ABSTRACT

Multi-Material Topology Optimization of IPMSM with Adhesive Interface Modeling

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Multi-Material Topology Optimization (MMTO) is gaining increasing attention in engineering design because it can improve performance by placing materials with customized properties in specific regions. Various interpolation methods have been developed to determine material distribution within MMTO. Among these, Discrete Material Optimization (DMO) is widely adopted due to its ability to control multiple candidate materials through independent design variables. However, the conventional DMO-based interpolation method cannot accurately represent the mechanical behavior at the interface between dissimilar materials, such as deformation mismatch and adhesive bonding effects. This limitation arises because conventional interpolation method fails to consider physical transition regions occurring at the interface and assumes a numerically perfect bonding state, thereby inducing abrupt discontinuity and numerical singularity in the interface boundary condition.

In motor topology optimization incorporating structural analysis, some researchers have simplified the model by weakening Young's modulus of permanent magnet (PM) to

the level of air. This is a conservative modeling approach that assumes a worst-case scenario where only iron withstands the force. However, this approach has limitations in that it cannot verify the stress of the PM and ignores the influence of the adhesive, which can lead to overdesign.

In this study, instead of adjusting the Young's modulus of the PM, we explicitly define the interface region between the iron and the PM and model the actual adhesive interface by assigning the property of the epoxy material to this region. The interface region is defined by applying a two-step filtering approach that utilizes the characteristics of the projection function. In the first filtering process, design variables are filtered and projected in the same manner as in the conventional 3-field topology optimization framework. In the second filtering process, the size of the interface region is controlled by filtering and projecting the results of the first process using adjusted filter radius and threshold parameter.

To evaluate the effectiveness of the proposed method, a comparative analysis was performed with results obtained by deriving the topology using the conventional DMO-based interpolation method and generating the interface through post-processing. The conventional method showed limitation in that the constraints activated during the optimization process were significantly violated after the interface was generated. On the other hand, the framework proposed in this study confirmed that it can consider the characteristics of interfaces between dissimilar materials by integrating two-step filtering-based adhesive interface recognition and generation tasks into the optimization loop in real time. As a result of numerical verification, the proposed method derived excellent topology optimization design results that satisfied the allowable stress constraint and improved average torque performance while achieving effective weight reduction compared to the reference model.