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A comprehensive study of feature definitions with solids and voids for topology optimization

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Abstract

In this paper, we present a CAD-oriented and feature-driven topology optimization methodology for engineering structures with freeform design domains. Mixed solid-void features are adopted as basic design primitives to build a unified formulation of feature definition, while pure solid or pure void features are considered as two special cases. Topology optimization is achieved as a Boolean intersection process between the so-called topology variation modeler (TVM) and freeform design domain modeler (FDDM) in terms of level-set functions (LSFs). The TVMs constructed with solid and/or void features are applied to clip the FDDM through Boolean operations. It is shown that sensitivity analysis with boundary integral scheme is independent of the mathematical expressions of the LSF. Numerical problems with freeform and periodic design domains are dealt with to demonstrate the proposed topology optimization method.

Keywords: Computer-aided design; Topology optimization; Feature-based design; Topology variation modeler; Freeform design domain modeler; Level-set function.

1. Introduction

In computer-aided design (CAD) systems, feature-based design is recognized as the basic enabling functionality with shape features as design primitives [1]. The common case is the parametric shape optimization where design variables are associated with the geometrical model instead of structural analysis model, e.g., the finite element model. Typical implementations are realized in conjunction with the body-fitted mesh or fixed mesh of the analysis model [2–7].

Topology optimization is an advanced design approach to find the optimal material layout within a specific design domain [8]. Homogenization method, density method and evolutionary structural optimization (ESO) method were historically developed and applied in various topology design problems [9–11]. Due to the fact that the definition of design variables is based on the finite element model in terms of elemental or nodal density variables, the design solution cannot reflect the intent of feature-based design. Alternatively, topology optimization is tackled in the way of generalized shape optimization with the introduction of level-set method (LSM). Design variables then rely on how the structural boundary is represented with zero level-set values, e.g., the interpolation of discrete level-set values at finite difference