A forcing fictitious domain/immersed boundary method for super-quadric shape of particulate flow simulation of cementitious material

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ABSTRACT

Fictitious domain/immersed boundary method (FD/IBM) has recently been used for particulate flows[1] and complex fluid-solid interaction problems[2,3]. The advantage of FD/IBM over the body-fitted method is that it substantially simplifies grid generation for immersed geometries, and it is easier to handle moving boundary situations. FD/IBM even allows the use of a stationary and non-deformation background mesh, as well as it reduces the cost of computation by avoiding generation of a body-fitted mesh for each time step.

In this work, we develop a new platform to directly simulate super-quadric (SQ) particles in fluid based on a forcing fictitious domain method. Specifically, a super-quadric particle function is used to represent particle with varying shapes and sizes as encountered for concrete and mortar. The immersion of particles in fluid is handled by imposing a rigidity solid body motion in the particle domain, as well as adding a forcing term to the Navier-stokes equation by integral of pressure gradient and particle related velocity over the whole particle domain. Particle shapes are given by changing the super-quadric parameters of SQ equation. Particle motions, which occur during pumping of cementitious material, can be calculated and tracked by solving Newton’s equations of motions using the extended discrete element method (XDEM)[4] while the data of fluid flow properties are obtained by solving the Navier-Stokes equations which govern the fluid phase. Hence, a particle interface resolving solver is developed by coupling XDEM and IBM. We validate our solver by performing flow around particles and free falling of a particle in channel at different parameters in 2D and 3D. The final objective of this work is to develop a particle resolved direct numerical simulation platform to predict highly packed fluids with different shapes of particles and over a wide range of particle sizes.

Keywords: fictitious domain, immersed boundary, super-quadric, XDEM, particle flow, cementitious mortar

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