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主 論 文 の 要 旨

論文題目　**A Study on Topology Optimization for Two-Dimensional Steady-State Heat Conduction Problems Using Boundary Element Method**
（２次元定常熱伝導問題に対する境界要素法を用いたトポロジー最適化に関する研究）

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論 文 内 容 の 要 旨

Topology optimization is one of the structural optimizations and is a mathematical approach to find the optimal material layout within the given design domain. The objective function appropriately defined reaches its optimum value after optimization under given constraints by using a certain numerical method to solve this optimization problem. It is the most flexible structural optimization compared with other sizing and shape optimizations since it allows appearances of holes in the optimum material layout. Topology optimization has received wide attention and has been implemented through the use of finite element methods based on plenty of optimization techniques, such as homogenization method (HM), solid isotropic material with penalization (SIMP), evolutionary structural optimization (ESO) and level set method (LSM). Based on these popular techniques, topology optimization has been applied to many physical problems and engineering applications such as mechanics, vibration, acoustic, thermal and electromagnetic problems. However, most of the approaches suffered some drawbacks such as checkerboard patterns, intermediate density material and dependency on initial configurations. Moreover, these approaches take much computational time and result in non-smooth boundaries.

This dissertation aims at constructing a level set-based topology optimization method using the boundary element method for heat conduction problems to find the optimal material configuration. The boundary element method is used for the heat conduction analyses by meshing the boundary of the material for each iterative step of optimization to avoid the intermediate density problems.

This dissertation is organized as follows: Chapter 1 includes a classification of structural optimizations and the development of the popular optimization techniques, and reviews starting from their appearance to working principles, applied problems, and advantages and disadvantages. Chapter 2 introduces the concept of the level set method to represent the property (material or void) of design domain, combining the boundary element method which is used to solve heat conduction problems, then constructs an time evolution equation for updating the level set function. In the evolution equation, topological derivative or sensitivity concept is introduced and a regularization term is used to control the complexity of the configurations; Chapter 3 provides a topology optimization algorithm and gives a discretization of the time evolution equation for updating level set function. Chapter 4 presents a treatment of the newly generated boundaries as insulating boundaries and derives the topological derivative under the insulating boundary condition for heat conduction problems using boundary element method. The correctness of the topological derivative and its dependency on mesh and initial configuration of the material are validated. Chapter 5 derives the topological derivative under the heat transfer boundary condition using the boundary element method and demonstrates its validation through a numerical example. Also, a topology optimization for two dimensional heat conduction problems under heat transfer boundary condition is developed. Chapter 6, while basing on the topology optimization scheme under heat transfer condition in preceding chapter, considers the cases in which the objective functions for the temperature and heat flux are also defined on the morphing boundaries generated through the iterative steps of the optimization computation. The topological derivatives of the objective functions both for the temperature and the heat flux are verified through numerical examples. The chapter also presents the topology optimization examples using the corresponding topological derivatives. Finally, Chapter 7 reaches the conclusions of this dissertation.

In conclusion, the level set-based topology optimization for two-dimensional heat conduction problems using the boundary element method under insulating boundary condition, heat transfer boundary condition, as well as morphing boundary considered in the objective functions of temperatures and the heat flux, are proposed. The use of the boundary element method and re-meshing of the boundaries through every iterative step of optimization computation enables this novel characteristic. The proposed method does not suffer checkerboard patterns, intermediate density and zigzag boundaries of the optimum layout of the material. Moreover, it can provide designers with various optimal configurations with smooth boundaries by adjusting the regularization parameter value. It possesses the advantage of easy meshing compared with the finite element method. Also, the boundary element method is especially convenient and accurate when objective function is defined on boundaries of the configurations. The level set method works well in obtaining boundary element information for solving heat conduction problems using boundary element method. Hereto, the significance of this work lies in the combination of the level set method and the boundary element method in topology optimization for heat conduction problems. Thus, the proposed method will have a great contribution in the designs of thermal devices in engineering applications. Meanwhile, it is suggested that the level set-based topology optimization combining with the boundary element method can be used in other physical problems, such as mechanics, acoustics, and electromagnetic problems, especially in the problems with objective functions defined on boundaries of the new material configurations.