Materials Science & Engineering Doctoral Defense

On the Microstructure, Morphology, and Mechanics of Thin Wall Laser Powder Bed Fusion Structures

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Abstract

Applications such as heat exchangers, surface-based cellular structures, rotating blades, and waveguides rely on thin metal walls as crucial constituent elements of the structure. The design freedom enabled by laser powder bed fusion has led to an interest in exploiting this technology to further the performance of these components, many of which retain their as-built surface morphologies on account of their design complexity. However, there is limited understanding of how and why mechanical properties vary by wall thickness for specimens that are additively manufactured and maintain an as-printed surface finish. Critically, the contributions of microstructure and morphology to the mechanical behavior of thin wall laser powder bed fusion structures have yet to be systematically identified and decoupled. This work focuses on elucidating the room temperature quasi-static tensile and high cycle fatigue properties of as-printed, thin-wall Inconel 718 fabricated using laser powder bed fusion, with the aim of addressing this critical gap in the literature. Wall thicknesses studied range from 0.3 - 2.0 mm, and the effects of Hot Isostatic Pressing are also examined, with sheet metal specimens used as abase line for comparison. Statistical analyses are conducted to identify the significance of the dependence of properties on wall thickness and Hot Isostatic Pressing, as well as to examine correlations of these properties to section area, porosity, and surface roughness. A thorough microstructural study is complemented with a first-of-its-kind study of surface morphology to decouple their contributions and identify underlying causes for observed changes in mechanical properties. This thesis finds that mechanical properties in the quasi-static and fatigue framework do not see appreciable declines until specimen thickness is under 0.75 mm in thickness. The added Hot Isostatic Pressing heat treatment effectively closed pores, recrystallized the grain structure, and provided a more homogenous microstructure that benefits the modulus, tensile strength, elongation, and fatigue performance at higher stresses. Stress heterogeneities, primarily caused by surface defects, negatively affected the thinner specimens disproportionately. Without the use of the Hot Isostatic Pressing, the grain structure remained much more refined and benefitted the yield strength and fatigue endurance limit.

October 27, 2022; 3 PM;

Zoom Link: https://asu.zoom.us/j/87856108650