Eulerian-Lagrangian Simulation on Microbubbles in Turbulent Channel Flow

Xiaosong Zhang*, Jianhua Wang and Decheng Wan†

Collaborative Innovation Center for Advanced Ship and Deep-Sea Exploration
State Key Laboratory of Ocean Engineering
School of Naval Architecture, Ocean and Civil Engineering
Shanghai Jiao Tong University, Shanghai, China
†Corresponding Author, e-mail: dcwan@sjtu.edu.cn

ABSTRACT

In recently years, microbubble drag reduction technology is getting more and more attention because it can reduce frictional resistance of ships significantly. Microbubbles can reduce surface friction by a variation of the viscosity of the fluid around the ship and makes a modification in the structure of the turbulent boundary layer. However, underlying physical mechanism of drag reduction is not well understood. In this paper, the authors tend to use Euler-Lagrange method to study the interaction between microbubbles and a fully developed turbulent channel flow.

In the present study, turbulent flow field is solved using large eddy simulation (LES) method. The microbubble trajectories were tracked by the motion equation following Newton's second law in Lagrangian framework. Four-way coupling method is adopted in the calculation. Specifically, both the force of the fluid on the bubble and the reaction of the bubble on the fluid are considered in the calculation. At the same time, the interaction between bubbles is simulated using soft-sphere model. The collision process and collision deformation are calculated. The computational code is developed based on the open-source platform OpenFOAM to form a solver dealing with bubbly flow.

Before introducing bubbles, a fully developed single-phase turbulent channel flow is obtained at shear Reynolds numbers $\mathrm{Re}_\tau = 375$. The mean streamwise velocity, turbulent normal and shear stresses are verified by comparison with standard DNS results [1]. Microbubbles are injected uniformly into the channel and eventually form a bubble layer on the upper plate due to buoyancy. About 6% drag reduction effect is obtained in the steady state. The drag reduction effect results from two aspects: On the one hand, microbubbles attached to the wall change the local viscosity. On the other hand, turbulent vortexes are inhibited by microbubbles in a certain degree. Both turbulent intensities and Reynolds stress decrease in the presence of microbubbles.

REFERENCES

[1] Moser, R.D., Kim, J., Mansour, N.N. "Direct numerical simulation of turbulent channel flow up to Re τ= 590", *Physics of Fluids*, Vol. **11**, pp. 943–945, (1999).