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EDITORIAL

Special issue: structural integrity of additively manufactured materials—developments in damage, fracture, fatigue and failure assessments

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1 Preface

Additive manufacturing (AM) or 3D printing has developed into an effective technology for fabricating unique and complex geometries beyond what is possible with more traditional manufacturing. This has resulted in significant interest in all areas of engineering. However, the use of AM in safety–critical applications is still limited due to an incomplete understanding of failure mechanisms of AM-built materials, sensitivity to process-induced defects, and in-service damage from complex dynamic multi-directional loads. However, fracture and fatigue behaviour associated with additive manufacturing is more complex than that with conventional fabrication techniques because of numerous influencing factors such as defects, microstructures and anisotropy. Each combination of AM method and material introduces unique defects and damage mechanisms into the product, making the prediction of fracture or other failure modes complex. To obtain the real potential benefits of additive manufacturing technology in critical load bearing applications, such as aerospace, automotive, marine and other industries, the fracture and fatigue performance of additively manufactured materials must be understood under potential different loading conditions. In this context, this special issue aims to present articles focusing on contemporary developments on the characterization of defects, damage, and failure analysis for the category of additively manufactured materials.

The articles scheduled for the special issue address many challenges in the integrity and durability of contemporary engineering structures produced using additive manufacturing technology. The articles thus encompass the characterisation of fracture and fatigue properties of different types of metal alloys produced using common metal additive manufacturing processes. The topics of interest broadly include types and characteristics of defects, modelling of defects, damage, and cracks, fracture mechanisms and fatigue behaviour of AM metal alloys. The effects of AM process parameters (e.g., build direction) and defects (e.g., porosity, voids, and lack of fusion defects) on fracture and fatigue properties of AM metal alloy are of specific focus here in relation to the structural integrity of engineering components.

The special issue starts with a review article by Afroz et al. that summarizes the published literature on fracture and fatigue properties of popular alloys (titanium, aluminium and steel) produced by the AM process. The effects of various parameters, such as build orientation, microstructure, heat treatment, surface roughness and defects, on the fatigue strength and crack growth characteristics are critically evaluated. The articles are ordered in terms of materials systems—steel, titanium and aluminium alloys.

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First, we introduce articles that encompass AM processed structural steel. Ermakova and co-authors analysed the fatigue crack propagation behaviour of structural steel (ER70S-6) produced by the Wire and Arc Additive Manufacturing (WAAM) technology and also studied the effect of build orientation on fatigue life. Kumar et al. investigated different mechanisms of fracture toughness in additively manufactured 316L stainless steel, produced by two different AM methods [selective laser melting (SLM) and wire arc additive manufacturing (WAAM)] and compared with conventionally fabricated 316L steel. This work established that the microstructure of SLM steel samples is primarily responsible for enhanced fracture toughness compared to WAAM or conventional samples. Macek and co-workers also explored SLM processed AM steel and analysed the mechanics of crack propagation in AISI H13 steel under fatigue loading through micro-CT and fractography. They showed that an increase in fatigue load or applied stress leads to an increased fracture surface roughness, and the porosity distribution also affects the crack initiation sites and mechanisms of fatigue crack growth.

Next, we present articles on titanium that investigated the effects of AM processing conditions and porosity on the fracture and fatigue properties. Hasib et al. studied the fracture toughness of pure titanium produced by the laser power bed fusion (LPBF) process, considering the effect of build orientation as well as specific post-processing using the hot isostatic pressing (HIP) condition. HIP is shown to be an effective method in enhancing fracture toughness significantly compared to as-built materials. Li and co-workers studied TC17 titanium alloy samples and specifically focused on the effect of porosity on the stress distribution due to high cycle fatigue conditions. This work demonstrated the complex stress field around pores near the surface and in the interior of samples, and how both the pore size and location affect the stress concentration and crack initiation in AM components.

Finally, we incorporate articles on AM aluminium alloys considering the effects of heat treatment and build direction on fracture properties as well as understanding their creep-fatigue fracture behaviour. Qin et al. investigated high cycle fatigue properties of aluminium alloy (Al–Mg–Sc–Zr) manufactured via selective laser melting (SLM) with potential applications to the aerospace industry. A comprehensive characterization of SLM induced defects and their effect on fatigue life is the highlight of this study. Menezes et al. studied how different types of heat treatment processes can alter the mechanical properties, including static and fracture properties, of AlSi7Mg aluminium alloy produced by the LPBF process and also can potentially reduce build orientation induced anisotropy in alloy samples. Furthermore, Wang et al. investigated the creep-fatigue fracture mechanism of a similar SLM aluminium alloy (AlSi10Mg) through in-situ scanning electron microscopy based testing and characterization of fatigue behaviour at an elevated temperature for different dwell times.

I would like to thank Professor Krishnaswamy Ravi-Chandar, the Editor-in-Chief of the International Journal of Fracture, for his support throughout the organisation of the special issue. I would like to express my sincere appreciation to the authors, reviewers and journal production team for their valuable contributions to composing this special issue. I hope the articles will serve as a basis to continually refine our understanding of fatigue and fracture critical processes from process parameters and microstructural perspectives.