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Eulerian-Eulerian modelling of gas-solid suspensions with bidisperse charged particles

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Abstract

Gas-solid flow systems have implications of a build-up of electrostatic charge in many industrial processes such as fluidized bed polymerization reactors, pneumatic transports of fine powder, etc. The electrostatic charge significantly alters the hydrodynamics and cause particle clustering and sheeting at solid boundaries. The accumulation of charge can also cause hazards such explosions in silo storages or pneumatic conveying [1]. Several modelling approaches have been developed to study the electrostatic charge and its interplay with the flow hydrodynamics. The Eulerian-Lagrangian approaches, where the locally-averaged equations of motion for the fluid phase are solved in an Eulerian framework (often denoted simply as CFD of the gas phase) and the particles are tracked in a Lagrangian fashion by solving Newton's equations (called as DEM) with a charge transfer model, have been used for widespread applications [2]. However, this approach is limited to very small laboratory-scale flow configurations and not affordable for large industrial scale applications due to the computational expenses. Alternatively, the Eulerian-Eulerian (or called two-fluid) models, where solid and fluid phases are modelled as interpenetrating continua, have been developed for gas-solid flows at industrial-scale using the kinetic theory of granular flow [3] for last few decades. Very recently, the electrostatic charge has been included into these models via an additional transport equation for the mean charge evolution in gas-solid systems with mono-disperse particles [4].

In this study, we proposed a Eulerian-Eulerian model for gas-solid flows with *binary mixture* of charged particles. We used the Boltzmann equation to describe the statistical behaviour of gas-solid mixture. Using a number density function, *f*, defined as a Maxwellian distribution both for charge and velocity of solid phases and the collisional operators closed by following Jenkins and Mancini [5], we derived the transport equations for mass, charge, momentum and the fluctuating kinetic energy and the constitutive relations for particle properties such as charge conductivity and diffusivity. The derived models have been assessed through hard-sphere simulations in a periodic 1D domain. Several simulations have been performed with varying diameter, the domain-averaged solid volume fraction inside and the fluctuating kinetic energy of each phase. The model predictions are in a good agreement with the hard-sphere simulations results. For further studies, we will implement these models into an open-source multiphysics platform, OpenFOAM, to simulate realistic flow configurations and validate the models with available experimental data in literature.

References

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