- AND DESIGN-ENGINEERING-BASED SELECTIVE AUTOMATION IN 3D CONCRETE PRINTING

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ABSTRACT

Often challenged by fragmented value chains and limited early-stage comparability, leading to technology-driven adoption of 3D concrete printing rather than component- or process-driven evaluation. This paper presents modelA, a decision framework for modular- and design-engineering-based selective Automation in 3D concrete printing. The framework aims to systematically modularize construction processes, adapt component and process design for robotic fabrication, and selectively automate only those subprocesses that provide measurable technical or economic benefits. Building on comparative insights between additive and conventional construction methods, modelA is further developed as a generic decision-making framework. modelA is structured as a sequential workflow integrating decision filters on process structure, technical feasibility, and economic performance. Its applicability is demonstrated and validated through a case study on a slotted foundation.

Keywords: 3D Concrete Printing, selective Automation, Decision Framework, Modular Engineering, Design Engineering

PRESSURE DROP EVALUATION OF DIFFERENT FIN DESIGN FOR A COLD PLATE PRODUCED WITH ADDITIVE MANUFACTURING

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ABSTRACT

In this study, the fin details of liquid cold plates, widely used in practice and increasingly so in recent years, featuring different fin patterns, were investigated using computational fluid dynamics techniques. The fin design plays a direct role in conduction and convection heat transfer in cooling electronics, which have very high heat fluxes. The fin types examined in this study include straight rectangular, short and slit rectangular, staggered, wavy, square pin fins, twisted fins and teardrop fins. The aim here is to test whether various fins can be manufactured using additive manufacturing techniques. Furthermore, in a subsequent study, a test setup will be established using relevant data, and flow tests will be conducted to technically investigate the effect of high surface roughness values achieved with SLM (Selective Laser Melting) additive manufacturing on pressure drop, creating a database. The first phase of this study includes design, analysis, and fabrication processes, and the significant engineering work carried out during this process will be discussed in the article.

Keywords: Cold Plate, Fin Design, Additive Manufacturing, Pressure Drop, Electronic Cooling

EFFECTS OF GEOMETRIC COMPENSATION ON ELECTROMAGNETIC LOSSES IN ADDITIVELY MANUFACTURED WAVEGUIDES

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ABSTRACT

Additive manufacturing (AM) enables the production of complex waveguide geometries but may introduce geometric distortions due to its layer-by-layer process. Since electromagnetic performance is highly sensitive to geometric accuracy, such deviations can increase reflection and transmission losses. This study investigates the effectiveness of geometric compensation, implemented through distortion-informed CAD modifications, to improve the electromagnetic transmission performance of additively manufactured waveguide structures.

Keywords: Additive manufacturing, Waveguide, Geometric compensation, Electromagnetic losses, Distorsion

RF PERFORMANCE OF ADDITIVELY MANUFACTURED ALUMINUM ALLOYS IN KU-BAND ANTENNA APPLICATIONS

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ABSTRACT

Additive Manufacturing (AM) provides new opportunities for the fabrication of Radio Frequency (RF) components with complex geometries. In this study, horn antennas were manufactured by Laser Powder Bed Fusion (LPBF) using four different aluminum alloys and compared with a conventionally produced reference antenna. The fabricated antennas were characterized in terms of surface roughness, electrical conductivity, and radiation pattern measurements in the Ku-band frequency range. Differences in material properties among the alloys were observed, while small variations in antenna radiation behavior were also recorded during RF measurements. Despite the significant differences in cost and mechanical properties among the aluminum alloys investigated, only limited variations were observed in their RF radiation performance within the Ku-band frequency range. This study provides experimental data for the comparative evaluation of aluminum alloys in Kuband antenna applications.

Keywords: Powder Bed Fusion, RF Components, Ku-Band, Horn Antenna

AN INDUSTRIAL-GRADE SIMULATION PLATFORM ENABLING ADVANCED MODELLING FOR L-PBF, MBJ DEBINDING, SINTERING, AND HIP

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ABSTRACT

The increasing complexity of powder metallurgy–based additive manufacturing (PM-AM) and Hot Isostatic Pressing (HIP) processes requires predictive tools capable of capturing strongly coupled multi-physics phenomena throughout the manufacturing chain. This work presents an industrial-grade simulation platform for advanced AM process modelling covering Laser Powder Bed Fusion (L-PBF), Metal Binder Jetting (MBJ) debinding and sintering, and HIP processing. The objective is to develop a physics-based digital twin framework to improve process understanding, reducing experimental trials, and enabling reliable process optimisation. The modelling framework is based on first-principles and fully coupled three-dimensional computational fluid dynamics (CFD) and thermo-mechanical simulations. Conservation equations for mass, momentum, energy, radiation, chemical reactions, and material deformation are solved simultaneously to capture melt pool dynamics, thermal gradients, gas flow, binder decomposition, densification, shrinkage, and distortion across AM processing and post-processing stages. Industrial and aerospace-oriented case studies demonstrate partially validated digital twin models for L-PBF optimisation, MBJ debinding and sintering, and coupled thermo-mechanical HIP simulations under extreme temperature and pressure conditions. Comparisons with selected experimental and industrial data show good agreement for key thermal and densification behaviours. The results highlight the potential of the framework to support virtual process optimisation, accelerate qualification, and improve first-time-right manufacturing in powder-based AM and PM-HIP technologies.

Keywords: Advanced modelling; Digital twins; Laser Powder Bed Fusion; Metal Binder Jetting debinding and sintering; Hot Isostatic Pressing

TRIBOLOGICAL PERFORMANCE OF MEX-MANUFACTURED ULTEM 9085 PARTS AFTER POLISHING AND SAND-BLASTING

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ABSTRACT

The production of advanced polymers using additive manufacturing technologies offers significant opportunities for high-performance engineering applications. In this context, ULTEM (PEI) material, which stands out with its high temperature resistance, mechanical strength, and chemical resistance, is increasingly used in functional parts produced by additive manufacturing (MEX) methods based on material extrusion. However, studies on the tribological behavior and surface properties of ULTEM parts produced by the MEX method are limited in the literature. In this study, the wear performance, surface morphology, and surface topology properties of ULTEM samples produced using the MEX method were investigated in detail. Tribological behavior was evaluated through wear tests performed on the samples, and the surfaces were visualized and analyzed after wear. In addition, surface topology parameters were measured to reveal the effects of surface irregularities resulting from layered manufacturing on wear mechanisms. The results obtained show that the surface structure plays a decisive role in the wear performance of ULTEM samples produced by the MEX method. This study contributes to a better understanding of the tribological properties of ULTEM material and provides a unique contribution to the literature regarding the design and use of advanced polymers produced by additive manufacturing.

Keywords: ULTEM (PEI), Material Extrusion, Additive Manufacturing, Surface Characterization, Wear

HYBRID SURFACE TREATMENT OF SLM TOOL STEEL PARTS FOR PLASTIC INJECTION MOLDING: PEENING & NITRIDING

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ABSTRACT

Selective Laser Melting (SLM) enables the production of tool steels with complex internal geometries, such as conformal cooling channels, which significantly enhance thermal management in plastic injection molding. However, as-built SLM parts often exhibit high surface roughness and insufficient mechanical properties for industrial use. This study investigates a hybrid post-processing route—combining shot peening (SP) and nitriding to optimize the surface integrity of SLM-fabricated maraging and stainless steels. The methodology involves a multi-step optimization of SP parameters (shot angle, duration, and media diameter) to reduce surface roughness, applied only to the open mold surfaces in contact with the plastic material, while internal or closed channels are excluded from the treatment. This is followed by heat treatment and nitriding cycles to enhance hardness and impact resistance. Initial results indicate that the hybrid approach successfully bridges the gap between additive manufacturing flexibility and the stringent surface requirements of the molding industry. The proposed hybrid route demonstrates that surface quality and hardness requirements can be met through controlled sequencing of established post-processing steps rather than additional machining. This enables scalable integration of SLM tooling into existing production lines while maintaining consistent surface and mechanical performance.

Keywords: SLM, Maraging Steel, Stainless Steel, Shot Peening, Nitriding, Surface Integrity.

EXPERIMENTAL COMPARISON OF DAMPING PERFORMANCE IN ADDITIVELY MANUFACTURED PARTICLE DAMPER

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ABSTRACT

According to recent literature studies, volume cells containing unfused powder produced by additive manufacturing have been shown to effectively reduce vibration amplitudes around the resonance frequency. In electro-optical systems, mechanical resonance cause image degradation such as image blur and jitter. One common approach to mitigating mechanical resonance is the use of isolation materials; however, adding damping into the electro-optical devices typically requires significant design modifications. This study investigates an alternative damping enhancement approach that does not require any change to the original structural design. By utilizing unfused powder within additively manufactured structures, damping is increased and resonance severity is reduced while preserving the same external geometry. To evaluate this approach, fused and unfused test samples with identical dimensions were manufactured using additive manufacturing techniques and experimentally tested under vibration loading. The damping performances of the samples were compared to demonstrate the effectiveness of unfused powder as a passive damping mechanism

Keywords: Unfused Powder, Particle Damping, Additive Manufacturing, Vibration

MECHANICAL CHARACTERIZATION OF TIB2-REINFORCED ALUMINUM METAL MATRIX COMPOSITE PRODUCED BY LASER POWDER BED FUSION

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ABSTRACT

Additive Manufacturing technologies enable the production of innovative materials and complex geometries. Metal matrix composites (MMC) have increasingly been adopted in additive manufacturing processes due to their advantages of enhanced mechanical properties and high corrosion resistance. This study investigates the influence of varying TiB2 content in AlSi10Mg, which commonly used in aerospace applications via Laser-Powder Bed Fusion (L-PBF). Following the determining reinforcement content and mixing parameters, the TiB2 powders were uniformly combined with Aluminum powders using Resonant Acoustic Mixer (RAM), resulting in a homogenous mixture without agglomeration. Various specimens were fabricated using composite powder followed by stressrelief heat treatment. Tensile, wear and hardness tests were conducted and all test results were thoroughly evaluated to define influence of varying reinforcement content on the outcomes. All test results were thoroughly evaluated and the influence of varying reinforcement content on the outcomes was analyzed. Furthermore, several potential avenues for future research were identified.

Keywords: Additive manufacturing (AM), Metal matrix composites (MMC), Reinforcement, Laser Powder Bed Fusion (L-PBF), Resonant Acoustic Mixing (RAM)

SHAPE MEMORY EFFECT IN AS-BUILT FE–30MN–6SI ALLOY PRODUCED BY LASER POWDER BED FUSION

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ABSTRACT

This study investigates the as-built microstructure and shape memory response of Fe–Mn–Si specimens fabricated by laser powder bed fusion (PBF-LB/M). Microstructural features were characterized by optical microscopy and scanning electron microscopy, and the shape memory response was assessed by cyclic compression (loading–unloading) followed by controlled recovery heating in a furnace. The asbuilt microstructure showed clearly defined melt-pool boundaries and no obvious porosity or cracking in the inspected areas. The findings demonstrate that PBF-LB/M-fabricated Fe–Mn–Si can exhibit a robust shape memory response directly in the as-built condition, without any post-build heat treatment.

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

ADVANCED SLA ADDITIVE MANUFACTURING OF SI3N4 STRUCTURAL COMPONENTS: OVERCOMING THERMOMECHANICAL CHALLENGES IN LARGE-SCALE CERAMIC FABRICATION

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ABSTRACT

Stereolithography (SLA) 3D printing has emerged as a premier technique for producing technical ceramic parts, transitioning from a prototyping tool to a standard industrial shaping process. As the demand for complex, large-scale components grows—particularly within the aerospace, defence, and space sectors—new challenges arise regarding material behaviour and process stability. This presentation explores the technical requirements for successfully printing large-dimension parts using advanced materials such as Silicon Nitride (Si3N4), a material of increasing importance due to its high-performance properties.

The Challenge of Scale and Geometry

The production of large ceramic parts with highly variable cross-sections requires a mastery of the entire manufacturing chain. Achieving structural integrity remains a significant hurdle; specifically, ensuring that large-scale parts undergo de-binding and sintering without cracks or deformations. Success in this area is heavily dependent on:

- Hardware Capabilities: Utilizing printing platforms with large build volumes (such as the C1000 FLEXMATIC) that are designed to handle the specific rheology of ceramic slurries.

- Material Printability: Refining slurry formulations to ensure consistency across large surface areas.

Process Intelligence and Industrialization

To move beyond prototyping toward repeatable series production, the integration of Artificial Intelligence (AI) and automation is essential. We identify AI as a "process intelligence layer" that assists in:

- Parameter Optimization: Real-time adjustments based on in-situ data to manage material behaviour during the build.

- Repeatability: Reducing human-induced variability and waste through structured workflows—from preparation to post-processing.

By combining large-format SLA technology with AI-driven process control, it is now possible to manufacture robust, high-performance nitride components that meet the rigorous standards of the defence and aerospace industries.

Keywords: Silicon nitride, ceramics, additive manufacturing, artificial intelligence, 3d printing

INVESTIGATION OF MECHANICAL PROPERTIES OF ALUMINA COUPONS PRODUCED BY STEREOLITHOGRAPHY METHOD AND COMPARISON WITH TRADITIONAL METHOD

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ABSTRACT

Additive Manufacturing (AM) transforms digital CAD models into physical objects through layer-wise deposition. In the ceramic sector, AM is increasingly pivotal due to its capacity for complex geometries and rapid prototyping. Stereolithography (SLA), a prominent AM technique, utilizes laser-induced photopolymerization to solidify liquid resin, offering superior dimensional precision. This study evaluates the structural integrity of alumina coupons produced via SLA compared to those manufactured through traditional isostatic powder pressing. The objective is to analyze the evolution of elastic properties and mechanical performance both at ambient conditions and following severe thermal shock. Experimental characterization involves the Archimedes method for densification, Impulse Excitation for determining Young's Modulus, and 4-point bending tests to quantify flexural strength. By comparing these disparate manufacturing routes, the project assesses how additive processing influences damage tolerance and microstructural stability, providing critical insights into the reliability of 3D-printed ceramics in extreme environments.

Keywords: Ceramics, Addictive Manufacturing, Stereolithography, 4-point bending, Impulse excitation technique, Alumina, Powder Pressing

EXPERIMENTAL IDENTIFICATION AND VALIDATION OF JOHNSON–COOK STRENGTH AND DAMAGE PARAMETERS FOR SLM-FABRICATED TITANIUM

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ABSTRACT

Additive manufacturing technologies, particularly Selective Laser Melting (SLM), enable the production of titanium components with complex geometries for aerospace and defense applications. However, the reliable numerical prediction of their mechanical response under extreme loading conditions requires accurate constitutive and damage models that account for strain rate, stress state, and temperature effects. In this study, the Johnson–Cook (JC) strength and damage parameters of SLM-fabricated titanium alloy specimens are systematically identified through a comprehensive experimental campaign and subsequently validated. Quasistatic tensile and compression tests are conducted on specimens with different geometries to achieve varying levels of stress triaxiality, enabling the identification of triaxiality-dependent damage behavior. High strain rate mechanical responses are characterized using Split Hopkinson Pressure Bar (SHPB) tests under both tensile and compressive loading modes. In addition, elevated temperature tests are performed to capture thermal softening effects and to determine temperature-dependent JC parameters over a wide range of strain rates. The obtained experimental data are employed to calibrate the Johnson–Cook constitutive and damage models, including strain hardening, strain rate sensitivity, thermal softening, and failure strain evolution. The calibrated parameters are then implemented into finite element simulations, and experimental–numerical comparisons are performed to validate the predictive capability of the identified model under different loading conditions.

Keywords: Selective Laser Melting; Titanium Alloys; Johnson–Cook Model; Split Hopkinson Pressure Bar; High Strain Rate Behavior; Damage Modeling

FATIGUE STRENGTH OF DIFFERENT DUPLEX SURFACE-TREATED TOOL STEELS PRODUCED BY POWDER BED FUSION ADDITIVE MANUFACTURING TECHNIQUES

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ABSTRACT

This study evaluates the axial fatigue behaviour of additively manufactured tool steels, including Laser Powder Bed Fusion (L-PBF) produced 18Ni-300 and MAR60 maraging steels, and Electron Beam Melting (EBM) produced Vanadis 4 Extra SuperClean cold-work tool steel. The effect of duplex surface treatments consisting of plasma nitriding followed by Plasma-Enhanced Chemical Vapour Deposition (PECVD) Ti(C,N) coating is compared with conventional heat-treated conditions. Particular attention is directed to the influence of bulk hardness, surface hardening, and microstructural features on fatigue performance. The results demonstrate a consistent improvement in fatigue strength for all investigated materials after duplex treatment. This enhancement is attributed to increased surface hardness and the introduction of compressive residual stresses, which promote a shift in fatigue crack initiation from the surface towards the subsurface or bulk material.

Keywords: Laser powder bed fusion, Electron Beam Melting, Tool Steels, Duplex surface treatment, Fatigue strength.

STRESS-RELIEF ANNEALING WINDOW FOR IMPROVED TRIBOLOGICAL PERFORMANCE OF LPBF TI-6AL-4V

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ABSTRACT

Laser powder bed fusion (LPBF) of Ti-6Al-4V enables lightweight, high-performance components, but the alloy's intrinsically poor tribological response (high friction and adhesive wear) can limit service life in load-bearing interfaces. This study maps stress-relief annealing parameters to microstructure, hardness, and dry-sliding wear behavior to define a practical post-processing window. Specimens built under constant LPBF conditions were annealed in vacuum at 600, 700, and 800 °C for 90-180 min (12 conditions). Optical microscopy confirmed progressive decomposition of as-built martensitic alpha-prime into alpha+beta lamellae, with increased beta fraction and lamella coarsening at higher temperature and longer dwell. Hardness improved relative to the as-built state and reached its maximum at 600 °C (about 400-413 HV), whereas the best tribological performance was obtained at 700 °C/120 min, combining stable friction with the minimum wear rate (0.0013 mm3/N·m) at 393 HV. Excessive coarsening at 800 °C increased wear and friction instability. The results provide a process-property guideline for selecting stress-relief schedules when tribological stability is a design driver for LPBF Ti-6Al-4V.

Keywords: Laser powder bed fusion, Ti-6Al-4V, stress-relief annealing, microstructure, wear, tribology

INFLUENCE OF PRE- AND POST-WELD HEAT TREATMENTS ON THE MICROSTRUCTURE AND WELDABILITY OF SLM-FABRICATED TI-6AL-4V

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ABSTRACT

Selective Laser Melting (SLM) of Ti-6Al-4V produces a martensitic α' microstructure that limits weldability. In this study, alternative pre- and post-weld heat treatments were applied to SLM-fabricated plates produced using a Nikon SLM 500 system to achieve microstructural modification comparable to Hot Isostatic Pressing (HIP). Microstructure, hardness, and fracture behavior were evaluated after laser welding. The results show that appropriate heat treatments transform α' martensite into a lamellar α+β structure, leading to improved microstructural homogeneity, reduced hardness gradients, and enhanced weldability. These findings demonstrate that conventional heat treatments can serve as practical alternatives to HIP when size or cost constraints exist.

Keywords: Selective Laser Melting, Ti-6Al-4V, Heat Treatment, Weldability, Microstructure, Laser Welding

INVESTIGATION OF HIP TREATMENT EFFECTS ON THE MECHANICAL BEHAVIOR OF TI-6AL-4V LATTICE STRUCTURES

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ABSTRACT

Additive manufacturing is an important production method for fabricating high-performance lightweight lattice structures from Ti-6Al-4V material. However, the widespread production of this alloy using the LPBF method is limited by process-induced defects such as porosity, lack of fusion, and high residual stresses, which adversely affect mechanical performance. In this study, tensile and compression specimens with BCC and fluorite lattice structures, designed using the nTopology software, were fabricated using Tekna Ti-6Al-4V powders on a Nikon SLM 280 HL machine. This study investigates the mechanical properties of LPBF-fabricated Ti-6Al-4V lattice structures under tensile and compressive loading and highlights the effect of HIP heat treatment on these properties. Compression test results show that HIP treatment increased compressive strength by approximately 80% and the energy absorption capacity by approximately 210% for BCC lattice structure. In addition, the tensile test results indicate that HIP treatment did not cause a significant change in tensile strength. However, the BCC and fluorite lattices exhibited nearly a three- to four-fold increase in elongation at break. These results indicate that HIP heat treatment improves the stability of fracture behavior. HIP treatment markedly enhanced the ductility and energy absorption of the test specimens, emphasizing the role of α+β lamellar microstructure formation and defect mitigation via HIP in LPBF-produced Ti-6Al-4V. In future work, various lattice structures will be added, and the influence of annealing treatment as an alternative to HIP on the test outcomes will be examined.

Keywords: Ti-6Al-4V; hot isostatic pressing; tensile testing; compressive testing; energy absorption.

EFFECT OF THE WAAM PARAMETERS AND SUBSTRATE THICKNESS ON THE GEOMETRY AND HARDNESS OF 316L STAINLESS STEEL

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ABSTRACT

This study investigates effects of process parameters and substrate thickness on the geometrical quality and hardness profile of 316L stainless steel (SS) structures produced by WAAM using the Cold Metal Transfer (CMT) process. A systematical series of single weld bead deposition were performed using a central composite design (CCD) as a design of experiment, varying the wire feed (Wf), and welding speed, which are key factors affecting cooling rate. Using response surface methodology (RSM), a process window was developed that establishes correlations between WAAM parameters, and their effects on weld bead geometry and hardness facilitating their investigation for additive manufacturing (AM). In addition to the process parameters of Wf and welding speed, the influence of different substrate thicknesses on weld bead geometry and hardness was also investigated.

Keywords: WAAM, Stainless Steel, 316L, Optimization, Hardness

PROCESS DEVELOPMENT OF H13 WIRE FOR DED-LB/W WITH COAXIAL WIRE FEED

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ABSTRACT

Laser-based Directed Energy Deposition with wire (DED-LB/w) offers efficient material use and clean feed handling for tooling repair, feature build-up and additive manufacturing. Yet H13 hot-work tool steel remains difficult to process due to cracking and dilution. This study establishes a practical process window for H13 wire using a coaxial feed, enabling flexible deposition strategies for complex molds. Single- and multi-track beads were deposited on 316L stainless steel and H13 substrates while varying laser power, travel speed, wire feed rate, and deposition angle. Process response was assessed through wire capture, bead morphology, and stability; metallographic cross-sections characterized fusion, dilution interfaces, and microstructure; hardness testing quantified property gradients. The selected window produced stable, repeatable bead geometry on both substrates, with sound fusion and coherent bonding. Dilution was controlled by synchronized energy input and feed, minimizing spatter and promoting consistent wetting. Hardness increased markedly in deposited H13 relative to substrates, from 205 HV1 in 316L to 540 HV1 in the first H13 layer and 605 HV1 in the second. These results demonstrate the feasibility of coaxial H13 wire DED-LB/w for mold and die repair and build-up.

Keywords: DED-LB/w, die repair, coaxial wire feeding, H13 tool steel, process development

IN-SITU DEFECT DETECTION AND PROCESS TRACEABILITY IN WIRE ARC ADDITIVE MANUFACTURING

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ABSTRACT

Wire Arc Additive Manufacturing (WAAM) is increasingly adopted for the production of large-scale metal components; however, ensuring consistent quality requires effective control of its welding-based deposition process. This study presents an approach centered on in-situ defect recognition through real-time process monitoring, supported by non-destructive testing (NDT) for validation. The objectiveis to demonstrate how continuous acquisition and evaluation of critical process parameters enable early detection of abnormal conditions and enhance process traceability. WAAM components manufactured from titanium alloys and stainless steels were monitored by recording parameters such as welding current, voltage, wire feed speed, travel speed, interpass temperature, and torch positioning. Deviations from predefined process windows triggered real time warnings via a control panel, allowing timely operator intervention. Radiographic and liquid penetrant testing were subsequently applied to confirm the correlation between in situ detected anomalies and actual internal or surface defects. The results show that proactive process monitoring significantly reduces reliance on post-process inspection alone and enables effective root-cause analysis at the layer level. The study confirms that integrating in-situ defect recognition with controlled parameter management is a key enabler for achieving high quality, traceability, and industrial reliability in WAAM.

Keywords: WAAM, Process Monitoring, NDT, Defect Recognition, Process Control

COMPARATIVE MECHANICAL PERFORMANCE OF WAAM-FABRICATED AL 6061-RAM2 AND AL 6063 ALLOYS UNDER DIFFERENT HEAT TREATMENT CONDITIONS

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ABSTRACT

Wire Arc Additive Manufacturing (WAAM) enables the fabrication of large aluminum structures; however, alloy selection and post-processing strongly affect mechanical performance. In this study, WAAM-fabricated Al 6061- RAM2 and Al 6063 walls were comparatively evaluated. Process parameters were optimized using a Fronius TPS 500i CMT system, employing a hybrid strategy of Pulse Multi Control (PMC) for initial layer penetration and Cold Metal Transfer (CMT) for subsequent layers to minimize heat accumulation and porosity. X-ray inspection was used to identify defect-free regions, from which horizontal and vertical tensile coupons were extracted. Mechanical testing was conducted in the as-built condition, after only aging, and after solution + aging heat treatment in accordance with AMS 2770. In the as-built condition, Al 6061-RAM2 exhibited approximately 60– 70% higher yield and tensile strength than Al 6063. After solution + aging, the strength advantage of Al 6061- RAM2 remained significant, with 25–30% higher yield strength and 20–25% higher tensile strength, while anisotropy between horizontal and vertical directions was reduced to below 5%. The superior performance of Al 6061-RAM2 is attributed to its filler wire chemistry and enhanced precipitation hardening response under WAAM thermal cycles and different heat treatment conditions.

Keywords: Wire Arc Additive Manufacturing (WAAM), Aluminum alloys, Al 6061-RAM2, Heat treatment.

ADDITIVE MANUFACTURING OF CARBON FIBER–EPOXY COMPOSITES VIA FREEFORM REVERSIBLE EMBEDDING: EFFECTS OF INTERFACIAL ENGINEERING

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ABSTRACT

Freeform Reversible Embedding (FRE) is an advanced additive manufacturing strategy that utilizes a yield-stress gel bath to support extruded liquids, thereby enabling the printing of materials with extended curing times, such as thermosetting polymers. This support medium is critical for maintaining structural integrity, preventing collapse or deformation prior to solidification. In this study, we investigated the printability of epoxy-based inks reinforced with varying carbon fiber loadings (2, 4, and 8 wt.%). Mechanical characterization of the FRE-fabricated composites initially revealed significant interfacial incompatibility between the carbon fibers and the epoxy matrix, which compromised the reinforcement efficiency. To address this, a dual-step surface treatment comprising plasma treatment followed by silane activation was applied to the fibers, and its impact on mechanical performance was evaluated. Surface activation led to improved mechanical performance of reinforced composited. In addition, Scanning Electron Microscopy (SEM) fractography was performed on fractured specimens to assess interfacial bonding and identify dominant damage mechanisms including fiber pull-out.

Keywords: Freeform Reversible Embedding, carbon fiber, composites, surface treatment

COMPARATIVE ANALYSIS OF MECHANICAL INTEGRITY AND WEAR BEHAVIOR OF FDM-FABRICATED 15% CF-REINFORCED PLA, TOUGH-PLA, AND PLA MATERIALS IN COMPARISON WITH CAST POLYAMIDE 6

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ABSTRACT

This study demonstrated that manufacturing orientation plays a decisive role in the impact resistance of PLAbased samples produced by the FDM method. At a manufacturing angle of 0°, the highest impact resistance was observed in Tough-PLA samples (9 kJ/m^2), followed by PLA with 15% carbon fiber reinforcement (6.5 kJ/m^2) and pure PLA (3 kJ/m^2), respectively. Increasing the manufacturing angle to 90° reduced the impact resistance by 50-65% in all FDM samples, exhibiting significant anisotropic behavior. Notably, cast polyamide 6 samples showed a stable impact resistance of 12 kJ/m^2, regardless of manufacturing orientation. Wear tests also support this performance difference; the highest wear was observed in Tough-PLA (1300 µm), while the highest wear resistance was recorded in cast polyamide 6 samples (400 µm). The data obtained demonstrates the high sensitivity of the mechanical reliability of parts produced with FDM to the production parameters.

Keywords: Fused Deposition Modeling, 15% CF-reinforced PLA, Tough-PLA, Cast polyamide 6, Impact behavior, Wear resistance

INVESTIGATION OF THE EFFECT OF CURING PARAMETERS ON DLP PRINTING RESINS

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ABSTRACT

Digital Light Processing (DLP) resins are widely used in high-precision additive manufacturing, where curing behavior strongly affects the mechanical performance of printed parts. In this study, the influence of curing parameters and formulation composition on the curing kinetics of DLP photopolymer resins was systematically investigated. Resin formulations based on urethane acrylate (UA) and urethane dimethacrylate (UDMA) were evaluated using a design of experiments (DoE) approach. Photo-DSC was used to analyze curing behavior under different light intensity and exposure conditions, while TGA was employed to evaluate the thermal stability of the resin formulations. The results show that light intensity is the dominant parameter controlling curing kinetics, while post-exposure time and UDMA content significantly influence mechanical performance. These findings highlight the importance of optimizing both curing conditions and resin formulation in DLP-based additive manufacturing.

Keywords: Digital Light Processing (DLP); UV-curable photopolymer resins; curing parameters; Photo-DSC; mechanical performance; additive manufacturing

MECHANICAL CHARACTERIZATION OF PETG/TPU BLENDS FOR 3D PRINT APPLICATIONS

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ABSTRACT

The industrial viability of Material Extrusion (MEX) technology is inextricably linked to the mechanical performance and processability of the constituent materials. While Polyethylene Terephthalate Glycol (PETG) is recognized for its high strength and ease of processing, Thermoplastic Polyurethane (TPU) provides exceptional flexibility and energy damping capacity. However, the standalone application of these polymers often falls short in specific engineering contexts—either due to the inherent brittleness of PETG under impact loads or the printability challenges of TPU arising from its insufficient rigidity. This study presents the development of PETG/TPU blends at various ratios via melt blending, aimed at synergizing the structural rigidity of PETG with the elasticity of TPU. Within the scope of the research, pure PETG, pure TPU, and blends containing 25%, 50%, and 75% TPU by volume were formulated into filaments and subsequently utilized to fabricate test specimens via MEX. The mechanical characterization of both the raw filaments and 3D printed components was conducted through tensile testing. The findings reveal that increasing the TPU volume fraction significantly enhances material ductility and elongation at break, albeit at the expense of elastic modulus and tensile strength. Furthermore, a discrepancy was observed between the mechanical values of specimens produced via MEX and their filament counterparts, attributed to interlayer voids and fusion defects inherent to the additive manufacturing process. Notably, the 25 vol% TPU blends demonstrated an optimal balance between rigidity and flexibility, effectively mitigating the brittle fracture behavior of PETG while maintaining excellent printability. This research quantifies the performance gap between raw materials and final products, underscoring the potential of PETG/TPU composites in advancing MEX applications.

Keywords: Material Extrusion (MEX), PETG/TPU Blends, Polymer Blending, Mechanical Properties, Additive Manufacturing.

CONTROL OF GRAIN STRUCTURE IN ARC DIRECTED ENERGY DEPOSITION (ARC/W) OF TITANIUM ALLOYS: THE INFLUENCE OF NOVEL ALLOYING ELEMENTS AND REFINERS

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ABSTRACT

This study investigates the grain refinement strategies for Ti6Al4V Grade 5 alloys produced via Wire Arc Directed Energy Deposition (DED-Arc/W) to overcome the challenge of coarse dendritic structures. Within the scope of the project, the effects of various alloying elements (Fe, Ni, Cu) and ceramic grain refiners (TiB2) on microstructural evolution were analyzed using experimental validation. Findings indicate that specific alloy compositions combined with nanoparticle additions effectively constrain beta grain growth leading to a more homogenized and fine grain microstructure. These results provide a strategic foundation for enhancing the mechanical performance and qualification of additively manufactured aerospace components.

Keywords: Directed Energy Deposition, Ti6Al4V, Grain Refinement, Alloy Design, Microstructure

FABRICATING SKELETON STRUCTURES USING ROBOTIC WAAM SYSTEM

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ABSTRACT

Wire Arc Additive Manufacturing (WAAM) has established itself as a primary technology for large-scale industrial fabrication, predominantly favored for its high material deposition rates and cost-effectiveness compared to powder-bed alternatives. Although traditional WAAM workflows typically rely on conventional planar slicing algorithms, these methods often struggle with the geometric constraints of non-solid, skeleton-like topologies. To address these limitations, this study introduces a novel vectorial path generation framework specifically designed for the automated production of complex wireframe structures. The developed methodology shifts from traditional horizontal layering to a vector-based deposition approach, allowing toolpath trajectories to align precisely with the structural topology of the workpiece. This integration, implemented within a robotic environment, enables a more flexible and adaptive manufacturing process that minimizes the need for support structures. By utilizing line vectors instead of discrete horizontally aligned points, the proposed vectorial approach generates continuous welding paths, thereby reducing robotic travel time and enhancing deposition accuracy compared to traditional horizontal slicing methods. Ultimately, the results demonstrate that the integrated robotic WAAM system provides a versatile and robust framework for the efficient

Keywords: Wire Arc Additive Manufacturing, Gas Metal Arc Welding, Slicing, Robotic Manufacturing

INVESTIGATION OF HIGH-TEMPERATURE MECHANICAL PROPERTIES OF INCONEL 718 MANUFACTURED BY LP-DED METHOD

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ABSTRACT

Laser Powder Directed Energy Deposition (LP-DED) is a promising additive manufacturing technique for the fabrication of large-scale, high-performance components in defense and aerospace industries. In this study, Inconel 718 (IN718) specimens were fabricated using an LP-DED system and subjected to different heat treatment combinations, including homogenization, solution heat treatment, and double aging. Room-temperature tensile properties were evaluated for both horizontal and vertical specimens to assess the influence of build orientation and heat treatment. Based on the obtained results, the optimum heat treatment condition will be determined. Subsequently, high-temperature tensile tests will be performed on vertically built specimens, which generally exhibit lower mechanical strength due to build-direction-induced anisotropy. The results provide insight into the mechanical performance of LP-DED-fabricated IN718 and its suitability for large-scale defense and aerospace applications.

Keywords: IN718, LP-DED, High-Temperature Mechanical Properties, Heat Treatment, Homogenization

SIMULATION AND EXPERIMENTAL VALIDATION OF POROSITY DEFECTS IN LASER POWDER BED FUSION OF TI-6AL-4V

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ABSTRACT

Laser Powder Bed Fusion (L-PBF) is an additive manufacturing technique that selectively melts metal powder with a high-power laser, building parts layer by layer. Its high geometric precision and material efficiency make it a preferred choice for aerospace industry for complex and lightweight components. Nonetheless, the intricate melting and solidification dynamics often generate porosity defects, which degrades mechanical performance and structural reliability. This study investigates the formation mechanisms of porosity in Ti-6Al-4V alloy fabricated by L-PBF, validates observed porosity types, and models the defects through process simulations. Dominant processing parameters were selected and experimental design was employed to produce specimens on an L-PBF system. The manufactured specimens were then scanned using computed tomography (CT) to analyze the size, shape, location, and volumetric distribution of porosities in three dimensions. Subsequently process parameters were fed to a commercial simulation tool to numerically reproduce the defects. Comparative analysis of experimental and simulated results revealed correlations and evaluated effect of process parameters on porosity formation. The findings support L-PBF parameter optimization and aim to enhance part quality. Implementation of these insights can substantially reduce defect rates in additively manufacturing of parts.

Keywords: Optical imaging, defect formation, analytical modeling, energy density, parameter window

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DETERMINATION OF THE PRINTABILITY PARAMETER WINDOW IN PULSED LASER MELTING ADDITIVE MANUFACTURING OF INCONEL 718 POWDER

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ABSTRACT

Additive manufacturing enables the fabrication of complex geometries with high mechanical performance and is widely used in aerospace, defense, and energy sectors. Pulsed laser melting–based metal additive manufacturing provides enhanced control over laser–material interaction, improving microstructure, surface quality, and part performance, while the nonlinear coupling of process parameters makes experimental process window identification costly. Inconel 718 is widely applied in high-temperature environments due to its excellent mechanical strength and oxidation resistance yet its high melting temperature and narrow processing window pose challenges for additive manufacturing. In this study, a Computational Fluid Dynamics (CFD)-based approach was employed to determine the printability parameter window of Inconel 718 powder in a pulsed laser melting process. Powder size distribution measured using a Camsizer X2 particle analyzer was used as realistic input for simulations conducted with FLOW-3D AM software. Powder spreading, laser–powder interaction and melt pool dynamics were modeled using a single-track approach. Pulse durations of 50–80 μs and laser powers of 125–200 W were investigated. Melt pool depth, layer thickness, and stability were quantitatively analyzed, enabling numerical identification of a feasible process window and demonstrating the potential of CFD simulations to reduce experimental effort and support process optimization.

Keywords: Pulsed laser melting, Inconel 718, Powder Bed Fusion, CFD simulation, Melt pool dynamics

BRIDGING ACTIVE COOLING AND LATENT HEAT STORAGE: THE CRITICAL ROLE OF ADDITIVE MANUFACTURED LATTICE TOPOLOGIES IN HYBRID THERMAL MANAGEMENT

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ABSTRACT

Additive manufacturing (AM) enables the fabrication of complex lattice structures that can significantly enhance heat dissipation when integrated with phase change materials (PCMs). In this study, the thermal performance of PCM-enhanced additively manufactured lattice heat spreaders under active cooling conditions is experimentally investigated. Test specimens were fabricated from AlSi10Mg using three lattice topologies—Body-Centered Cubic (BCC), Octet, and Kelvin—with porosity level of 0.85. A single PCM (RT-70HC) was incorporated into lattice structures to provide latent heat storage. The experimental setup consists of a liquid-cooled cold plate providing active cooling from the bottom surface, while uniform heat loads of 60 W and 90 W are applied from the top using a 50 mm × 50 mm heater. This configuration allows the assessment of temperature stabilization and spatial temperature uniformity under simultaneous heat input and active cooling. The results demonstrate that PCM-integrated lattice heat spreaders can maintain a nearly constant and homogeneous surface temperature during operation. Furthermore, lattice topology and porosity significantly affect the thermal response, with distinct differences observed among BCC, Octet, and Kelvin structures. These findings highlight the design flexibility offered by additive manufacturing and its critical role in developing advanced thermal management solutions for high-heat-flux electronic applications.

Keywords: Lattice structures, phase change materials (PCM), active cooling, electronics cooling, additive manufacturing

EXPERIMENTAL COMPARISON OF THERMAL AND HYDRAULIC PERFORMANCE BETWEEN CONVENTIONAL AND ADDITIVELY MANUFACTURED COLD PLATES

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ABSTRACT

Efficient thermal management is crucial for the reliability of high-power electronics. This study experimentally compares the thermal and hydraulic performance of conventional and additively manufactured gyroid and lattice cold plates. The primary objective is to evaluate the trade-offs between heat transfer enhancement and hydraulic resistance in complex geometries. An experimental setup was established to test the cold plates under various flow rates. During the tests, wall temperatures, inlet-outlet fluid temperature, and pressure drops were measured simultaneously to determine Nusselt numbers, thermal resistances, and friction factors. The findings reveal that the gyroid and lattice structure cold plates offer superior heat transfer performance compared to the conventional design due to their continuous surface area and fluid mixing capabilities, albeit with a concomitant increase in pressure drop. The study concludes by identifying the most effective channel geometry based on a combined thermal-hydraulic performance evaluation, demonstrating the potential of additive manufacturing in developing compact, high-efficiency cooling solutions for advanced electronic systems.

Keywords: Cold plate, Additive Manufacturing, Thermal Management, Experimental Analysis, Thermal Performance.

TOPOLOGY OPTIMIZATION OF A LOAD-CARRYING ELEMENT FOR MASS REDUCTION AND IMPROVED DYNAMIC PERFORMANCE

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ABSTRACT

Topology optimization is a high-level design methodology that refines structural layouts by iteratively removing material from non-essential regions, as identified through finite-element-based numerical analyses under prescribed loads and boundary conditions. The process yields lighter, stiffer, and performance-efficient components compared with conventional design approaches. Key objectives include minimizing structural mass while maintaining or improving critical attributes such as mechanical strength, stiffness, and load-carrying capacity—particularly vital in aerospace and space systems where mass directly influences fuel consumption, range, payload capability, and overall efficiency. By re-routing load paths, the technique reduces stress concentrations and enhances structural safety, enabling the elimination of superfluous material without compromising reliability. Effective use of topology-optimization software requires explicit definition of design goals (e.g., compliance minimization, mass/volume reduction, stiffness maximization, targeted natural-frequency increase), loading scenarios, and constraint sets. static/dynamic loads, support conditions, and contact interfaces must faithfully represent real-world operating environments. Manufacturability constraints are integrated simultaneously, encompassing minimum wall thickness, symmetry, preservation of non-design regions, and avoidance of thin or disconnected features. For additive manufacturing, additional limits such as overhang angles, build direction, support requirements, and internal void feasibility are enforced to ensure producible geometries.

Keywords: Topology optimization, additive manufacturing, dynamic performance, AlSi10Mg

COMPARISON OF MACHINE LEARNING METHODS FOR FATIGUE LIFE PREDICTION OF ADDITIVELY MANUFACTURED PARTS

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ABSTRACT

The fatigue performance of components fabricated via Laser Powder Bed Fusion (LPBF) is governed by a complex interplay between process parameters specifically laser power and scan speed and resulting microstructural features such as grain size and residual stress. Conventional empirical models often fail to capture the non-linear crack propagation behavior induced by these process-dependent variables. This study presents a comparative assessment of three machine learning frameworks Physics-Informed Neural Networks (PINNs), Generative Adversarial Networks (GANs), and Support Vector Machines (SVMs) for predicting the fatigue crack growth rate (da/dN) of LPBF-manufactured alloys. A unified dataset comprising experimental observations of process inputs, microstructural properties, and fracture mechanics variables (ΔK, R-Ratio) is utilized for model training and evaluation. PINNs embed the Paris-Erdogan law directly into the loss function, ensuring physically consistent predictions even in extrapolation regimes. To address the data scarcity observed at high stress ratios ($R \geq 0.5$), GANs are employed for synthetic data augmentation, enhancing model robustness against class imbalance. SVMs serve as a baseline for benchmarking data-driven performance. The results demonstrate that PINNs achieve superior accuracy (R2 > 0.98) by decoupling the effects of residual stress on crack growth, while GAN-based augmentation significantly reduces prediction error in data-limited high-mean-stress scenarios. This hybrid framework offers a reliable pathway for rapid fatigue life assessment in additive manufacturing.

Keywords: Additive Manufacturing, Machine Learning, PINNs, SVM, GANs

SHRINK-LINE FORMATION IN LPBF: MECHANISM AND NUMERICAL DETECTION

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ABSTRACT

Shrink-line formation is a recurrent defect in laser powder bed fusion (LPBF), particularly at abrupt cross-sectional transitions, degrading surface appearance, dimensional accuracy, and fatigue performance. This work investigates shrink lines in LPBF-built specimens and correlates defect occurrence with layer-to-layer area changes. Experiments show shrink lines localize between successive layers exhibiting substantial areal discontinuities. Thermomechanical finite element simulations predict shrink-line initiation and location when an appropriately refined voxel mesh—selected via mesh convergence—is used, balancing computational efficiency with fidelity to internal thermo-mechanical behavior. The predicted height of the shrink line from the part base matches measurements within a 5% error, demonstrating that process-aware simulation can anticipate defect formation and guide parameter or geometry adjustments to mitigate it.

Keywords: shrink line, laser powder bed fusion, build simulation, area change, defect

OXIDATION BEHAVIOR OF OXIDE DISPERSION STRENGTHENED IN718 PRODUCED BY SELECTIVE LASER MELTING

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ABSTRACT

Inconel 718 (IN718) is a nickel-based superalloy essential for high-temperature applications in turbine engines due to its excellent mechanical properties. However, surface degradation through oxidation at temperatures above 650°C remains a critical concern for long-term structural integrity. This study focuses on the fabrication of an Oxide Dispersion Strengthened (ODS) version of IN718 by incorporating 2 wt.% Yttria (Y2O3) using Selective Laser Melting (SLM). The primary objective is to investigate how the uniform dispersion of Y2O3 nanoparticles influences the formation, growth kinetics, and stability of the protective oxide scale. To evaluate this, isothermal oxidation tests were conducted in an ambient atmospheric furnace at 900°C for 24 hours. The results demonstrate a significant enhancement in oxidation resistance; Compered to the conventional SLM-ed IN718, the ODS-IN718 exhibited an approximately 30% reduction in mass gain after oxidation exposure. This reduction indicates that the Y2O3 dispersion effectively acts as a diffusion barrier and promotes the formation of a more stable, slow-growing oxide layer.

Keywords: Superalloy, ODS, oxidation, additive manufacturing

EFFECT OF REUSED POWDER ON DENSITY/POROSITY OF ALSI10MG PARTS MANUFACTURED VIA SELECTIVE LASER MELTING

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ABSTRACT

Additive Manufacturing (AM) via Laser Powder Bed Fusion (LPBF) is widely used to produce complex components. AlSi10Mg is favored for its processability and mechanical performance. Limited research has addressed the effect of reused powder on density and porosity. In this study, AlSi10Mg powder was sieved after each build, and specimens were fabricated under fixed LPBF parameters. Powder morphology and size distribution (D10, D50, D90) were analyzed using Scanning Electron Microscope (SEM) and light scattering. Apparent density and porosity were measured via Archimedes Testing and Computer Tomography (CT). Results show that repeated powder reuse increases particle size and satellite formation, reducing apparent density from an average value of 98.35% to 97.37%. Density varied depending on build orientation, and CT analysis reported higher values than Archimedes measurements, likely due to imaging resolution. Overall, repeated powder resulted in satellite formation and increased porosity amount.

Keywords: Additive Manufacturing, Laser Powder Bed Fusion, Archimedes Test, Computer Tomography, Powder Size Distribution.

ROBOTIC WIRE ARC ADDITIVE MANUFACTURING OF LARGE-SCALE STIFFENED AEROSPACE SHELLS: PROCESS AND CHARACTERIZATION

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ABSTRACT

Wire Arc Additive Manufacturing (WAAM) represents a strategic technological advancement for the production of large-scale, complex components, offering significant advantages in lead time and design flexibility over traditional manufacturing methods. In this study, a comprehensive process was developed and validated for manufacturing a large, reinforced cylindrical component, measuring 600 mm in diameter by 600 mm in height, using ER2319 aluminum alloy wire. The methodology detailed herein covers the critical stages of the manufacturing lifecycle, beginning with the finalization of process parameters and robotic toolpath generation using parametric design tools, proceeding through thermo-mechanical simulation and component fabrication, and concluding with post-process heat treatment and in-depth material characterization. The stability and success of the entire manufacturing chain are predicated on a meticulously defined set of foundational welding and robotic parameters, achieving a successful integration of robotic control and metallurgical requirements. Analysis of the produced parts reveals that despite localized variations in cooling rates, the implementation of standardized heat treatments results in mechanical properties that meet the rigorous standards required for satellite launch systems.

Keywords: Wire Arc Additive Manufacturing (WAAM), ER2319 Aluminum Alloy, Robotic Path Planning

NUMERICAL INVESTIGATION OF PARTICLE FEEDING RATES ON THE SPHEROIDIZATION OF TITANIUM POWDERS IN RF-ICP SYSTEMS

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ABSTRACT

Spherical morphology and high purity of powders are of critical importance for achieving high-quality components in additive manufacturing (AM) processes. Radio Frequency Inductively Coupled Plasma (RF-ICP) systems serve as an effective method for the spheroidization of powders due to the high-temperature environment they provide. Owing to the complexity of the plasma temperature's effect on particles and the high cost associated with experimental procedures, it is a critical necessity to investigate these processes through numerical studies. In this study, the effects of powder feeding rates on the spheroidization process of titanium particles were analyzed using numerical simulations. The numerical investigations have enabled the determination of the ideal powder feeding rates required to achieve efficient spheroidization performance within the system.

Keywords: RF induction plasma spheroidization, CFD, Spheroidization, Titanium, Spherical powder.


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