A fluid topology optimization method using unsteady Lattice Boltzmann method for low Reynolds number flow

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We propose topology optimization method for low Reynolds number flow. In existing methods for flow topology optimization, design domain is updated only after flow has been totally calculated. To the contrary, in our approach, we update the design domain concurrently with solving fluid. In particular, flow is calculated for one time step delta t, then the domain is updated. Our approach is expected to need less calculation time than existing methods. The design domain is represented by porous medium which is widely used in existing methods. In this case, the design domain is assumed to be fulfilled by porous medium with local porosity, and local porosity is updated as a design variable. In this case, the porosity would change in the process of unsteady CFD calculation. Therefore, calculation condition is concerned to become ill-conditioned. To avoid calculation fail and execute stable calculation, we use Lattice Boltzmann method.
Lattice Boltzmann method is relatively new CFD method, whose algorithm is simple and stable. The algorithm does not contain iterative convergence calculation, and calculation complexity per a grid is less than many other CFD methods.

In our approach, the design domain is updated based on sensitivity analysis. The sensitivity is defined to optimize flow at just one time step future, since our approach updates domain at each one time step of CFD calculation. In this report, we derive this sensitivity. In general, we need adjoint variables in a formulation of sensitivity for Navier-Stokes equations. However, in our formulation, we do not necessarily need adjoint variables. It is due to the fact that the sensitivity is just for one time step future and we use Lattice Boltzmann equations.

The proposing method is formulated for quasi-static flow, in other words, for low Reynolds number flow. In this report, we show some numerical examples. Examples show that lattice Boltzmann method can solve the flow stably even though the porosity changes its value during the calculation.