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DESIGN OF ADDITIVELY MANUFACTURED LIGHTWEIGHT STRUCTURAL COMPONENTS USING TOPOLOGY OPTIMIZATION

Abstract

Topology optimization is a powerful tool capable of generating component designs that offer significant mass reductions over existing concepts. Although applicable to a wide range of manufacturing processes, topology optimization is particularly well-suited to exploit the geometric freedom provided by additive manufacturing (AM) and is thus considered to be a key technology enabler to reach unprecedented levels of structural efficiency in components for space systems. Despite the ideal pairing of topology optimization and AM, these technologies must be fully integrated in order to harness their full potential, such as maximal reductions in mass, design cycle time, production (and post-production) time, and cost.

This talk will discuss a newly developed topology optimization framework that is tailorable to the specific capabilities of a manufacturing process. In particular, we will focus on the wire-fed process of Electron Beam Freeform Fabrication (EBF3) being studied at NASA Langley Research Center; EBF3 is particularly suitable for large scale components due to its high deposition rate. The topology optimization framework is based on projection methods and allows incorporation of manufacturing considerations directly into the design exploration, including minimum feature size and separation constraints, process-dependent material parameters, and geometric lineography. The design problem is posed formally as a requirements-driven optimization problem and solved using large scale gradient-based optimizers. A key feature of the approach is the mathematical consistency of the sensitivity analysis, allowing it to be readily extended to other wire-fed metal AM methods, provided that the geometric resolution and resultant material properties have been characterized. The resulting integrated design-manufacture framework is demonstrated on multiple case studies and is shown to successfully design lightweight structural components that are directly manufacturable.