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TOPOLOGY OPTIMIZATION FOR LIGHTWEIGHTING OF COMPONENTS CONSIDERING MANUFACTURING VARIABILITIES

Abstract

Space exploration poses an array of challenges, one of which stems from the balance of cost, mass, and structural reliability. Structural optimization, and specifically topology optimization, are powerful design tools for driving down the mass of structures and components. Yet for a given topology design, reducing mass requires thinning structural features, typically resulting in increased sensitivity to manufacturing variations, such as geometric imperfections (geometric variations) and material flaws (material property variations). This issue becomes amplified for most manufacturing processes, where decreasing feature sizes leads to increased variability in the manufacturing process output. This motivates the consideration of new structural topologies that are more robust (insensitive) to manufacturing variations. This paper discusses the integration of uncertainty quantification within the topology optimization framework such that the design process considers the possibility of manufacturing variations, ultimately enabling the design of lightweight components with robust structural performance. Various methods are considered, including intrusive and non-intrusive uncertainty quantification, and selective sampling approaches. The approach is coupled with manufacturing constraints in a requirements-driven design framework. Materials characterization of additively manufactured samples provides uncertainty data, which is then used to inform the probability distributions input into the robust topology optimization framework. The approach is demonstrated on structural component design problems and results confirm that components designed using robust topology optimization outperform those found considering only deterministic conditions when uncertainty is present.