11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

Topology optimization method for three-dimensional flow field using transient information of lattice Boltzmann method

K. Yonekura[1] and Y. Kanno[2]

[1] IHI Corporation
1 Shin-nakahara-cho, Isogo-ku, Yokohama 235-8501 Japan
kazuo_yonekura@ihi.co.jp

[2] Department of Mathematical Informatics, University of Tokyo
7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8656, Japan
kanno@mist.i.u-tokyo.ac.jp

Key Words: *Flow Optimization, Lattice Boltzmann Method, Sensitivity Analysis.*

A topology optimization method for three-dimensional flow field is formulated using the lattice Boltzmann method (LBM). In the field of flow topology optimization method, computational cost is too large from a practical point of view. In two-dimensional cases, the computation of a flow field is not so much long. However, in three-dimensional cases, the computation can be long due to its large number of degrees of freedom. Hence, it will cost long computation time to perform optimization for three-dimensional flow. In many conventional methods, the computation of the flow field and the update algorithm of design variables are executed separately. In contrast, in the present method they are coupled and solved together. In the optimization process, the sensitivity is computed using transient information of flow field. In addition, the computational cost is reduced by using LBM which often needs shorter time compared with the other computational fluid dynamics methods. The authors had reported previously that the computation time for two-dimensional example is sufficiently short. In this research, the method is applied to three-dimensional examples, and its computation time and stability are reported.

The objective functional in the present method is the dissipation functional. The domain is assumed to be composed of porous medium, and its porosity distribution is considered as a design variable. The fluid is assumed to be the Navier-Stokes fluid at low Reynolds number. The optimization method is formulated in the form of partial differential equations (PDEs). The PDEs consist of unsteady Navier-Stokes equations and time evolution equations of porosity distribution. Since the flow in the porous medium is subjected to a frictional force due to porous medium, the external force term of the Navier-Stokes equations depends on local porosity. When the PDEs are solved, the variables of the flow and the porosity distribution are updated all together. We solve the PDEs starting from an initial condition, and we will terminate when all the variables become independent of time. If all the variables of the PDEs converge to a steady state, then the porosity distribution attains the optimal solution. It is proved that the local optimality of the solution is guaranteed under the condition that all variables become independent of time in the final state.

The PDEs are formulated based on the Navier-Stokes equations. In order to solve the PDEs numerically, the Navier-Stokes equations are discretized as lattice Boltzmann equations which are solved by the LBM. Three-dimensional ninteen-velocity (D3Q19) model is used as three-dimensional LBM model. In the formulation of the time evolution equations of porosity distribution in the PDEs, the sensitivity of the objective functional is used. If we solve the Navier-Stokes equations directly, adjoint equations are necessary for calculating the sensitivity. In contrast, by using LBM in the formulation of PDEs, the sensitivity coefficients can be computed without adjoint equations. By avoiding adjoint equations, the computational cost is reduced.

In this research, three-dimensional examples are studied to demonstrate that the computational cost is sufficiently small from a practical point of view. The PDEs are stably solved in all examples.