ABSTRACT

Material Interpolation and Joint Design in Multi-material Topology Optimization

Youngsuk Jung

Dept. of Automotive Engineering

The Graduate School

Hanyang University

The topology optimization method is a design technique that can find a layout from an unconstructed design space. It has been successfully applied in a variety of industries and is gaining attention with the development of additive manufacturing. This interest is directed to multi-material topology optimization (MMTO) to achieve a multi-functional and lightweight structure. Although MMTO is easily implemented by modifying the material interpolation function from single material topology optimization (SMTO), the diversity of design with multiple materials makes the optimization problem more complex and introduces additional manufacturability issues such as undesignable shapes and the joining problem.

In this thesis, guidelines are presented first to obtain the best solution by choosing

suitable material interpolation schemes concerning the material types and manufacturability. Although non-unique material interpolation schemes are employed for MMTO research, a study has not been carried out to compare the characteristics and performance of different material interpolation schemes concurrently. The performance profiles method is employed for measuring the general performance of different interpolation schemes because the optimized results depend on the initial design and the parameters. Second, a welding surface function, thermal stress design, and joint material design method are proposed to solve the manufacturability issues. In the MMTO problem, very small parts and a thin-coated structure around stiff material can appear during the optimization process. This is because the interface area between different materials is not considered, the welding surface function can control the complexity of the result by tradeoffs with performance. In addition, different thermal expansion coefficients of dissimilar materials can cause increases in stress on the interface under changes in temperature. Thermal stress design considering multiple temperature conditions can avoid undesired failure when a product is used in different temperatures. As the perfect bonding of dissimilar materials is only possible with the assumption of soft materials, the physical joint material design may be required for multi-material structures. A new joint material design method is proposed that can find the structural layout and the joint location simultaneously and can perform without the shape function modification or pre-structured mesh elements. Numerical examples are provided for the validation of the guidelines and the proposed methods. These include the magnetic problem, which has non-ordered material properties, as well as the well-known structural problem in topology optimization.