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Arbitrary void feature control in level set topology optimization

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Abstract

Feature-driven topology optimization has been extensively studied in the past decade, and the majority of the works have treated it as the multi-component/void layout optimization problem. A major limitation of this treatment is that the number of components/voids should be defined in advance. To overcome this limitation, this paper presents a novel void feature control method, through which the specified void feature (in any geometric form) could be well-contained by each interior void in the finalized topology design, regardless of the quantity. Numerical stability of this method is discussed and an auxiliary algorithm has been developed to enhance it. Other than that, the proposed method also serves the purpose of void length scale control, which is also a hot issue in the topology optimization field. To be specific, by tailoring the specified void feature size, the void length scale is guaranteed to be larger than that. To the authors' knowledge, the void length scale control was rarely studied under the level set framework. Through a few numerical case studies, it is proven that the void feature control method is effective while only limited compromise of the structural performance has been observed.

Keywords: Void feature control; Level set; Topology optimization; Length scale control

1. Introduction

Topology optimization has been actively investigated in the past few decades. So far, the SIMP (Solid Isotropic Material with Penalization) [1,2], ESO (Evolutionary Structural Optimization) [3], and level set [4,5] are the main topology optimization methods. These methods all have their unique characteristics and at the same time, are tightly associated. A broad range of design problems governed by different physical disciplines have been solved through these methods, i.e. solid mechanics [1,3–6], fluid dynamics [7–10], and thermal dynamics [1,11–14], etc. A few comprehensive literature surveys can be found in [15–20].

On the other hand, topology optimization is still not fully developed in several aspects, which include the feature-driven topology optimization and length scale control issue and will be highlighted in this work.

Feature-driven topology optimization is motivated by the need that engineering features are commonly-used design elements, which occasionally are forced to be preserved during freeform topology optimization process [21–23]. Hence, feature-driven topology optimization, so far, has mainly been treated as a multi-component/void layout optimization problem, where the components/voids only have DoF (degrees of freedom) of movement, rotation, and scaling. A major limitation is that the component/void feature quantity is pre-determined but cannot be dynamically changed during solution of

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