

ABSTRACT

Multiscale Topology Optimization for Heat Flux Manipulation

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Metamaterials, designed material to have material properties or characteristics that are not found in nature from a macroscopic perspective through changing geometry, composition ratio, and arrangement of dissimilar materials, are studied in various areas such as thermal, optical and electronic engineering. Heat flux manipulating device is one of the fields of thermal engineering of metamaterials, which can shield, concentrate, or change direction of heat flux from external heat sources. It can be used in a variety of fields, such as thermal dissipation modules, thermal power generators, and improving the efficiency of solar energy.

Topology optimization is often applied to obtain the targeted physical properties of metamaterials since it can find the layout which has optimal performance while satisfying the given analysis conditions and constraints. However, the material property expression of topology optimization is expressed as isotropic and have limitations in controlling the field variable such as heat flux, which varies highly in magnitude and direction depending on the anisotropic property of the material. In addition, excessive increase in the number of elements in order to derive optimal design results considering the size of microstructure can increase the computational time.

Multiscale topology optimization is a method that divides scales into macroscale and microscale and can obtain both optimal layout and optimal microstructures which constitute the layout concurrently. The material properties of the macroscopic finite element are expressed as effective properties of the microstructure calculated by homogenization method. This is suitable for the design of heat flux manipulating devices, since the effective properties of the elements can be expressed both isotropic and anisotropic. In addition, for problems where the design area and the analytical area are not identical, the design area can be subdivided into microstructure elements making it more efficient to calculate compared to single-scale topology optimization

Therefore, this paper proposes a new design for heat flux manipulation problem that could not be achieved by single-scale topology optimization through multiscale topology optimization. Three situations were selected to prevent, converge, and rotate the target area in the presence of external thermal flux, and optimal design was derived for each situation. In addition, the computational efficiency of multi-scale topology optimization resulting from decreasing elements of the analytical domain was verified by comparing objective functions and computing time to single-scale topology optimization.