Multiscale mechanical testing of hybrid additively manufactured 420 stainless steel

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Abstract

While additive manufacturing (AM) generally involves building components layer by layer, the term 'hybrid AM' refers to a process that combines printing with a secondary process such as machining or surface treatments. This approach enables the manufacturing of parts with complex geometries, tailored microstructures, and enhanced mechanical properties that are difficult to achieve with AM alone. In this context, printing was combined with interlayer laser peening of individual layers. Laser peening is a cold working surface treatment technique known for improving fatigue life through strain hardening and microstructure refinement. The hybridization of AM through interlayer laser peening is an effective approach to control grain size from printing, which enhances material properties by impeding dislocation motion at grain boundaries (1) or by a local strain hardening. By selectively incorporating laser-peened layers, it becomes possible to create architected materials with tailored mechanical properties. Despite this potential, the interplay between macroscopic and micro/nano properties remains unexplored. In addition, the alternation between printing and peening introduces complex thermal effects and microstructural variations in each layer, which are not yet well understood. The aim of this study is to understand the link between macro-, micro-, and nanoscale properties of interlayer peened 420 stainless steel. The resulting changes from cyclical printing and peening were characterized across multiple length scales, using macroscopic compression tests to assess overall mechanical properties, and locally via micropillars to evaluate small-scale behavior. It was revealed that though as-printed samples were tougher, interlayer laser peening increased ductility at the macroscopic level, with local gradients in mechanical properties observed across the build height. Knowledge of the texture created from interlayer peening will be further evaluated by examining the role of peened layers on the fracture behaviour of hybrid specimens, building on previous research conducted on as-printed samples (2). Understanding the structural architecture created by interlayer peening constitute a first step towards establishing a model linking manufacturing parameters to mechanical properties and optimizing peened layer placement in hybrid AM.

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