SFF SYMPOSIUM MANUSCRIPTS APPEARING IN THE MARCH 2020 ISSUE OF *JOM*

Nine materials-related manuscripts from the 2019 SFF Symposium were selected by the Organizing Committee for publication in the TMS journal *JOM* (March 2020). Papers may appear in only one publication, or they must be substantially revised and improved for submission to *JOM*. The titles and abstracts appear here so readers will know that the papers have appeared in print.

The following authors chose to publish their manuscript only in *JOM*, so their papers do not appear in this proceedings.

Electrophotographic Multi-layer Powder Pattern Deposition for Additive Manufacturing

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In this paper, the use of electrophotographic polymer powder transfer for the preparation of patterned powder layers is discussed with respect to a possible multi-material application in powder bed-based additive manufacturing technologies such as selective laser sintering. Therefore, an experimental setup with a two-chamber design was realized, which enables the electrophotographic transfer of SLS powder materials at typical process conditions. The powder development (pick up) step was investigated thoroughly for different powder materials in order to evolve a deep understanding of the underlying electrostatic effects and the influence of distinct powder properties. While using two different development modes, differences in the development results were correlated to differences in their particle size distribution, bulk density as well as relative permittivity. Moreover, a new strategy was invented, which allows the residual electrophotographic powder deposition in general being independent from the already produced part height. This is known to be a huge challenge, but it is mandatory for the buildup of three-dimensional multi-material components.

Mechanical Performance of Additively Manufactured Fibre-Reinforced Functionally Graded Lattices

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Latticing has become a common design practice in AM and represents a key lightweighting strategy to-date. Functional grading of lattices composed of strut-based or surface-based unit cells have recently gained immense traction in the AM-community, offering a unique way of tailoring the structural performance of AM-parts. This paper constitutes the first-ever investigation in combing these graded lattice-types with fibre-reinforced AM to further increase the performance-to-weight ratio. Cubic lattice-specimens, considered for a uniaxial compression test and build from body centred cubic (BCC) and Schwarz-P (SP) unit cells with different severities of grading, were investigated for their energy absorption behaviour. Practically, these are printed with short fibre-reinforced nylon employing FDM. Highly different structural responses and deformation behaviour were noted, with the BCC lattice demonstrating a gradual bending-dominated failure whilst the SP lattice showed local instabilities accompanied by load-drops. The results elucidate the effect of the severity of grading on the energy absorption capability and failure mechanisms of these continuously graded lattices. BCC lattices were found to generally absorb more energy for a given lattice strain, only more severe grading has led to better absorption capabilities for the SP lattices. A power law approach was used to fit the energy absorption behaviour with respect to the unit cell type and degree of grading. This knowledge will allow engineers to better select an adequate lattice configuration for their AM-design based on a given load profile.

Fabrication and Characterization of High-purity Alumina Ceramics Doped with Zirconia via Laser Direct Deposition

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Additive manufacturing of ceramics via laser direct deposition is particularly challenging owing to high thermal gradients and subsequently high tendency for thermally induced cracking. Therefore, it is necessary to have an improved understanding of the effects of processing conditions and material compositions on the quality of deposited ceramic parts. In this paper, thin wall structures of high purity ceramics were fabricated with commercially available alumina powder. The effects of zirconia dopants, varying from 0 wt.% to 10 wt.%, were studied. The microstructure and compositions of the manufactured specimens were characterized using scanning electron microscopy and energy dispersive x-ray spectroscopy. The obtained images were then used to study grain size, orientation, and distribution. Grain size distribution varied within the deposited ceramic parts due to the non-uniform temperature distribution during printing. The zirconia dopant was found to mainly accumulate within grain boundaries. An increasingly finer microstructure was observed with increased zirconia doping materials in the printed samples.

Towards Functionally Graded Sand Molds for Metal Casting: Controlling Thermo-mechanical Properties via 3D Sand-printing Processing Conditions

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Growing applications of additive manufacturing (AM) have now extended to metal-castings via indirect hybrid AM, i.e., 3D Sand-Printing (3DSP), which is a binder-jetting AM process. A comprehensive study on thermo-physical properties of 3DSP molds and its effects on aluminum castings is presented in this study. The effect of furan binder content (i.e. 1-3%) is evaluated for as-printed 3DSP molds to determine changes in: dimensional accuracy, density (Helium Pycnometry), actual binder content (Loss on Ignition Test) and mechanical strength (3-Point Bending and Tensile Tests) and heat diffusivity. As binder content increases, both mechanical tests follow the same increasing trend. Pore network characterization via Mercury Intrusion Porosimetry does not reveal any significant differences in pore structure between samples of different binder concentration. Permeability is reduced as binder content increase. In order to examine the effects of binder content in the mold on metal castings, casting experiments are carried out to determine the solidification curves of 99.9% elemental aluminum. Large grain formation is observed via optical microscopy, which correlates with measured solidification curves. Findings from this study will enable the optimum selection of binder content for adequate degassing capacity and mechanical strength, which can be readily implemented in foundries. Finally, a framework for a novel approach to mold design and manufacturing is presented, using graded binder concentration across the mold.

PENELOPE: A Novel Prototype for In-situ Defect Removal In LPBF

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A new Laser Powder Bed Fusion (LPBF) prototype for in-situ monitoring of defects and in-situ and in-line flaw removal has been developed and patented in Politecnico di Milano (Italy). This prototype allows one to identify a defective layer thanks to an innovative in-situ monitoring approach that combines image and video-image data in the visible and infrared ranges. When the alarm is issued, the layer containing the defect is removed in-situ and in-line, thanks to a novel self-repairing system acting as a grinder on the powder bed. After this removal step, the following layers are additively produced starting from the healed height. By comparing specimens obtained with and without the intermediate layer removal, this preliminary study aims to investigating the feasibility of the methodology, showing that no discontinuity is introduced in the part by the novel in-line removal operation. This solution is conceived to enable novel zero-defect and first-time-right capabilities in additive manufacturing.

Effective Moduli of Fused Filament Fabrication Material with Aligned Mesostructure

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We derive closed-form expressions for the effective in-plane moduli E_c and G_c of fused filament fabrication material with an aligned mesostructure at low porosity values. The void shape is approximated using a hypotrochoid, allowing stress and displacement fields around a single void to be calculated using the complex variable method of elasticity. The effective moduli are then calculated by equating strain energies between a unit cell containing a void and an effective unit cell. Experimental results for E_c as well as unit cell simulations show good agreement with predictions.

Hydrothermal-assisted Powder Bed Fusion of Ceramics for Achieving High Green Density

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Ceramic additive manufacturing (AM) provides a freeform fabrication method for creating complex ceramic structures that have been extremely difficult to build by traditional manufacturing processes. However, ceramic structures made by AM processes usually exhibit a relatively low density, which is largely due to the use of a large amount of organic binder in shaping green bodies. In this research, we present a new ceramic AM process, named hydrothermal-assisted powder bed fusion (HPBF), which utilizes a water-based hydrothermal mechanism to fuse particles, eliminating the use of binders in forming green bodies. A prototype system for the proposed HPBF process is introduced. The effects of process parameters (such as layer thickness, printing passes, prepressing and final pressing pressure, temperature) on the properties of achieved green parts are investigated. Experimental results indicate that with optimized process parameters, HPBF can achieve three-dimensional (3D) ceramic green parts with a high density up to 90%.

The following authors chose to publish their manuscripts in this proceedings and to publish a substantially improved paper in *JOM*.

Additive Manufacturing of Fatigue Resistant Materials: Avoiding the Early Life Crack Initiation Mechanisms during Fabrication

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The full potential of additive manufacturing (AM) has been limited by the process induced defects within the fabricated materials. Defects such as lack of fusions and gas entrapped pores act as stress concentrators and result in premature fatigue crack initiation, severely limiting the applicability of AM in fatigue-critical applications. However, by understanding the failure mechanisms associated with AM materials and leveraging the intimate localized thermal input (i.e. process conditions), the failure mechanisms for some materials may be avoided during the fabrication process. This study investigates the crack initiation behavior of an AM austenitic stainless steels subjected to fatigue testing. The microstructural features responsible for fatigue crack initiation are captured at the surface by ex-situ electron backscatter diffraction. Results show that the higher cooling rates during AM offer the opportunity to fabricate fatigue resistant austenitic stainless steel parts by avoiding the microstructural features that are most detrimental to fatigue performance.

Compressive Response of Strut-reinforced Kagome With Polyurethane Reinforcement

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Lattice structures find immense application in lightweight structures for their high specific strength, modulus, and energy absorption. Strut-reinforced Kagome (SRK) structures provide better compressive performance compared to many existing lattice structures. In this study, the performance of acrylonitrile butadiene styrene (ABS) SRK lattice structures, fabricated by fused deposition modeling, under compression loading is investigated. Further, SRK structures were filled with different polyurethane in the empty space and their effect on the compressive performance was examined. The SRK structure demonstrated abrupt failure at the joints in the vicinity of face sheet, thereby reducing the energy absorption of the structure. The SRK with flexible foam (low-density polyurethane foam) had no significant effect on peak failure load and moduli, whereas energy absorption per unit mass was higher by 16.5%. The SRK with the rigid foam (high-density foam) displayed not only the better energy absorption per unit mass (116%) but also different failure behavior than SRK only.