Multi-material Topology optimization Considering Material Interfaces

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Abstract For multi-material structures, possible displacement discontinuity associated with material interfaces is an important issue concerning the structural integrity and durability. In most of existing topology optimization studies of multi-material structures, however, the interface of different materials was assumed to be perfectly bonded. In this study, we focus on topology optimization of multi-material structures considering interface behaviors described by the cohesive model. The multi-material Velocity Field-Level Set (VF-LS) method, in conjunction with the extended finite element method, is employed to represent the distribution of different material phases and to capture the evolution of the material interfaces. This enables modeling of possible separation of material interfaces, and thus provides a more realistic model of multi-material structures. The optimized designs considering interface behaviors exhibit tension/compression asymmetric topologies, in which material interfaces mainly undergo compression.

Material interface-related uncertainties induced by inter-diffusion or reactions between different materials may significantly worsen the actual performance of optimized structures. With the aim to develop a rational method to address this issue in the design of multi-material products implemented by some novel fabrication techniques, we also study robust shape and topology optimization method accounting for uncertain graded interface properties. Using the level set function to track the evolving material interfaces during the optimization process, we model the material interface uncertainties by introducing an intermediate zone with graded properties represented by a random field. The uncertain propagation analysis is implemented with the Polynomial Chaos expansion (PCE) to predict the stochastic response. Then the robust shape and topology optimization problem is stated as a multi-criteria optimization problem to minimize the expected value and the standard deviation of the structural mean compliance. Numerical examples demonstrate the effectiveness of the method.

References

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