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Assessment of experimental residual stresses measured into an additively manufactured 316L austenitic stainless steel with finite element simulations and effect of heat treatment on stress relief

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Laser powder bed fusion (LPBF) is a method for selectively or partly melting a bed of powdered material using a laser, where each subsequent layer of molten or partly melted material is bonded to the previous layer [1, 2]. The rapid cooling rates inherent to this process result in large stress gradients, which can have a significant effect on the performance during service of metallic components, reducing fatigue lifetime or provoking sudden localized failures. Thermal treatments applied after the build but before the components are removed from the build plate usually release these residual stresses (RS). As a result, estimating the RS and their distribution has become critical for maximizing the viability of manufacturing parameters. 316L austenitic stainless steel is a well-known and characterized steel in Additive Manufacturing (AM) that is industrially relevant. Because this material is stable against microstructural changes in temperature and segregation, it is a good choice for this study.

Two arch-shape samples with a hollow region have been manufactured to measure the RS in as-built and heat treated (HT) conditions. This HT was developed for stress relief on this steel based on microstructural and experimental analysis i.e., tensile and distortion tests. The microstructure of both samples was characterized by means of different techniques (i.e., LOM, FEG-SEM, EBSD, XRD, and hardness maps) and the RS were measured with non-destructive depth-resolved syn-chrotron X-ray diffraction experiments. RS measurements are compared to computer-based simu-lations. The novelty of this research is the combined evaluation of these three fields i.e., microstructure, experimental RS and calculated RS, all in all evaluated in an end use geometry. This work is being developed in the frame of the EU Horizon 2020 EASI-Stress project under grant agreement No 953219. The aim of the project is to standardized the use of non-destructive syn-chrotron x-ray and neutron diffraction based residual stress characterization and understand the formation and progression of RS to strengthen industrial access to these non-destructive large-scale facilities. As a result of this work, it is expected to produce more trust experimental data to develop more robust mathematical models.

References

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