

# **An Efficient Immersed Boundary Method for Simulation of Heat and Mass Transfer Problems**

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The immersed boundary method (IBM) has been proven to be an effective technique for the study of flow characteristics with complex geometries. It models the effect of the immersed boundary to the surrounding fluid through the introduction of forcing terms in the momentum equations. In this regard, IBM has a difficulty to be directly applied to heat transfer problems since they also involve the energy equation. Currently, very few work is available in the literature to apply IBM for thermal flow problems. Among available works in the literature, a heat source term is usually introduced in the energy equation to consider the effect of the immersed boundary. However, like the conventional IBM, the heat source term is computed explicitly and is pre-calculated, and there is no mechanism to enforce the boundary condition for temperature (Dirichlet condition) and heat flux (Neumann condition). Consequently, the physical boundary condition is not accurately satisfied. In this work, we target on this challenging issue and present the boundary condition-enforced IBM for simulation of thermal flow problems. The essence of the method is that the heat source/sink is not calculated in advance. Instead, it is considered as unknown and determined in such a way that the physical condition at the boundary point is enforced. For the thermal flow problem, accurate and effective calculation of average Nusselt number is a critical issue. This work also presents two simple and efficient ways to compute the mean Nusselt number directly from the temperature correction at Eulerian points and heat flux at Lagrangian points, which completely avoid evaluation of temperature gradients at the boundary points. Numerical experiments for both forced convection and natural convection problems are conducted to demonstrate the capability and efficiency of present method, and proposed ways to calculate the average Nusselt number. The obtained numerical results agree very well with available data in the literature.