CFD simulation of turbulent flow over immersed bluff bodies modified by porous materials

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Key Words: *Turbulent flow, Bluff body, Porous, flow control, CFD*

There is evidence that the application of porous media to the surfaces of bluff bodies immersed in turbulent fluid flows has a profound effect on the associated aerodynamic phenomena [1]. The majority of the numerical studies on flow around circular cylinders that have had their surfaces modified by porous media find that the drag coefficient is reduced and the shedding of vortices is delayed [2,3]. This idea is further explored in this study by performing a series of simulations on a square cylinder. The square bluff body was modified so that its upstream and downstream halves consisted of solid and porous materials respectively. Values of permeability equal to 4.64×10^{-7} m^2, and 6.87×10^{-8} m^2 with the corresponding porosities of 91.8%, and 82.1% have been used for the porous material. Three-dimensional, unsteady and turbulent flows around a square cylinder were studied numerically. The governing equations, together with the relevant boundary conditions, are solved using the finite-volume method (FVM). Reynolds-averaged Navier–Stokes (URANS) method at a Reynolds number of about 53,000 based on the height of the square cylinder has been used. The results are compared and validated against experimental data. The fluctuating forces and velocity distribution in the wake of the cylinder are analysed, and the effects of permeability on aerodynamic features such as wake structure, and streamlines are explored and compared with those generated by a solid square cylinder. The numerical results reveal that permeability has a profound effect on flow characteristics of the wake of the square cylinder and significantly mitigated the fluctuations of aerodynamic forces. As a result, vortex shedding from a bluff body that has a porous region is suppressed. It is also found that the aerodynamic forces and velocity distribution in the wake of the cylinder are sensitive to the permeability of the porous medium. The numerical results indicate that the wake length and shear width increase in the presence of porous material and as might be expected, the largest effect was observed in the wake generated by the most permeable material.

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