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LEVEL SET-BASED TOPOLOGY OPTIMIZATION FOR A COUPLED THERMAL-FLUID PROBLEM USING THE LATTICE BOLTZMANN METHOD

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This paper presents a topology optimization method for a coupled thermal-fluid problem using the lattice Boltzmann method. In this study, the optimization problem is formulated as a heat exchange maximization problem to obtain optimal configurations that function as a high-performance cooling device.

Topology optimization [1], which offers the highest degree of design freedom among structural optimization methodologies, has been extensively applied to a variety of optimization design problems, such as stiffness maximization problems, thermal diffusion problems, and fluid dynamics problems. In 2003, Borrvall and Petersson [2] pioneered a topology optimization method for minimum power dissipation in a Stokes flow problem. Based on this methodology, many kinds of optimization problem dealing with fluid dynamics have been treated in recent research, for example in wing shape design problems and designs for fluid channel devices.

The above-mentioned studies use the finite element method (FEM) to compute the governing fluid equations, i.e., the Navier-Stokes equations, which, due to their nonlinearity, is computationally very costly. Since the state field in structural optimization problems must be computed at least once during an optimization iteration, such methodologies cannot easily deal with large-scale fluid optimization problems.

To overcome this problem, the lattice Boltzmann method (LBM) [3] has attracted attention as a new numerical scheme for computing incompressible viscous flow. The LBM, being based on kinetic theory, is a completely different approach than that of conventional numerical schemes such as the FEM. Since the LBM can be formulated as a linear explicit scheme for computing the flow field, its algorithm can be simply constructed. This advantageous property of the LBM holds even for computational flow fields that include complex flow problems such as thermal-fluid coupling problems and multiphase flow problems.

Exploiting the above advantage, this paper proposes a new topology optimization method using the LBM for a complex flow channel optimization problem dealing with a coupled thermal-fluid problem. Furthermore, the level set method is used to represent clear structural boundaries in the optimal configuration [4]. Several numerical examples are presented to validate the utility of the presented methodology.

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