ABSTRACT BOOK

AMCTURKEY 2021
ADDITIVE MANUFACTURING CONFERENCE
09-10 SEPTEMBER 2021, GREEN PARK HOTEL PENDİK - İSTANBUL

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Dear Colleagues,

Manufacturing concepts are rapidly changing and manufacturing processes are completely being redefined in the last decade. Industry 4.0, digitalization and IoT are at the core of next-generation manufacturing technologies. Additive Manufacturing, considered to be one of the cornerstones of next- generation digital manufacturing, is replacing/will replace some of the traditional manufacturing methods in several industries.

For digital transformation of manufacturing industries, it is critical that scientific research and R&D studies on Additive Manufacturing technologies need to be shared on a common platform where scientific community and researchers from industry come together. The second "Additive Manufacturing Conference" in Turkey ("AMCTURKEY", http://2021.amcturkey.org/) is being held in İstanbul on September 09-10, 2021 for this purpose on site and online, as a hybrid conference.

AMCTURKEY brings local and international scientists, researchers, and representatives both from academia and industry, where they can present and share their recent scientific discoveries, research activities and emerging applications in Additive Manufacturing and related technologies. The conference covers all the areas of Additive Manufacturing and will include internationally-renowned invited speakers as well as panel discussions and industrial presentations. In addition to these, several certified training sessions will be held on various topics of additive manufacturing just before or during the conference.

We have 6 keynote speakers who are well-known in the area of Aditive Manufacturing. Their contribution to AMCTURKEY 2021 is considered as great and very valuable. Besides, 33 papers and 8 extended abstracts will be presented in the conference. Organizing committee also thanks to authors of these papers and extended abstarct for their contribution to AMCTURKEY 2021. Special thanks goes to our sponsors. Their strong support amd motivation makes this hybrid conference possible in this pandemic year. Last but not least, we would like to thank to Origin organizing company and Mr. Deniz Derinsu and Kunter Alkan for their endless effort to maket his conference great.

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INDEX

Influence of laser energy density on geometrical forms produced by laser metal deposition of PH 13-8 Mo stainless steel

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Abstract

Additive manufacturing (AM) is getting more popular in many industries due to direct manufacturing facilities, design flexibility and effective lead time. Directed energy deposition (DED) is a variation of AM and laser metal deposition (LMD) is regarded as a DED process and it uses laser as a heat source to melt and deposit the raw material fed through a nozzle in the powder form. This paper presents a research work that investigates the forms of laser metal deposited parts in S-shaped using PH 13-8 Mo stainless steel powders. Experimental work was conducted to produce S-shaped single bead walls with main process parameters affecting the energy density. The results have been discussed by considering the energy density levels as low, medium and high. It is clear to observe that the low energy density level parameters produce no or improper S-shaped walls. However, high energy density level parameters produce relatively well deposited walls but the geometrical forms of the walls are not steady due to heat accumulation during the deposition. Balling on the deposited walls can be seen in each energy density level. This defect occurs when there is insufficient heat energy to melt and deposit the powder from the moving nozzle.

Keywords: Additive manufacturing, Laser metal deposition, PH 13-8 Mo stainless steel

Manufacturing and Characterization of Topologically Optimized Inconel 718 Engine Bracket Manufactured using Electron Beam Melting (EBM) Process

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Abstract

Nickel-based alloys are widely used for aerospace applications since they exhibit tremendous mechanical strength under extreme conditions. Additive manufacturing (AM), especially electron beam melting (EBM), technology is of interest due to its potential of direct digital manufacturing of highly complex fully functional light-weight critical components such as engine brackets. Most critical tasks of the brackets in their use, are to damper the vibration and support the engine weight. Consequently, it is desired simultaneously to reduce weight and maintaining good mechanical properties where the topology optimization is the right tool. In this study, the reference and weight-reduced brackets are fabricated via EBM method, and then followed by subjecting to the hot isostatic pressing (HIP) procedure. The engine bracket is weight reduced with a value of 32.08% utilizing a developed finite element analyses (FEA) based topology optimization. Furthermore, the effect of different loading conditions on the topology optimization of the EBM-built Inconel 718 bracket is studied. The mechanical property values for the FEA are obtained based on experimental data. The reference and topologically optimized brackets are subjected to the tensile tests using a tailor-made fixture and the area under the 'Load vs. Tensile Extension' curves are estimated to obtain average energy values using software where a 16.3% energy increase is witnessed.

Keywords: Nickel-based alloys, additive manufacturing, bracket, topology optimization, finite element analysis, tensile tests.

Optical Laser Pre-heating Effects on SS 316L Metal Powder

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Abstract

The Selective Laser Melting (SLM) process is characterised by repeated heating and cooling of successive layers of powder during component manufacture, leading to rapid cooling effects and high temperature gradients within the build. As a result, the general microstructural features are different to those obtained by conventional manufacture. There are three pre-heating methods in SLM/SLS, which are build chamber pre-heating, base-plate heating and laser pre-scanning heating. This research aims to investigate optic laser pre-heating effect on SS 316L metal powder and development of an optimum optic laser pre-heating system for conventional additive manufacturing machines. Optic laser pre-heating experiments were carried out using a 220 W Fibre Coupled Diode Laser. Temperature distributions of bottom left – top left – centre – bottom right – top right of specimens were measured by a pyrometer. The preliminary experimental results show that the pre-heating time and laser power should be set so that the maximum core temperature is below the 550^{o}C to avoid cracking of the sample.

Keywords: Additive manufacturing, optic laser, pre-heating, microstructure, SLM,.

Distortion and dimensional deviation of Inconel 718 auxetic structures produced by DMLM

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Abstract

Due to their geometrical shapes, auxetic structures expand laterally when stretched and contract laterally when compressed. These structures find their usages in different industries where high energy absorption, toughness, flexural rigidity or buckling under pure bending are required. Additively manufactured parts have some amount of distortion due to the nature of the process and this distortion has a great influence on mechanical properties of the final part. Knowledge about distortion characteristics of thin-walled lattice structures manufactured by additive manufacturing is very important to better estimate and evaluate the mechanical behavior of these parts when used in industrial applications. For this purpose, this study focuses on distortion characteristics of IN718 re-entrant, anti- tetrachiral and honeycomb lattice structures manufactured by powder bed fusion additive manufacturing. To investigate distortion and geometrical deviations produced thin-walled lattice structures were scanned in two conditions with blue light device: just after printing when parts are still on build plate, and just after removing the specimens from build plate and splitting them into three pieces. Printed structure geometries were compared with the original CAD model and finite element analysis. Numerical results showed acceptable results in the directions, in which the re-coater effect is inconsiderable.

Keywords: lattice structures, powder bed fusion additive manufacturing, blue light scan, geometric deviation, distortion.

Peridynamics-Informed Effect of Micro-Cracks on Topology Optimization of Lightweight Structures

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Abstract

Most structures are preferred to be light-weighted when they are used in industrial applications such as automotive, aerospace, and naval structures. Classical continuum mechanics (CCM) formulations are commonly adopted to solve the topology optimization problems. However, CCM brings about some restrictions to the modeling, analysis, and solution of complex structures with structural discontinuities, defects, and micro/macro damages. Unlike CCM, peridynamic theory provides a wider range of analysis options because of its nonlocal integration nature, which can eliminate the need for partial derivatives in the equation of motion, thereby being suitable for effective modeling of cracks, damages, etc. This paper presents an application of peridynamics based topology optimization (PD-TO) to study the effect of micro-damages for designing lightweight engineering structures. The PD-TO algorithm used herein is based on the coupling of bond-based method and Optimality Criteria (OC) topology optimization method. The structure is designed by locating various microcracks for investigating the microdamage effect on the optimal topologies. To this end, the PD-TO model is implemented using an in-house MATLAB code, and strain energy density distributions are compared between different topologies. As a result, the importance of including damage regions within the lightweight design optimization stage is revealed.

Keywords: Topology optimization; microcracks; optimality criteria; peridynamics; lightweight design.

Comparison of Finite Element and Empirical Model Prediction of Surface Residual Stress in Inconel 718 Parts Fabricated by Laser Powder Bed Fusion Additive Manufacturing

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Abstract

Inconel 718 parts produced by Laser Powder Bed Fusion (LPBF) generally have excessive residual stresses (RS) due to the extreme temperature gradients and high cooling rates that occur during production. These stresses can damage the mechanical properties and fatigue life of parts. Therefore, RS are one of the main reasons that hinder the widespread use of the LPBF process. The main purpose of this study is to predict the RS that may occur by finite element modeling and empirical approach of the production process in order to minimize the RS and distortions that occur during production. According to the simulation and theoretical calculation results, it has been observed that the RS in the build direction are generally large tensile stresses in the upper and lower regions and compressive stresses in a large middle region in between. One of the most important parameters that determine the residual stress magnitude is the scanning speed, which affects the energy density. The change in energy density due to constant laser power and increasing laser speed alters the amount of residual stress in the parts. This paper illustrates that when fabricating components with lower energy density leads to an increase of tensile residual stress, however, increasing energy density with altering process parameters results in reduced tensile residual stress.

Keywords: Laser powder bed fusion, Finite element modeling, Residual stress

Investigation of process simulation and additive manufacturability of lattice-type support structures

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Abstract

Laser powder bed fusion is an additive manufacturing technology that enables manufacturing complex structures with the capability of design freedom. However, owing to the essential nature of the process, it generally requires support structures. Correct selection of support structures allows a part to be manufactured successfully by avoiding inefficient heat dissipation, process-based failures, redundant material usage and long labor intense post-processes. For this purpose, alternative support structures to commercial solutions may be needed for manufacturing of the parts. In this study, different lattice-type support structures with nearly same density are investigated in terms of process simulation, manufacturing and inspection. Process simulation results indicate that the simulated lattice-type support structures exhibit similar trend with the actual ones, although up to 35% discrepancy was seen between displacement values which is a result of modeling thin and complex lattice structures. The results from manufacturing show that the lattice-type support structures present more stability than the perforated block type support structure, although they have the same density. Among the lattice-type support structures, FCC had the minimum deformation in both simulation and manufacturing results. Besides, inspection results show that the manufactured lattice structures have accurate geometrical dimensions which is consistent with its engineering design models.

Keywords: Laser powder bed fusion, lattice structure, support structure, process simulation, additive manufacturing

Investigation of energy density on porosity and mechanical properties of AISI 316L parts built using DMLS

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Abstract

Direct metal laser sintering (DMLS) is a popular additive manufacturing method for the fabrication of metal parts by sintering with a laser source. This paper presents a study of the porosity of AISI 316L stainless steel specimens produced by DMLS. Two different energy densities, 88,9 and 17,8 J/mm^3 were chosen to investigate the energy density effect on porosity. The porosity distribution of the specimens was determined by micro-CT scanning. The influence of the pore shape and surface area of the pores on the mechanical properties of the specimens were examined. Results show that the specimen built with the lower energy density has more porosity, 1.49%, because of insufficient sintering. Since the pore shapes away from the sphericity, it causes notch-effect during tensile testing and results in lower 5% oftensile strength and 80% of elongation. Overall, higher density and better mechanical properties can be obtained with higher energy density.

Keywords: DMLS, micro-CT, porosity, tensile test

Directed energy deposition process development for functionally gradient Copper-Inconel 718 materials

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Abstract

Bimetallic systems are widely used in applications requiring combination of different material properties, such as in the aerospace industry, nuclear industry. Especially in rocket propulsions, Copper-Inconel alloys provide significant advantages due to the excellent heat conduction and wear resistance of Copper alloy and corrosion and oxidation resistance of the Inconel alloy. However, bimetallic systems produced by traditional methods could fail because of different material behavior under extreme conditions. Recently, additive manufacturing (AM) is considered as a promising technique to produce functionally graded materials (FGM) for large and complex parts with a short lead-time. In this paper, we aim to develop a CuSn10-Inconel 718 functionally gradient material using directed energy deposition (DED) AM process to elucidate the relation between process parameters and the microstructure. The DED process parameters have been optimized to produce desired FGM structure, and thermodynamic calculations have been conducted to investigate undesired phases within the gradient structure. Microstructure and the elemental composition of the gradient material have been investigated using scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS). The study aims to combine the experimental and thermodynamic computational modeling, to demonstrate the viability of assessment through computational work for a gradient material additively manufactured by DED processes.

Keywords: Additive manufacturing, Thermodynamic computational modeling, Directed energy deposition, Microstructure

Investigating cause of the dissimilar ductility of Inconel 718 fabricated by electron beam melting (EBM)

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Abstract

Additive manufacturing has become mainstream many areas. In recent years, aviation has been one of the leading industries using additive manufacturing. While generally metal materials are used in this sector, the production of metal materials with additive manufacturing can be in different ways. Electron beam melting(EBM) method is based on the powder bed fusion(PBF) principle. Thanks to the PBF, it is possible to produce parts that are difficult to produce by traditional methods. In this study, it is aimed to explain the different ductility behavior of IN718 produced by EBM method by phase analysis. When all the tensile test results are examined, it is seen that the final tensile strength and yield strength results decreased by about 3%, the area reduction was reduced by about 65%, and the decrease between the elongation results after fracture was 85%. The fracture surfaces were examined different phase images were seen in the samples with value of low ductility. To understand this difference, fracture surfaces and shiny surfaces were examined with electron microscopy and XRD. As a result of the examination, differences were observed in the areas with high Nb content and in the amount of a precipitate phase in the structure.

Keywords: EBM, Ductiliy, Phase Analysis.

Development of bone-like composite filaments for FDM 3D Printing

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Abstract

The number of 3D printer filament development studies are increasing day by day by using composite materials to respond the need to create implants which have personalized design by using fused deposition modelling (FDM) 3D printing technology in bone tissue engineering. The aim of this study is to investigate the effect of Hydroxyapatite content in properties of composites and to produce filaments from developed composite materials. 10%, 15%, 20% and 25 wt. % Hydroxyapatite (HA) filled Polycarbonate (PC) composite granules were produced by using twin-screw extruder. Filaments were produced by filament production line. Characterization samples were obtained by using hot press in accordance with the standard dimensions. Density and MFI (Melt Flow Index) measurements, thermogravimetric analysis (TGA), and mechanical tests including tensile, three-point bending, and Izod un-notched impact strength tests are performed. Scanning Electron Microscopy (SEM) analysis was carried out to investigate the morphological changes. Tensile strength and elongation at break values were decreased but Young's modulus was increased with increasing amount of HA in the composition. Similar results were obtained for flexural tests. Izod impact strength values were decreased by increasing HA amount. 3D printer filaments were produced and flexural test specimens were printed in 3D printer.

Keywords: composite, filament, fused deposition modeling, polycarbonate, hydroxyapatite.

Embedding information on additively manufactured parts using Mondrian patterns

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Abstract

With Additive Manufacturing (AM), parts having complex geometries can be produced easily compared to the traditional manufacturing methods. AM gives the opportunity to produce those complex parts in a very straightforward manner. This simplification creates the capability of embedding different structures, patterns or assets to the part without the burden of additional manufacturing processes. It has been observed that the most common approach for this purpose is to use QR codes. This article discusses a different method combining science and art together. A simple coding approach inspired by the Dutch painter Mondrian, who is known to have paintings consisting of grids and contrast colors, has been developed. In this paper, details of the proposed method to embed information onto the AM parts are presented and results are discussed.

Keywords: Additive manufacturing, embedding information, Mondrian, FFF

Use of a nozzle with a rectangular orifice on a hybrid FFF system

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Abstract

Fused Filament Fabrication (FFF) process has lower surface roughness quality, precision and it takes longer to fabricate compared to the conventional manufacturing operations and some additive manufacturing technologies. In order to overcome these issues, a rotary extruder head with a nozzle having a rectangular orifice has been utilized in this work. A new tool path planning for a rectangular nozzle is designed to increase the efficiency of the extrusion process by this nozzle. As a result, finer features (such as outer surfaces, edges, corners, etc.) can be 3D-printed with greater accuracy, and inner regions can be extruded in less time. The design algorithms for outer shells, inner regions, and infill paths are presented here to show the procedure of the tool path planning and examined for different test cases. Some modifications in the case of concave curves as the outer shells are also offered. Moreover, these test cases have been fabricated in our hybrid manufacturing system named HYBRO, which has five axes plus milling and rotary extruder heads to demonstrate this new strategy. The results demonstrate the smallest and the largest bead widths obtained with the same rectangular nozzle.

Keywords: Hybrid Additive Manufacturing - Nozzle with Rectangular Orifice – Process Planning

Multi-axis 3D printing of spiral parts without support structures

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Abstract

The recent developments in Additive Manufacturing (AM) have accelerated the spread of 3D printers all over the world. Fused filament fabrication (FFF) has become the prevalent technology for use in printing typical thermoplastics. Sometimes, the nature of layer-wise production brings about the necessity of using support structures, leading to (i) increased material consumption, (ii) reduced production speed, (iii) deterioration in the part quality, and (iv) extra post-processing. To eliminate these shortcomings of FFF, researchers proposed several methods, one of which is to benefit from particular multi-axis hardware. In this study, the capability of a multi-axis FFF machine in support-less printing is introduced. The quality of the produced part is compared with that of its identical counterpart printed on a conventional (i.e., 3-axis) FFF setup.

Keywords: *Additive manufacturing; 3D printing; Multi-axis; Fused filament fabrication; support-free*

3D Thermal Modelling and Simulation of Ti–6Al–4V alloy Processed by Selective Laser Melting

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Abstract

Selective laser melting (SLM) is the most widely used metal additive manufacturing (AM) technique due to its ability to manufacture complex-shaped parts with the desired tolerances. In the present study, a three-dimensional finite element (FE) heat transfer model for the SLM process was developed and multi-track simulations were conducted to predict maximµm temperatures and melt pool dimensions depends on the process parameters such as laser power, scanning speed and hatching distance for Ti6Al4V powder. FE simulations for different process parameters were conducted in ABAQUS as it provides a parametric job possibility within its Fortran subroutines. Goldak volumetric laser heat source model was used as the flux source and material properties were revealed as temperature-dependent. During laser scanning, it was observed that powder material is melted by heat source through at least one layer and this leads to interlayer connection as expected. Besides, maximum temperatures were found stable from the beginning to the end of the track until it achieves an equilibrium regime in view of temperature distribution. The fidelty of the simulation was revealed by comparing melt pool dimensions and maximum temperatures with both experimental and simulation studies in the literature. Furthermore, the melt pool depth to width ratios were examined comparing to the literature. Maximum track temperatures rises from 1st track to the last 4th track as in 2550-3250 ^{0}C. On the other hand, selected process parameters were revealed that are suitable to fuse laser tracks effectively as D/W ratio is ≤ 0.5 possible keyhole limit.

Keywords: Heat transfer modeling, process simulation, selective laser melting.

A numerical approach to assess the impact of the SLM laser parameters on thermal variables

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Abstract

Due to extraordinarily high heating and cooling rates, understanding the selective laser melting (SLM) process remains a challenge. To evaluate the impact of processing parameters on distinct underlying surfaces, a three-dimensional finite element model is presented. To forecast the temperature distribution inside a finite solid model, a moving Gaussian heat source was created to scan the model with temperature-dependent material properties. In the finite model, the impact of processing factors such as laser power, scan rate, and scan spacing were investigated to measure thermal variables such as cooling rate, thermal gradient, and solidification rate in a layer with solid and powder bases. The maximum track temperature was observed to be increasing over the whole track length, which had a substantial influence on the thermal gradient, cooling rate, and solidification rate. The maximum track temperature, melt pool form, and thermal variables were shown to be strongly influenced by laser power and scan speed when compared to scan spacing. Furthermore, the underlying base had a substantial influence on the observed temperature values and melt pool shape.

Keywords: Selective laser melting, finite element analysis, 316L, cooling rate, temperature gradient, additive manufacturing, powder bed.

A numerical investigation of the effect of support thickness and void ratio on thermal behavior and possible martensite decomposition in laser powder-bed fusion process

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Abstract

Laser powder-bed fusion additive manufacturing process allows the production of complex parts. However, the thermal nature of the process involves spatially and rapidly changing heating-cooling cycles. This type of thermal process causes the formation of highly martensitic microstructures with poor ductility and crack resistance. To overcome this issue, a more lamellar structure for improved physical properties can be obtained either by an approach during production or by a post-production heat treatment. In this context, the support structure together with the substrate temperature are factors that can make a difference during production. If these two factors are properly determined by an assessment prior to production, martensite decomposition can be achieved In this study, the effect of the thickness and void ratio of a support structure with a constant cross-sectional area on the thermal behavior of the process was investigated numerically for the Ti6Al4V alloy. For this purpose, a case is examined for different void ratios and support thicknesses. As a result, it was predicted that the cases with a support thickness of 2 and 4 mm and a void ratio of 0.75 could initiate martensite decomposition.

Keywords: Laser powder bed fusion, additive manufacturing, support thickness, support void ratio, martensite decomposition.

Numerical Simulation of Multimaterial Polymer Mixing for Bioprinting Applications

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Abstract

In tissue engineering, three-dimensional (3D) functional constructs (cellular or acellular) with tailored biological properties are needed to be able to mimic the hierarchical structure of biological tissues. Recent developments in extrusion based additive manufacturing considerably improved the ability to fabricate sophisticated tissue constructs by allowing to extrude multiple materials through different printing heads. This paper investigates the flow behavior of two miscible biomaterials inside an extrusion chamber incorporated with a Kenics static mixer (KSM). A computational fluid dynamics (CFD) model for isothermal non-Newtonian fluid flow was developed to numerically analyze the flow behavior of the fluids. The power-law model was used to characterize the shear-thinning behavior of the studied biomaterials. The mixing performance of designed chamber was also investigated by varying the inlet angles and velocities as well as the effect of the number of mixing units, pseudoplastic behavior of fluids, and pressure drop throughout the fluid domain. The results indicated that the inlet angle did not have a significant impact on the mixing quality and the proposed mixing channel showed good mixing performance regardless of the inlet velocities. The mixing index increases by increasing the power-law index and the shear-thinning behavior decreases the pressure drop value compared to Newtonian fluids.

Keywords: Bioprinting, CFD, multi-material, 3D-printing, mixing index

Investigating Compressive Strength of Laser Powder Bed Fusion Manufactured Ti6Al4V Lattice Structures for Bone Implant Applications

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Abstract

Lattice structures are becoming more and more attractive and preferred structures day by day because of their ultra-light weight properties with specific strength, load bearing capacity and time-cost-material efficiency. Due to their complex geometries it is impossible to generate these structures by conventional manufacturing methods. Laser powder bed fusion (LPBF), one of the most widely used and rapidly developing additive manufacturing (AM) method, provide opportunity to build up complex geometries. Ti6Al4V is commonly used AM material for biomedical lattice structure applications especially for bone implant researches. Mechanical properties of the lattice structures can be altered with lattice parameters (strut diameter, strut shape, unit cell dimensions and orientation). Compressivestrength properties are the most critical concern for biomedical lattice structures as they are mostly employed under high compressive load. So, for developing functional, biomedical lattice geometries it is necessary to investigate the compression behavior of different lattice topologies. In this study, octahedral, star and dodecahedron cubic lattice structures were manufactured with Ti6Al4V powder by LPBF technique for investigating their compressive behavior. Young modulus, maximum compression stress, experimental load values are determined and compared with literature. Mechanical properties of lattice structures were evaluated for bone implant applications.

Keywords: Compression test, lattice structures, additive manufacturing, Ti6Al4V, bone implants.

Effect of process parameters of the positive displacement pump for extrusion based bioprinting application

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Abstract

Bioprinting is an emerging technology that provides the ability to fabricate customized tissue constructs. One of the most common methods is Extrusion Based Bioprinting (EBB) which allows extruding high viscosity materials at a low cost. While currently available EBB methods provide an acceptable extrusion process, several disadvantages remain a challenge such as low extrusion accuracy in terms of start and stop accuracy. The present study aimed to explore the relationship between the extrusion accuracy and syringe features including plunger rubber compressibility and amount of volume inside the syringe. The weighing scale and the flow rate sensor are used to assess the extrusion accuracy. Results show that the plunger rubber has a negative impact on extrusion accuracy due to its compressibility. Likewise, when the amount of compressed volume inside the syringe increases, the start and stop accuracy of extrusion decreases. The time required to reach desired flow rate was measured as 17, 25, 29 seconds (±0.5) for 20, 30 and 40 ml filled syringe volumes respectively. The findings can contribute to a better understanding of the positive displacement pump and the extrusion accuracy relationship. As a result of these investigations, suggestions for a better extrusion pump were identified for future research.

Keywords: Additive manufacturing, 3D printing, Bioprinting, Extrusion-based bioprinting, Direct ink writing

Evaluation of suitability of polypropylene parts manufactured via SLS for spare part applications

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Abstract

The production of spare parts can be adapted to distribute supply chains with Additive Manufacturing (AM) and can be carried out without molds. In the home appliances sector, the production of spare parts by AM has gained importance in recent years. However, the suitability and sustainability of the parts produced by AM for use in the final product are of critical importance. In line with this scope, the suitability of the parts produced with polypropylene (PP) powder with Selective Laser Sintering (SLS) technology for use as spare parts was examined in accordance with the determined criteria. In this direction, samples were produced via both the SLS method and the injection molding (IM) method using PP powder. In addition, the effects of the build direction and the sealing post-process were also examined for the parts produced with SLS. The mechanical properties, surface roughness, surface contact angles and water impermeability of these samples were investigated. It was observed that PP parts produced with SLS have a hydrophobic surface, do not leak water even at 0.7 mm wall thickness and they are less ductile under uniaxial tensile force.

Keywords: selective laser sintering, polypropylene, spare parts, sealing post-process, home appliances.

DEPOSITION PATH PLANNING STRATEGY FOR GEOMETRIES WITH VARYING CROSS-SECTIONS IN WIRE ARC ADDITIVE MANUFACTURING

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Abstract

Wire arc additive manufacturing (WAAM) method has emerged as a powerful platform for fabricating medium-to-large scale structural parts and it has some some advantages, such as low cost, high deposition rate, and efficiency over other additive manufacturing (AM) methods. This research work proposes a deposition tool path strategy for parts with varying cross-sections in building directions. First, the deposition characteristics as Wire Feed Speed and Torch Travel Speed (TSS) were determined based on the material and number of layers and thickness of the wall. Afterward, the tool path has been generated by considering the geometric attributes such as cross-section area, type of border lines, curves and their continuities. Finally, the workpiece was built up by using the WAAM process with robotic cold metal transfer (CMT) system using aluminum wire (AWS ER5356) material. The results have shown that the proposed deposition strategy results with steady transition from circular cross-section deposition to hexagonal cross-section with less distortion and waviness.

Keywords: Wire arc additive manufacturing (WAAM), Aluminum alloy, CMT, deposition parameters

High deposition additive manufacturing by tandem plasma transferred arc welding

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Abstract

Plasma Transferred Arc Welding (PTA) is an important method for efficient component coating. In that field PTA has advantages, such as the free integration and mixing of a variety of filler materials as well as the largely independent material supply in relation to the energy input. Increasingly, the market is being driven by the challenge of providing efficient, high-performance, and safe coatings of complex geometries and components with flexible material depositions, as well as increasing the deposition rate. These tasks are fulfilled by the systematic coupling of two plasma transferred arc welding systems to form a tandem PTA system. Both PTA torches are positioned in such a way that they act in a common melt pool. In previous research it was provided that, deposition rate is 140 % increased with tandem PTA method in comparison to classical single torch PTA coating method.

In this research, a direct comparison with classical single torch PTA with parallel driven tandem PTA for additive manufacturing was done. The additive deposition capacity of tandem PTA is 56 % higher than classical PTA for specified time.

Keywords: Additive manufacturing, Tandem welding, Plasma transferred arc, High deposition, Stainless steel

An effective parameter in the deposition of 17-4PH powder with LMD technique: Scanning Speed

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Abstract

Laser metal deposition (LMD) is a novel additive manufacturing technology that has recently been utilized in the aerospace and automotive sectors to improve performance and speed up the process by minimizing connecting operations (welding, screwing, etc.) in production. In this study, the effects of scanning speed parameter on the microstructure and microhardness of 17-4 PH stainless steel produced by LMD method were investigated. 17-4 PH and AISI 1050 materials were used as deposition and substrate, respectively. As one of the production parameters, the laser power (W), gas flow rate (L/min), and powder flow rate (rev/min) were kept constant while scanning speed varied between 10-15 mm/s. With the changing scanning speed, differences in microstructure and accordingly changes in microhardness were observed. The results showed that the effect of deposition and scanning speed on the substrate is important in the LMD production technique, and this effect significantly affects the mechanical and microstructural properties.

Keywords: Laser metal deposition (LMD), 17-4 PH stainless steel, scanning speed, microstructure, microhardness

An engineering approach for weight reduction campaign of a UAV pylon fitting by topology optimization and EBM additive manufacturing

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Abstract

The operating altitude of unmanned aerial vehicles (UAV) can be affected by many parameters. Lightening the structural parts to achieve target altitude is one of the design efforts. Weight reduction purposes are achieved by converting primary structures and some secondary structures from a metallic material to carbon composite material. In addition, some secondary structures, such as fittings, have to be produced metallic and usually their material is aluminum alloy. Another disadvantage of aluminum alloy is its galvanic incompatibility with carbon composite materials. At this point, additive manufacturing methods offer solutions with a combination of topology optimization. Complex geometries obtained from topology optimization can be easily manufactured by additive manufacturing methods during weight reduction campaigns of unmanned aerial vehicles (UAV) such as fittings. In this study, the pylon fitting of an unmanned aerial vehicle (UAV) is lightened by the topology optimization method using commercial software with an engineering approach. The resulting complex geometry was produced as Ti-6Al-4V by Electron Beam Melting (EBM) additive manufacturing method. As a result of the campaign, a fitting design that is both lightweight and galvanic compatible with carbon composite primary structures has emerged. In this way, an engineering approach has been developed for weight reduction campaigns.

Keywords: Topology optimization, EBM, Ti-6Al-4V, fitting, UAV

Powder coater monitoring for detection of anomalies in DMLM process

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Abstract

Additive Manufacturing (AM) is becoming more and more favorable in aerospace industry applications. However, the quality standards for this type of applications are very high, therefore a thorough investigation is required not only after manufacturing but also during the AM process. The tool introduced in this study visually demonstrates if there are any anomalies during powder coating in Direct Metal Laser Melting (DMLM) process. This tool is based on an algorithm that collects and analyzes the images of powder coating and determines whether the powder was spread evenly, or an anomaly occurred during coating. In this study, also a cross validation was carried out with the AM distortion simulation results of the corresponding test part. The same layers where an anomaly was detected in the powder coating analysis tool were investigated in the simulation results and a slight indication was observed, and that validates the outcome of the tool. This study demonstrates results of process anomalies observed in a test part build.

On the Z-Dimensional Accuracy of L-Powder Bed Fusion

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Abstract

Laser Powder Bed Fusion (L-PBF) is one of the commonly utilized metal Additive Manufacturing (AM) modalities in highly demanding industries such as biomedical and aerospace. Among other limitations, the dimensional accuracy of the L-PBF parts hinders the adoption of this technology for a wider application. The dimensional accuracy in L-PBF depends on several factors such as beam compensation, process parameters, .stl conversion errors and shrinkage factors. The shrinkage factors are very important and needed to compensate for down-scaling of nominal dimensions. Due to the inherent nature of the process, anisotropic shrinkage occurs due to the thermal recession and the difference of the densities from the powder material and solidified layer. Although, it is generally taken into consideration for XY-plane dimensional accuracy, Z-shrinkage factors are omitted since the layer deposition is assumed to take care of the shrinkage for every layer in addition to deep melt pools to enable layer-to-layer fusion. However, in this study, it is observed that especially for long builds from AlSi10Mg powder material, dimensional errors up to a half of a millimeter may occur along Z-direction depending on the total Z-height. Therefore, a suitable Z-shrinkage factor is calculated based on the obtained experimental results and applied to all builds leading to a much more accurate results along the build direction. Moreover, the suitability of the shrinkage factors along X and Y axes is tested and confirmed.

Keywords: AlSi10Mg, Laser-powder bed fusion, shrinkage, dimensional accuracy

Ordered multi-material SIMP approach applied to 3D topology optimization

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Abstract

This paper presents a topology optimization framework for multi-material 3D structures to be used in mechanical load carrying applications. This framework is an extension of an ordered multi-material interpolation scheme originally proposed in 2D to the 3D minimum compliance problem implemented in MATLAB. The algorithm starts by using the Young's moduli and cost of the selected materials, then picks binary combinations with ordered densities to interpolate the value for the current iteration. Following these interpolations, the next step of the design is the solution of the mechanical compliance problem until the desired minimum compliance is met subject to volume and cost constraints. The solution scheme is based on Optimality Criteria Method and standard density filtering schemes. The main contribution of this paper is that the proposed design scheme implemented in MATLAB is an easy-to-use 3D topology optimization scheme with multi-material constituents based on a modified SIMP interpolation. Results show that the 3D code is able to deliver similar design results when compared with the existing 2D version. This effectively expands the topology optimization based design capability to many practical 3D engineering problems in a standard topology optimization setting and easy-to-use implementation in MATLAB.

Keywords: Multi-material, Topology optimization, SIMP, minimum compliance, 3D design.

The Generative Design Process for Robotic Design Applications

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Abstract

Recent open-source explorations and research linked to the domain of Additive Manufacturing has led to the development of more complex geometries and organic components which can be easily manufactured. This has proven to be a crucial milestone for designers with a radical step change in the thought process to fully utilise its potential. Additive Manufacturing technologies including 3D Printing and Direct Digital Manufacturing (DDM) complement these design approaches as the complicated geometries and manifolds produced after optimization steps are not feasible to be produced using the traditional methods of manufacturing. Although still in its infancy, Generative Design (GD) has shown remarkable potential for industrial applications, particularly when coupled with 3D printing processes. Utilising generative design also has significant potential benefit for robotics as it has the capability to substantially reduce robotic arm weight whilst maintaining the overall strength. Lighter robotics systems designed using GD will allow for economical actuator solutions due to reduced motor torque requirements linked to a lighter manipulator configuration and unchanged end effector payload.

Keywords: Additive Manufacturing, Robotics, Generative Design, Computer Aided Design

Parametric Simulations for Residual Stresses and Distortions of Inconel 625 Fabricated by Laser Powder Bed Fusion Additive Manufacturing

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Abstract

Developments related to the laser powder bed fusion (L-PBF) expanded the application area of the additive manufacturing (AM) for metal alloys, and increased the variety of machines and materials. On the other hand, this increase exposed the need for process development to adapt new materials and shapes with acceptable metallurgical, mechanical and geometrical attributes. In recent years, researchers have sought to reduce the development costs by decreasing these process development needs for some requirements. Among these, modeling and simulations for residual stresses and distortions are common practices. Dedicated software for these applications provided remarkable savings in computational times. Nevertheless, it is still necessary to pay attention to dedicated software, due to the fact that they might have some assumptions which are unknown to the end users. This study provides an in-depth investigation of Simufact Additive software based on L-PBF of Inconel 625 alloy. In this regard, thermo-mechanical simulations were performed by comparing the results with experimental data. Simulation set-ups were fine-tuned according to comparisons, and parametric analyses were conducted. The laser power and scanning speed were found to be the most influential parameters on the resulting residual stresses.

Keywords: Inconel 625, Laser powder bed fusion, Process parameters, Simufact Additive, Thermo-mechanical simulations

Surface texture and high cycle fatigue of as-built metal additive AlSi7Mg0.6

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Abstract

The aluminium silicon alloy AlSi7Mg0.6 is gaining importance in additive manufacturing. This work is showing a correlation of surface quality and fatigue properties of three different AlSi7Mg0.6 as-built surfaces manufactured by laser powder bed fusion. All specimens were built in z-direction and the difference in surface quality was achieved by variation of the contour scanning parameters in the manufacturing process.

Focus of the evaluation is on the reduced valley depth Svk rather than the commonly applied Ra (arithmetic mean of the line roughness profile) and Rt (maximum total height of the line roughness profile) and their areal equivalents Sa and Sz. Svk is derived from the material ratio curve and is a measure of the size of the valley population across the sample. It was found to show a better correlation with number of cycles to failure than parameters based on local extreme values such as Sz and Sv (depth of deepest detected valley).

Keywords: Laser Powder Bed Fusion, Optical Surface Texture Measurement, Additive Manufacturing, Fatigue, AlSi7Mg0.6

Effect of annealing conditions on microstructure and hardness of CoCrFeNiMn-0.18Ti high entropy alloy manufactured by electron beam melting

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Abstract

The success of *in situ* alloying whilst developing high entropy alloys (HEAs) specific to the electron beam melting (EBM) process has been stated in the literature. Secondary phases forming on FCC matrix improved the mechanical properties of EBM-built; however, their random distribution limits the further improvement in mechanical performance. Herein, post-process heat treatments were designed to observe the effects on secondary phase morphology, distribution, and microhardness of EBM-built CoCrFeNiMn-0.18Ti HEA and establish the optimized heat treatments while reducing further cost. Systematic studies revealed that an increase in solutionizing time slightly enhanced the microhardness of the alloy despite the solutionizing temperature reversely affect the mechanical properties. On the one hand, reaching a solutionizing temperature of 1300°C would not be enough to dissolve all the secondary phases within a reasonable solutionizing time of two hours. Metastability of HEAs and the complex distribution of topologically formed secondary phases slowed down phase transformations through FCC matrix. On the other hand, the microhardness of samples was successfully reattributed at 600°C by annealing. Thirty minutes and fifteen hours of annealing improved the hardness of solutionized alloy by 58 and 150% while reaching 316 HV and 487 HV, respectively.

Keywords: Electron beam melting; High entropy alloys; Heat treatment; Thermal stability; Phase distribution

EXPERIMENTAL DETERMINATION OF THERMAL EMISSIVITIES FOR Ti6Al4V IN SLM METHOD

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Abstract

This study was carried out in order to precisely measure the temperatures, which play an important role in reducing the errors that occur during the manufacturing of Ti6Al4V materials by the Selective laser melting method. In order to use thermal cameras in SLM method, the thermal emissivity values of samples with different surface properties depending on the temperatures were experimentally determined. Emissivity values were determined up to a temperature of 550°C due to oxidation. Emissivity measurement was obtained by verification with the help of surface thermocouple. Emissivity values were obtained between 0.31-0.40 in measurements depending on the surface roughness and temperatures up to 550°C. The changes on the surface properties depending on the temperature cause changing of the emissivity.

Keywords: *Selective Laser Melting, Temperature measurement, In-situ monitoring, Thermal emissivity.*

INLET GEOMETRY DESIGN FOR GAS FLOW IN POWDER BED FUSION PROCESS

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ABSTRACT

Powder bed fusion process (PBFP) is the first commercialized and most popular method in additive manufacturing (AM). PBFP needs to be operated within a controlled environment and inert gas chamber. Most of machine vacuum the chamber first and then fulfill the chamber with an inert gas. To operate the process properly a flow characteristic that remove the unwanted particles and fume, has to be studied and optimized. Otherwise, it may cause poor quality production due to contamination and possible damage to laser optics due to fume. In this study, gas inlet geometries are studied to achieve proper gas flow according to the PBFP requirements. Two diffuser geometries (circular and plate) are compared based on gas flow streamlines and turbulence areas. Plate shaped geometry is found to be more effective than circular holes. The results of the proposed design of plate shape diffuser have shown that the turbulence volume is decreasing as the diffuser angle increases.

Keywords: CFD, Powder bed Fusion, Additive Manufacturing

DEVELOPMENT OF LASER POWDER BED FUSION PROCESS PARAMETERS FOR Cu-Al-Mn SHAPE MEMORY ALLOYS

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ABSTRACT

A Cu-Al-Mn shape memory alloy (SMA) was processed via laser powder bed fusion (LPBF) by using adjusted process parameters. Crack-free and dense samples were obtained, and the manufacturing could be conducted on the basis of a large processing window. Fine columnar grained single-phase microstructure with a strong texture in building direction was achieved. Uniaxial compression incremental strain tests were applied to as-built samples and a maximum recoverable strain of 3.8% (applied strain: 6%) was obtained. The first results for additively manufactured Cu-Al-Mn have shown that LPBF is a promising fabrication method to directly produce individual and cost-effective SMA parts with a pronounced superelasticity at room temperature.

Keywords: Laser powder bed fusion, Shape memory alloy, Cu-Al-Mn, Process optimization, Microstructure

DEPOSITION TOOL PATH STRATEGIES FOR TOPOLOGICALLY OPTIMISED AIRCRAFT PART FOR DED

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ABSTRACT

Directed energy deposition (DED) process uses laser as a heat source and powder material to melt and deposit layer upon layer. DED is used to deposit high-density and complex, organic geometrie parts such as aircraft components. Toolpath generation is an important factor that affects the quality and time of deposition process. This research work proposes making a new design to reduce weight by topology optimization and creating tool path strategies for aircraft bracket. The aircraft part was built by DED using 316L powders. Acomparative study is used to analyze the results in terms of producibility, build time and need for post processing. The proposed deposition tool path strategies result with and minimum or no-porosity, fastest strategy to build the part.

Keywords: Additive manufacturing, directed energy deposition, tool path strategy

INSPECTION OF ADDITIVE MANUFACTURED TITANIUM PARTS BY COMPUTED TOMOGRAPHY

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ABSTRACT

X-ray computed tomography (micro-CT) has become an unavoidable method of testing and analyzing additively manufactured parts in recent years, being especially useful and accurate for dimensional measurement and porosity analysis. In this paper, the application of micro-CT as a non-destructive testing method of additively titanium alloy samples which are in basic geometries are demonstrated. This review aims to summarize an initial CT parameter optimization for R&D parts to be basis of complex future aircraft structures that will be manufactured in company's technological road map vision.

Keywords: X-ray computed tomography, non-destructive testing, additive manufacturing, titanium alloy, porosity

PYSLM – AN OPENSOURCE PYTHON LIBRARY FOR RESEARCH INTO SELECTIVE LASER MELTING

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ABSTRACT

PySLM is a Python library for supporting development of scan strategy used in Additive Manufacturing or 3D Printing, in particular Selective Laser Melting platforms used across academia and industry. This library provides design tools for use in Additive Manufacturing including the slicing, hatching, support generation and related analysis tools (e.g. overhang analysis, build-time estimation) and visualisation of scan paths. The tool provides many opportunities to explore novel approaches for scan strategy development in research and deploy them directly on systems. PySLM project and source code is available at *github.com/drlukeparry/pyslm*

Keywords: additive manufacturing, selective laser melting, python, scan strategy

PREDICTING BINDER JET ADDITIVE MANUFACTURING PART QUALITIES USING SUPPORT VECTOR MACHINE AND K-NEAREST NEIGHBORS

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ABSTRACT

This study focuses on identifying the relationship between process parameters and part qualities during binder jet additive manufacturing by comparing machine learning techniques. First, an experimental investigation on Co-Cr- Mo alloy was employed and 243 samples were printed based on a design of experiment approach. The printed parts were divided into five different classes based on their qualities. Two commonly used supervised learning algorithms, support vector machine and weighted *k*-nearest neighbors were utilized to build a model between process parameters and part qualities. It was shown that both algorithms have good prediction capabilities, and k- nearest neighbors show a slightly better performance.

Keywords: Binder jet additive manufacturing, machine learning, support vector machine, *k*-nearest neighbors

Influence of powder characteristics on densification and crystallographic texture formation of pure tungsten via laser powder bed fusion process

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ABSTRACT

Laser powder bed fusion (LPBF) of pure tungsten encounters several challenges in the fabrication of near-fully-dense components, owing to its intrinsic properties. In this study, routine, gas-atomized, and plasma-processed W powders were characterized for powder shape, size distribution, tapped density, and flowability and then fabricated with identical LPBF process parameters to evaluate the influence of powder characteristics on densification and microstructure. We, for the first time, succeeded in formation of a prominent crystallographic texture in tungsten via laser powder bed fusion (LPBF) technology. It is difficult even to manufacture highly dense tungsten products by LPBF because of its extremely high melting point and thermal conductivity. By tuning laser process parameters, we succeeded in fabricating near fully dense pure tungsten parts with a relative density of 99.1% which is the highest value ever reported. Importantly, a single-crystalline-like prominent crystallographic texture in which <011> preferentially oriented in the scanning direction evolved. The results demonstrated that better powder characteristics increased density and prevented lack of fusion while tuning grain boundary characteristics and strengthening crystallographic texture formation, which decreased cracking and increased hardness of the as-built W components.

Keywords: Tungsten, powder characteristics, densification, crystallographic texture, laser powder bed fusion

Small-Scale Mechanical Behavior of Ti–6Al–4V Parts Produced by Electron Beam Melting

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ABSTRACT

Electron beam melting (EBM) based production of Ti-6Al-4V alloys is gaining wide attention due to the extensive use of this alloy in a wide range of industries combined with the excellent mechanical properties of EBM-produced parts. In this study, we investigate a previously unexplored aspect of EBM-produced Ti-6Al-4V, namely its micromechanical behavior. Nanoindentation measurements on EBM-produced parts provided decreasing hardness with indentation depth, which can be explained by the phenomenon called the indentation size effect.

Keywords: electron beam melting, titanium alloys, micromechanical testing, nanoindentation.

APPENDIX

Extended abstracts underwent a thorough review process, with selected ones being transferred to The *Journal of Additive Manufacturing Technologies* upon verification of the author's agreement. Below is the list of published articles at *Journal of Additive Manufacturing Technologies*.

Title	Given Name (Author 1)	Family Name (Author 1)	DOI
Experimental determination of thermal emissivities for Ti6Al4V in SLM method	Mevlüt Yunus	Kayacan	10.18416/JAMTECH.2111494
Effect of annealing conditions on microstructure and hardness of CoCrFeNiMn-0.18Ti high entropy alloy manufactured by electron beam melting	Mehmet	Caririci	10.18416/JAMTECH.2111526
The generative design process for robotic design applications	Kartikeya	Walia	10.18416/JAMTECH.2111528
Parametric simulations for residual stresses and distortions of inconel 625 fabricated by laser powder bed fusion additive manufacturing	Özgür	Poyraz	10.18416/JAMTECH.2111530
Surface texture and high cycle fatigue of as-built metal additive AlSi7Mg0.6	Theresa	Buchenau	10.18416/JAMTECH.2111531
On the Z-dimensional accuracy of L-powder bed fusion	Evren	Yasa	10.18416/JAMTECH.2111533
Investigation of process simulation and additive manufacturability of lattice-type support structures	Emre	Ozeren	10.18416/JAMTECH.2111539
Powder coater monitoring for detection of anomalies in DMLM process	Mehmet Bora	Islier	10.18416/JAMTECH.2111543
Ordered multi-material SIMP approach applied to 3D topology optimization	Egecan	Ozcakar	10.18416/JAMTECH.2111544
Evaluation of suitability of polypropylene manufactured by selective laser sintering for spare parts applications	Deha	Unal	10.18416/JAMTECH.2111548
A numerical investigation of the effect of support thickness and void ratio on thermal behavior and possible martensite decomposition in laser powder-bed fusion process	Ebubekir	Dogan	10.18416/JAMTECH.2111549
An effective parameter in the deposition of 17-4PH powder with LMD technique: scanning speed	Pelin	Sezer	10.18416/JAMTECH.2111551
Weight reduction of an unmanned aerial vehicle pylon fitting by topology optimization and additive manufacturing with electron beam melting	Fatih	Yilmaz	10.18416/JAMTECH.2111553
Investigating cause of the dissimilar ductility of Inconel 718 fabricated by electron beam melting (EBM)	Caglar	Unver	10.18416/JAMTECH.2111555
An additive manufacturing hub for individualized medicine	Thomas	Friedrich	10.18416/JAMTECH.2111556
Multi-axis 3D printing of spiral parts without support structures	Bartu	Fazla	10.18416/JAMTECH.2111558
Effect of process parameters of the positive displacement pump for extrusion based bioprinting application	Yusuf Furkan	Ugurluoglu	10.18416/JAMTECH.2111560
Distortion and dimensional deviation of Inconel 718 auxetic structures produced by DMLM	Kadir	Gunaydin	10.18416/JAMTECH.2111563
High deposition additive manufacturing by tandem plasma transferred arc welding	Gökhan	Ertugrul	10.18416/JAMTECH.2111566
Use of a nozzle with a rectangular orifice on a hybrid FFF system	Bahar	Gharehpapagh	10.18416/JAMTECH.2111577
Directed energy deposition process development for functionally gradient Copper-Inconel 718 materials	Muhammed Enes	Balkan	10.18416/JAMTECH.2111581
Topology optimization and manufacturing of engine bracket using electron beam melting	Murat	Işık	10.18416/JAMTECH.2111583
Deposition path planning strategy for geometries with varying cross-sections in wire arc additive manufacturing	Babak	Naseri	10.18416/JAMTECH.2111585
Embedding information on additively manufactured parts using Mondrian patterns	Kilyan Emre	Talhouet	10.18416/JAMTECH.2111586

Title	Given Name (Author 1)	Family Name (Author 1)	DOI
Production and characterization of thermo-mechanical properties of hydroxyapatitefilled polycarbonatecomposite filaments for FDM printing	Tugce	Uysalman	10.18416/JAMTECH.2111588
A numerical approach to assess the impact of the SLM laser parameters on thermal variables	Mobin	Majeed	10.18416/JAMTECH.2111589
Influence of laser energy density on geometrical forms produced by laser metal deposition of PH 13-8 Mo stainless steel	Talha	Muslim	10.18416/JAMTECH.2111591
Comparison of finite element and empirical model prediction of surface residual stress in inconel 718 parts fabricated by laser powder bed fusion additive manufacturing	Mert	Kaya	10.18416/JAMTECH.2111592
Investigating compressive strength of laser powder bed fusion manufactured Ti6Al4V lattice structures for bone implant applications	Binnur	Sağbaş	10.18416/JAMTECH.2111594
3D thermal modelling and simulation of selective laser melting	Mehmet Alper	Demiray	10.18416/JAMTECH.2111604
Numerical simulation of multimaterial polymer mixing for bioprinting applications	Gokhan	Ates	10.18416/JAMTECH.2111606
Peridynamics-informed effect of micro-cracks on topology optimization of lightweight structures	Peyman Lahe	Motlagh	10.18416/JAMTECH.2111610