Editorial

Additive Manufacturing in Industry

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Abstract: The advent of additive manufacturing (AM) processes applied to the fabrication of structural components has created the need for design methodologies and structural optimization approaches that take into account the specific characteristics of the fabrication process. While AM processes give unprecedented geometrical design freedom, which can result in significant reductions in the components' weight (e.g., through part count reduction), on the other hand, they have implications for the fatigue and fracture strength, because of residual stresses and microstructural features. This is due to stress concentration effects, anisotropy, distortions and defects whose effects still need investigation. This Special Issue aims at gathering together research investigating the different features of AM processes with relevance for their structural behavior, particularly, but not exclusively, from the viewpoints of fatigue, fracture and crash behavior. Although the focus of this Special Issue is on AM, articles dealing with other manufacturing processes with related analogies can also be included, in order to establish differences and possible similarities.

Keywords: additive manufacturing (AM); functionally graded (FG); directed energy deposition (DED); laser powder bed fusion (LPBF); cold metal transfer (CMT); wire arc additive manufacturing (WAAM); defects; fatigue; fracture; crash

1. Introduction

Modelling and optimizing structural behavior by using advanced materials and manufacturing processes is nowadays a key task for the engineering scientific community [1]. Additive manufacturing (AM) is a process that manufactures 3D objects by adding material layer upon layer. The concept of creating 3D geometries by growing them one layer at a time was an appealing idea that unlocked more than thirty years of innovation in materials, processing, design, and controls.

Though AM was invented to rapidly produce prototypes, the technology has the capability to release the design and manufacturing constraints in creating innovative products with great geometrical complexity [2].

AM is currently rapidly moving into various industrial applications to revolutionize product lifecycle performance, from flexible design optimization to functional improvement [3]. Inevitably, this introduces more cross-disciplinary and case-dependent research challenges, such as function-specific product design and simulation tools, high-quality cross-scale part fabrication, in-process monitoring and effective control, and reliable product lifecycle management. Addressing these challenges will bring concrete values to industries, as well as further stimulate fundamental research.

While AM processes give unprecedented geometrical design freedom, which can result in significant reductions in the components' weight, on the other hand, they have implications for the fatigue and fracture strength, due to residual stresses, microstructural features, and relatively high surface roughness [4]. This is due to stress concentration effects, anisotropy, distortions, and defects whose effects still need investigation.

This Special Issue contains nine research papers that cover a wide range of state-of-the-art topics in AM-enabled design and manufacturing, but also validation and procedures for AM components.

The performances of an AM automotive component were assessed numerically in [5], with respect to the delivered crashworthiness and compared with those of the traditional component. In particular, a frontal impact sled test was simulated, and the damages to the occupant's legs were assessed, with specific reference to the dashboard's glove box. The key aim was therefore to reduce weight and costs of the newly proposed AM component, guaranteeing at the same time a safe design for passengers. The materials analyzed were polyamide and polypropylene, both reinforced with 5% basalt. The tests were simulated according to Euro New Car Assessment Program (NCAP), and the main biomechanical parameters required by the Euro NCAP were estimated for both the current and the additive production of the component.

In [6], a porous functionally graded (FG) rotor-bearing system was simulated numerically via the finite element method (FEM). Stiffness, mass and gyroscopic matrices were derived for porous and non-porous FG shafts. The considered materials were FG, whose inner core was a stainless steel, whereas the outer layer was made of a ZrO2 ceramic. It was found that the power law index, volume fraction of porosity and thermal gradient provided a significant influence on the natural and whirl frequencies of the FG rotor–bearing system, thus providing several guidelines for their subsequent designing process.

FG materials were also studied in [7], with reference to a thick-walled cylindrical tube subjected to different combinations of loading conditions, such as internal pressure, thermal gradients and/or bending. The main aim was to derive the elastic-plastic responses of the component so as to give guidance to designers working with FG materials.

In [8], laser powder bed fusion (LPBF) technology was used to manufacture SS316L specimens. The impact of production-induced porosity on fatigue strength of 316L was investigated, and the fatigue strength compared with that of the base material and with that of a novel ferritic steel, named HiperFer, this latter promising an increased fatigue strength.

Directed energy deposition (DED) technology was considered in [9]. The aim was to determine how platform preheating and a sealed deposition environment, with respect to the exclusive use of an Ar flow as a protective mean, impacted on the final quality of Ti-6Al-4V samples built via DED. Information about the final quality of specimens was derived based on the environment in the chamber during manufacturing, with the end purpose of evaluating the possible up-scaling of this AM technology.

An article dealing with another manufacturing processes [10] was also included to highlight differences and possible similarities with AM technology. Single-lap multiple-riveted joint aluminum specimens were tested by considering pure tensile fatigue loads at different stress levels. Results in terms of fatigue lives and critical crack sizes were post-processed according to the Anderson–Darling test.

The cold metal transfer plus pulse (CMT+P) process was adopted to manufacture uniaxial samples [11]. Experimental tests were then performed in terms of stress–strain curve, micro-Vickers hardness, macro-morphology and microstructure. The aim of this research was to find the optimal linear energy suitable for arc-welding deposition wall by CMT+P through the comparative study of different parameters, and also providing a reference for the application of this technology as an AM-established technology.

Wire arc additive manufacturing (WAAM) process was used to manufacture Al–7Si–0.6Mg samples, as illustrated in [12]. The effect of heat input on the formability, microstructure, and properties of the WAAM alloy was investigated, and the results show that Al–7Si–0.6Mg alloy has a large processing window under the CMT process, and it can be effectively formed with a large range of heat inputs.

A review on WAAM technology was reported in [13], with special reference to stainless steels. This review covered the current status of stainless steel WAAM, microstructure, mechanical properties and defects related to different stainless steels and process parameters. Residual stress and distortion of the WAAM manufactured components were also discussed. Specific WAAM techniques, material compositions, process parameters, shielding gas composition, post heat treatments, microstructure and defects were reported as having a significant influence on the mechanical properties of WAAM stainless steels.

We hope this compilation has provided some insights into the latest advancements in AM, thereby stimulating more applications in the near future. We hope that this collection of articles, although small in number, could effectively represent a part of the active and diverse research occurring toward AM-enabled innovative applications.

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Conflicts of Interest: The authors declare no conflict of interest.

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