Hydrodynamics of plates in cross-flow near the free-surface

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Abstract

The flow around flat plates in cross-flow is an example of a canonical bluff body flow, that received much of the deserved attention several decades ago. Since then, only a few works have been devoted to the understanding for example, of the effects that parameters such as the aspect ratio, have on the drag forces that the plate generates.

We conducted simulations and experiments, including qualitative and quantitative flow visualization, in order to analyse the near wake structures and the forces on the plates. Initially, we studied a flat plate of varying aspect ratio in a domain in which boundaries did not play an important role. Afterwards, we studied the case of the plate being at different submergence depths. The drag on the plate increases abruptly prior subsiding with increasing submergence depth, with this jump in drag being more prominent in low aspect ratio plates. The abrupt rise in the drag is due to the existence of a gap-flow at the free surface and the modification of the recirculating flow region in the wake of the plate.

Moreover, we conducted experiments involving strategically located pores aiming drag reduction, especially when near the free surface. The porous models presented trends in drag that were similar to those observed in rigid plates, but it was confirmed that the location of the holes as well as their angle of orientation plays a major role in drag modulation. Both concepts resulted in significant drag reduction, especially near the free surface. The mechanism of drag reduction for porous models has been shown to be caused by the interaction between the jets formed at the holes, the shear layers and the gap-flow. Finally, the case of the plates being flexible and near the free surface was also studied, were reconfiguration leads to drag reduction away and near the free surface.