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Topological shape optimization of multiphysics actuators using level set methods

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ABSTRACT

This paper proposes a topological shape optimization method for the design of multi-material piezoelectric actuators using a level set method of piecewise constants. A level set function taking level sets of piecewise constants is applied to implicitly represent design boundaries in a multiphase design domain, in which each constant level-set of the level set function denotes one material phase. As a result, only one indicator function consisting of different constants is required to identify multiphase interfaces by making use of its discontinuities. In the design of smart actuators with in-plane motions, the optimization problem is defined to minimize a smooth energy functional under specific constraints. Thus, the design of smart actuators is transferred into a numerical iterative process to update the piecewise constants of the indicator function using a semi-implicit additive operator splitting (AOS) scheme. In such a way, multiple material phases are distributed simultaneously in the design domain until the compliant host structure and its piezoelectric actuators are optimized, in which the compliant structure serves as a mechanical amplifier to enlarge the small strain stroke of piezoelectric actuators. The proposed method can avoid numerical difficulties in most conventional level set methods, such as the CFL condition, periodic re-initializations for a signed distance level set function and the non-differentiability related to the Heaviside and Delta functions. Two typical numerical examples are used to demonstrate the effectiveness of the proposed topological shape optimization method.

Keywords: Topological shape optimization; Level set methods; Smart actuators; Multiphysics;