Numerical investigation of hydrodynamic coupling between a falling immersed sphere and its downstream wall

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Abstract

Hydrodynamic coupling between a fully immersed sphere when it descends towards a downstream horizontal wall in an incompressible viscous liquid has been investigated experimentally. As a consequence of wall-augmented hydrodynamic force, additional deceleration was detected and the interstitial distance, δ, at which the velocity drop reaches 5% of that measured without the wall was employed to define hydrodynamic coupling in a consistent manner. Through systematic experiments, we measured a monotonic decay of δ with the descend particle Stokes number, St, which number compares the particle inertia to the viscous drag of a characteristic value of Stokes' drag. Scaled by the sphere radius, the non-dimensional coupling distance δ^* is found to decay linearly with *St* as reported by Izard et al. (2014) but a faster exponential decay with *St* was found at greater *St*. In this work, we investigate this coupling phenomenon and the associated flow field via numerical simulation on the framework of the pressure implicit operator splitting (PISO) method with a finite volume scheme. Special treatment was made to suppress unphysical pressure field oscillation within the simulated sphere boundary so that the resulting vortex structure and hence the associated hydrodynamic force can be computed with greater accuracy. We reproduce the measured δ^*-*St* trend, fitted a relation $\delta(\mathrm{St})=\mathrm{ASt}^{-\mathrm{B}}\mathrm{e}^{-\mathrm{CSt}}$ and then discuss the findings with numerically revealed flow structure.

Keywords: **Hydrodynamic coupling, flow-body interaction, Stokes number, vortex structure, PISO,**