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# High-fidelity simulations of turbulent heat transfer on bluff bodies

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## ABSTRACT

The immersed boundary (IB) method has been widely used as a practical approach to model flow problems involving very complex geometries or moving bodies. In the present study, the IB method has been used as an efficient tool for a multi-material heat transfer problem - a cylinder in a channel heated from below ([1]). This problem involves complexities such as transition, turbulent natural convection, and interaction of fluid convection and solid conduction (conjugate heat transfer). Figure 1 and 2 show the instantaneous temperature contours from the side $(x - y)$ and the top $(x - z)$ views. The objective is to show that LES/DNS is easily applied to a conjugate heat transfer problem with the IB method by presenting accurate prediction of the wall heat flux. The method used in the present study is based on a second order velocity reconstruction near the immersed boundary. A novel algorithm has been developed to satisfy global and local mass conservation near the IB. Validation cases show that the current approach leads to good predictions of wall variables like the pressure and Nusselt number. The fluid-solid interface is constructed as a group of adjoining Cartesian faces from heterogeneous material zones. A communication tool for the interface group was developed such that continuity of the scalar and conservation of the flux are satisfied in an asymmetric way with second order accuracy. The local mesh refinement technique has been employed in order to reduce the overall mesh size. We found that the local mesh refinement technique is crucial when large geometric scale differences are present like in our heated cylinder problem. LES predictions of the local Nusselt number show a good agreement with the previous experiment (Figure 3). The effect of the subgrid-scale model on transition is present only in the entry region and is marginal on the heat flux at the cylinder. Also, the effect of the Boussinesq approximation on this problem was investigated. Although the fluid is water and has a small thermal expansion coefficient, the Boussinesq approximation and variable density formulation show somewhat different behavior of the large scale structures in the entry and transitional regions.

## REFERENCES

[1] G.M. Laskowski, S.P. Kearney, G. Evans, and R. Greif. "Mixed convection heat transfer to and from a horizontal cylinder in cross-flow with heating from below". *Int. J. Heat Fluid Flow*, Vol. **28**, 454–468, 2007.

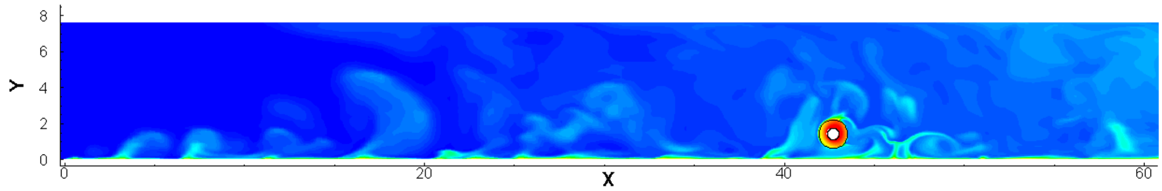


Figure 1: Contours of the instantaneous temperature: $x - y$ plane.

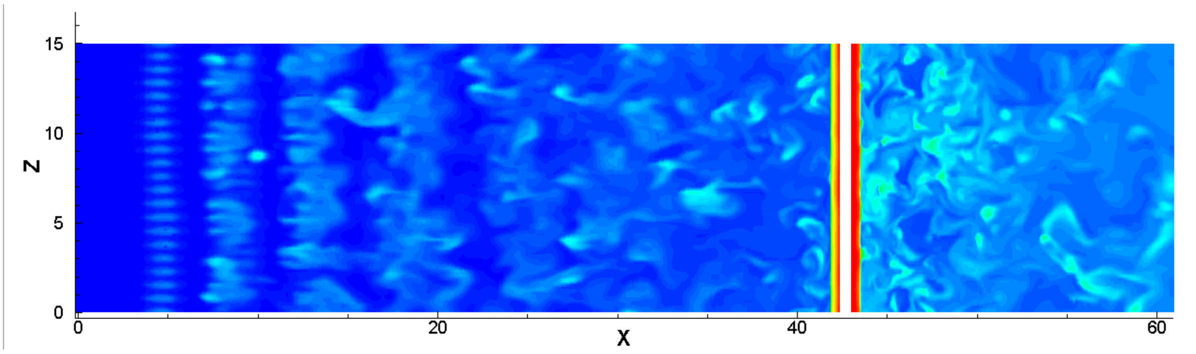


Figure 2: Contours of the instantaneous temperature: $x - z$ plane.

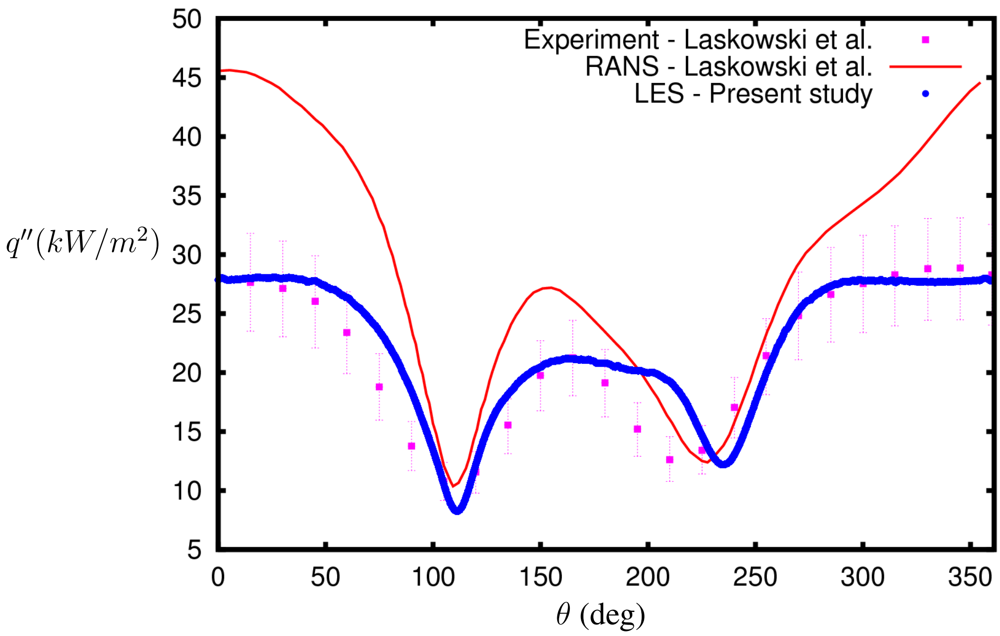


Figure 3: Averaged heat flux on the cylinder outer wall.