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A new multi-material level set topology optimization method with the length scale control capability

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Abstract

Multi-material level set topology optimization methods conventionally rely on the overlap of multiple level set functions to realize the multi-material structural representation. However, this representation may produce redundant material phases and the signed distance information is no longer available within the individual material regions. To fix these issues, a new multi-material level set topology optimization method is proposed in this paper, where *m* level set functions represent *m* material phases plus the void, and the signed distance information is straightforwardly available in each material phase. To be specific, each level set function corresponds to a material phase and the overlapping areas are filled with an artificial material type, the property of which is weaker than any of the involved material types. This artificial material plays the role of penalizing the overlap areas to vanish, which is different from the close-to-zero property material type for the void. Hence, the optimization process starts with any multi-level set interpolated input and the overlapping areas will gradually vanish. Based on this new method, we have successfully realized the component length scale control on multi-material structures and innovatively, an approach has been proposed to realize the uniform component thickness control without need of pre-specifying the thickness target.

Keywords: Multi-material; Level set; Topology optimization; Length scale control

1. Introduction

Multi-material structure is a type of composite, and because of the combined multiple material properties, it has the potential to produce creative structural design with multi-functionality. On the other hand, because of the enlarged design space, it is impractical to perform the multi-material structural design through the conventional trial-and-error approach. Therefore, multi-material topology optimization has attracted a great deal of attention. Also, owing to the rapid development of additive manufacturing, physically producing the multi-material component at a reasonable cost is no longer a major issue. So far, multi-material topology optimization has been implemented under the main topology optimization frameworks, including SIMP (Solid Isotropic Material with Penalization) [1], ESO (Evolutionary Structural Optimization) [2], and level set [3,4], and a brief literature survey is presented in the rest of this section.