Post-processing Additive Manufactured Parts for Enhanced Fatigue Performance

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ABSTRACT

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. Limited ductility, presence of tensile residual stresses and the rather high defect density, can adversely affect the structural integrity of SLM parts. Moreover, SLM parts, exhibit high degree of surface irregularity with randomly positioned balling features or satellites along the part's periphery, mainly caused by partially melted powders [1]. Poor surface quality and high surface roughness of the as built SLM parts can seriously deteriorate their mechanical and tribological performance, lead to limited dimensional control and affect their aesthetic functions. To address these challenges, mechanical and thermal post treatments can be used to obtain an improved fatigue behavior. Multiple surface finishing methods including mechanical milling and machining, laser re-melting and chemical electro-polishing have been exercised to enhance SLM surface quality. Apart from the additional costs, these methods commonly deal with other drawbacks including limited efficiency, inconsistency and lack of repeatability, slow application rate and environmental issues.

Herein, we investigate the effect of impact based surface treatments of sand blasting and shot peening on the surface quality and fatigue performance of SLM specimens. Despite following a quite similar concept in terms of impacting the target surface by shot stream, shot peening uses highly controlled peening media regarding size, geometry, impact velocity and exposure time compared to mildly controlled sand blasting treatment. We also paired these mechanical surface treatments with T6 heat treatment, which consists in a solution heat treatment followed by an artificial ageing and results in stress release and peak hardening of AlSi10Mg SLM specimens. This research was aimed at evaluation of the potential of impact based surface treatments paired with peak hardening to eliminate the need for an additional polishing step while promoting fatigue strength of SLM fabricated AlSi10Mg parts.

SLM specimens were manufactured using a SLMR 500HL system (SLM Solution Group AG, DE). Sand blasting was performed at a pressure of 0.7 MPa using micro-sphere glass medium with a diameter range of 200-300 µm. Shot peening was implemented using steel S170H medium (0.43 mm diameter), Almen intensity of 10A (0.001 inch) to a full surface coverage. T6 peak hardening thermal treatment was performed following the interval times and temperature range recommended in [2].
Six different sets of specimens were considered in order to investigate the sole effect of each post treatment as well as their synergistic influence on mechanical and physical properties of the SLM specimens. The studied series include as built (AB), heat treated (HT), sand blasted (SB), shot peened (SP), heat treated + sand blasted (HT+SB) and heat treated + shot peened (HT+SP).
Tensile test results reported in Table 1 indicated a notable difference between the quasi-static mechanical properties of the specimens before and after heat treatment, highlighting a significant increase in the elongation along with ultimate tensile strength reduction. SLM specimens exhibited an elastic modulus comparable with that of the conventionally manufactured cast material reported in EN1706 and [3] combined with higher yield and ultimate tensile strength. The elongation of the AB series is also comparable with that of the cast material; however, the HT specimens represented five times higher ductility.

Table 1: Monotonic mechanical properties of SLM specimens

	As built	Heat treated	Conventional material (EN1706 and [3])
Young modulus (GPa)	72 ± 1.5	73 ± 1	71
Yield stress (MPa)	273 ± 3	201 ± 6	180
Ultimate stress (MPa)	393 ± 20	265 ± 9	300-317
Elongation (%)	2.5 ± 0.4	13 ± 1	2.5-3.5

Fig. 1(a) reports the average roughness data on all series. As expected, AB and HT specimens exhibit similar surface roughness, which are quite higher than that of the surface treated series. Besides, measurements on AB and HT specimens were characterized by a quite high scatter considering the randomly located surface irregularities. The sand blasted specimens (SB and HT+SB) show quite similar roughness that are the lowest among all series. Whereas SP specimens represent higher surface roughness, that is further increased on the HT+SP specimens caused by the increased ductility. Fig. 1(b) and (c) respectively represent surface SEM morphology of AB and SP specimens. The AB specimen displayed a very irregular surface, characterized by randomly unmolten powder particles often forming agglomerates that lead to the high surface roughness. Shot peening strongly decreased imperfections on the surface reducing notably the number of the irregularities.

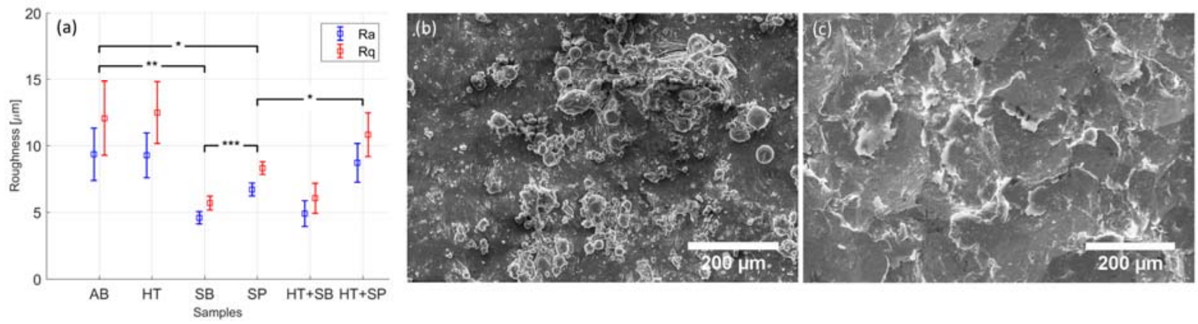

Figure 1: (a) Microscale surface roughness parameters; top surface SEM micrographs of (b) AB and (c) SP specimens (AB: as built, HT: heat treated, SB: sand blasted, SP: shot peened, HT+SB: heat treated and sand blasted, HT+SP: heat treated and shot peened)

Rotating bending fatigue strength corresponding to 3 million cycles indicated that the heat treatment considerably improved the poor fatigue performance of AB series up to 50%. Surface treatments further increased the fatigue strength, with the highest strength was obtained for SP series (270% improvement compare to as AB). The results indicate that besides regulating the surface roughness and reducing the effects of the discrete surface imperfections acting as stress raisers, these mechanical surface treatments are able to induce a compressive residual stresses field on the sub-surface layer of the treated material and thus enhance its fatigue performance.

References

[1] N.T. Aboulkhair, I. Maskery, C. Tuck, I. Ashcroft, N.M. Everitt, On the formation of AlSi10Mg single tracks and layers in selective laser melting: Microstructure and nano-mechanical properties. Journal of Materials Processing Technology, 230, 88-98, 2016.
[2] N.T. Aboulkhair, I. Maskery, C. Tuck, I. Ashcroft, N.M. Everitt, The microstructure and mechanical properties of selectively laser melted AlSi10Mg: The effect of a conventional T6-like heat treatment, Materials Science and Engineering: A, 667, 139-46, 2016.
[3] K. Kempen, L. Thijs, J. Van Humbeeck, J.P. Kruth, Mechanical properties of AlSi10Mg produced by selective laser melting, Physics Procedia, 39, 439-46, 2012.