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Editorial

Advances in Additive Manufacturing and Their Applications

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1. Introduction and Scope

Additive manufacturing (AM) has evolved rapidly in the last few years. It has been embraced by major industrial companies looking for ways to improve their products. The ability to deliver near-instant part production and fully custom designs that cannot be replicated with other manufacturing techniques has accelerated investment and research in additive manufacturing.

A number of different metals are now available in powdered form to suit exact processes and requirements. Stainless steel and titanium metal and its alloys are materials of interest in the fields of biomedicine [1], aerospace [2], and defense [3] and the automobile industry [4]. Other materials such as aluminum alloys [5], copper [6], and cobalt chrome, in addition to precious metals such as gold, platinum, palladium, and silver [7], are available in powdered form as raw materials in AM technologies.

Many studies in this field have been and are oriented toward the following:

(a) Structural optimization for AM is and will remain a hot and attractive issue. Moreover, further studies need to be carried out to optimize and design practical industrial structures [8,9];

(b) The interaction between building orientation and heat treatment may change the strength–stiffness behavior of steel manufactured by means of powder bed fusion (PBF) [10];

(c) Supports are optimized with respect to two different physical properties. First, they must support the overhanging regions of the structure to improve the stiffness of the supported structure during the building process. Second, support can help in channeling the heat flux produced by the source term (typically a laser beam), thus improving the cooling down of the structure during the fabrication process [11].

This Special Issue aims to present the latest developments in additive manufacturing processes, optimizations, new additive processes, rapid tooling, and applications from industry using metal powders as raw materials.

2. Contributions

This Special Issue contains a total of 10 articles covering the main topics in this field.

The goal of the study by Ayub H. et al. (Contribution 1) was to increase the laser power absorption capacity of copper powder through the inclusion of carbon nanotubes (CNTs), up to a maximum of 0.6 wt.%. The optical properties of the CNTs mixed with copper powder were examined through spectroscopy, which revealed that the IR laser reflectance of the copper powder was reduced by 8%. The results demonstrated that the addition of CNTs improved the sintering behavior and refined the grain structure, leading to an increase in strength and flexibility. The SEM analysis revealed that lower concentrations of CNTs and higher levels of laser power could cause residual porosity, while higher CNT concentrations and slower scan speeds led to better particle consolidation. The researchers also found that adjusting the laser parameters could help to enhance the density of CNT-reinforced composites. Overall, the research work provides valuable insights into optimizing the sintering process for CNT-based composites for various applications.

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Morri A. et al. (Contribution 2) investigated the aging and over-aging behavior of a commercially available PH-SS (AMPO M789) manufactured using laser powder bed fusion (LPBF) in the AB condition and after solution-annealing treatment in order to evaluate the effect of the heat treatment condition on the microstructure and aging and over-aging response, with the aim of assessing its feasibility for plastic injection molding applications. The main conclusion of the research is that direct aging (DA) of the LPBF AB structure appears to be a promising procedure to reduce heat treatment cost and duration without impairing the maximum achievable hardness and over-aging behavior. However, eventual differences in terms of mechanical properties, possibly related to the different microstructure and austenite content in peak-hardening conditions, must be evaluated in order to assess the suitability of one heat treatment procedure over another for this specific application.

The paper by Jones R. et al. (Contribution 3) examines crack growth in a range of tests on additively manufactured and conventionally manufactured Inconel 718. In the study, it is shown that whereas when the crack growth rate (da/dN) is plotted as a function of the range of the stress intensity factor (ΔK), the crack growth curves exhibit considerable scatter/variability, when da/dN is expressed in terms of the Schwalbe crack driving force ($\Delta\kappa$), then each of the 33 different curves essentially collapses onto a single curve. In contrast, when da/dN is expressed as a function of the range of ΔK, the crack growth curves associated with the 33 tests on both conventionally and additively manufactured Inconel 718 exhibit considerable scatter/variability; when da/dN is expressed in terms of $\Delta\kappa$, each of these 33 different curves essentially collapses onto a single curve regardless of the manufacturing process. Furthermore, to a first approximation, the resultant relationship between da/dN and $\Delta\kappa$ appears to hold over approximately six orders of magnitude in da/dN.

Song K. et al. (Contribution 4) investigated a 26-layer HSLA steel component fabricated through the wire arc additive manufacturing (WAAM) technique. Their research shows that the microstructure of the deposited wall of the HSLA steel is mainly acicular ferrite, and of note, there are longitudinal preferentially growing dendrites along the deposition direction. With the deposition height accumulation, the top sample's interlayer temperature increases, and the amount of acicular ferrite in the tissue decreases, while the amount of quasi-polygonal ferrite, Widmanstätten ferrite, increases.

Voigt O. et al. (Contribution 5) demonstrate the theoretical suitability of particles from removal and molten material congeals in the EDM dielectric for further usage as a secondary, recycled material in additive manufacturing. The authors' conclusion is that by using the reference materials, the parameter settings in AM machines will be determined and optimized, followed by the production of different specimens and investigations of them via several mechanical tests. Moreover, upper and lower rejects from processing could be used in further AM techniques, and it is worth considering a secondary usage of graphitic residues in different applications as well.

Cosma C. et al. (Contribution 6), in their study, investigated the use of selective laser melting (SLM) for depositing a superior material, such as CoCr, onto an existing stainless steel base. The study results show that the stated configuration of the SLM parameters leads to limited microporosity in the CoCr–304 interface and higher adhesion strength when compared to other reports. Mechanical testing revealed that the adhesion strength at rupture is 830 MPa and the fractures contain predominant dumpling regions. This notable adhesion strength can be attributed to the complete melting of CoCr particles after laser irradiation and the reduced thickness of the HAZ and IZ.

The study entitled "Effects of Electrode Negative Pulsing Ratio in Direct Energy Deposition via Variable-Polarity Cold Metal Transfer Process on the Deposition Behavior and Micro-structural Characteristics" was carried out by Lee T.H. et al. (Contribution 7). The study results showed that polarity switching and the frequency at which it occurs affected the final feature of the WAAM product under investigation. Additionally, researches has shown that R_{EN} (electrode-negative (EN) polarity pulsing ratio) is not only influence the bead width and height, but also the deposition area and substrate dilution. When the R_{EN} was zero, the weight of the deposited material was found to be less than 50% of the weight of one R_{EN}. Increasing the number of repetitions was found to increase the roughness of height and width.

Fan S. et al. (Contribution 8), in their study, investigated a double-wire cold metal transfer (CMT) arc additive manufacturing system. ER2319 and ER5183 wires were selected as feedstocks and a new type of high-strength, crack-free Al-Cu-Mg alloy was manufactured. The main conclusions of the study are that the microstructure of the as-deposited alloy was mainly composed of the second phase precipitated on the grain boundaries, with the eutectic continuously distributed along the grain boundaries, and the distributions of Cu and Mg elements were inhomogeneous. At the same time, after T6 heat treatment, most of the eutectic structure that continuously distributed along the grain boundaries dissolved into the α(Al) matrix, and the distributions of Cu and Mg elements became homogeneous.

Serrati D.S.M. et al. (Contribution 9), in their paper, present the latest developments in non-destructive testing (NDT) for WAAM and its limitations and potential. The main conclusions are that a multi-parametric in-line NDT approach for WAAM offers several benefits over using a single NDT method. It provides a more comprehensive assessment of the parts' quality and can detect defects and inconsistencies that may not be identified using a single technique. Additionally, it can help to optimize the manufacturing process by providing valuable information on the process parameters.

Rowe R.A. et al. (Contribution 10), in their review paper, discuss the formation and propagation of adiabatic shear bands in nickel-based superalloys. The conclusion is that few investigations into the formation of ASBs in AM materials have been conducted on nickel-based superalloys and they are limited to the high-speed cutting of AM Inconel 625. Future work on this topic could include comparing the shear localization behavior of AM and TM materials using the same sample geometry, such as the top hat, under the same shear strain rates. This will provide a better understanding of the ASB formation mechanism in AM materials and help with developing more comprehensive and versatile models.

3. Acknowledgments

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Conflicts of Interest: The author declares no conflicts of interest.

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