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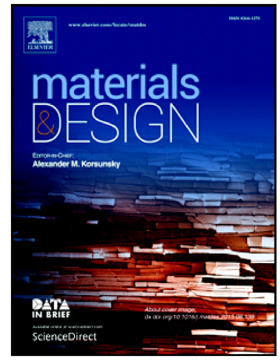

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On the fatigue strength enhancement of additive manufactured AlSi10Mg parts by mechanical and thermal post-processing

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Abstract
Selective laser melting fabricated materials regularly exhibit excellent static strength, thanks to the very high thermal gradient that characterizes the process; however, their performance under dynamic loading is somehow restricted due to the limited ductility, tensile residual stresses, the defect density and the inadequate surface morphology in the as built configuration. Currently mechanical or electrochemical surface polishing steps combined with various heat treatments are integrated into the production lines to respectively address these issues. However, these methods are reported to occasionally lead to inconsistent results apart from the burden of additional costs. Herein, we applied various post treatments including shot peening, sand blasting and heat treatment to evaluate their individual and synergetic effect to tackle the aforementioned challenges. Physical, microstructural and mechanical properties of SLM fabricated AlSi10Mg specimens were investigated with special focus on fatigue strength. The results highlight that appropriate post treatments can significantly enhance the fatigue performance of SLM specimens resulting in characteristics that are comparable and even better than conventionally manufactured material. Surface treatments, in particular, were found to be efficient in significantly enhancing the fatigue strength, while eliminating the necessity of polishing steps that are currently applied on as built material.

Keywords: Selective laser melting (SLM), AlSi10Mg Alloy, shot peening, sand blasting, T6 heat treatment, post-processing treatments

Introduction

With the advancement of selective laser melting (SLM) technology great attention has been devoted to assess the performance of SLM parts under static and cyclic loading for structural applications. The available literature on the structural integrity of SLM material indicates that limited ductility, the presence of tensile residual stresses caused by the complex thermal history and the rather high defect density can adversely affect the structural integrity of SLM parts, particularly under cyclic loading. Moreover, compared to conventionally manufactured components, SLM parts, exhibit high degree of surface irregularity with randomly positioned balling features or satellites along the part's periphery, mainly caused by ball form solidified material or partially melted powders [1]. Although surface roughness can be desirable for some specific applications including orthopedic implants [2-4], the poor surface quality of the as built SLM fabricated parts, can seriously deteriorate their mechanical and tribological performance, affecting also their aesthetic functions [5, 6]. Poor control on surface morphology may likewise lead to limited dimensional control [7].

To address these challenges, mechanical and thermal post treatments can come into play for modulating the properties towards an improved fatigue behavior. Application of suitable heat treatments is proved to be efficient in releasing the detrimental tensile residual stresses and recovering some degree of ductility [8]. The variability of the surface roughness features are known to be highly affected by the SLM manufacturing conditions especially the orientation of the surface during fabrication [9, 10]. While the effect of process parameters including scan speed, laser power and hatching distance have been studied to enhance the surface finish quality of additive manufactured parts [11-14], the resultant surfaces representing highly irregular re-entrant features are still far from ideal surface finish. To address this shortcoming, additional finishing operations including mechanical milling and machining [15, 16], blasting [17, 18], precision grinding and magnetic field assisted finishing [19], laser re-melting [20-22] and chemical electro-polishing [23] have been exercised. These methods often deal with other drawbacks including limited efficiency, inconsistency and lack of repeatability, slow application rate and environmental issues [20, 24]. Besides, the efficiency of these surface polishing methods depends highly on the failure mechanism