On the Effect of Static and Dynamic Particle Size Distribution on Flow Turbulence Modulation

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ABSTRACT

The structures in a turbulent flow are known to be highly complex, associated with time-dependent, three-dimensional phenomena covering a wide range of spatial and temporal scales. The degree of the complexity increases with the introduction of a dispersed particle phase. Additional effects include the interaction between phases in terms of mass, momentum and energy (as applicable) exchange, the interaction between particles and the walls, and particle collision, agglomeration and breakup. Since the system performance is a complex function of such underlying phenomena, a detailed knowledge regarding the hydrodynamics and the evolution of the dispersed phase is essential for understanding the system. The governing features of the dispersed phase are its size and velocity distributions, both of which have a major influence on the flow turbulence.

Previous works have focused on the effect of particle size distribution (PSD) on fluid turbulence. These have been performed by studying two-way coupling and four-way coupling where the effects of two-way coupling between the particles and the flow, and inter-particle collisions, on fluid turbulence are considered. To the best of our knowledge, there has been no work on the effect of an evolving PSD due of particle agglomeration and breakup on turbulence modulation. Work to date therefore considered the effect of a static, poly-dispersed PSD on turbulence modulation. In this paper, an eddy-resolving simulation for prediction of the fluid velocity distribution is adopted to improve confidence in the results. Large eddy simulation (LES) is preferred to direct numerical simulation (DNS) to benefit from LES's lower computational cost as compared to DNS. Discrete particle simulation (DPS) taking into account particle drag, shear-lift, pressure gradient, added mass forces and sub-grid scale velocity fluctuation contributions on particle acceleration is applied to treat the particle dynamics in the turbulent flow. The classical particle-in-cell technique is used to treat the two-way coupling. In resolving the four-way coupling aspect, the search for possible binary particle collisions is based on a deterministic method following domain decomposition. The outcome of all collisions are determined using a hard-sphere collision model while all collisions are subjected to an energy-balance agglomeration to test for possible agglomeration [1]. All agglomerates are subjected to hydrodynamic shear stresses for possible breakup of agglomerates [2].

The LES-DPS developed for predicting the dynamic PSD and turbulence modulation is tested on flows of relevance to the transport of nuclear waste sludge. Channel flow is the simulation domain while calcite particles suspended in water are the nuclear waste simulant. Results will be presented in terms of the PSD, and profiles of fluid and particle velocities, with simulation time, focussing on the impact of the evolving particle size distribution on the flow turbulence.

REFERENCES

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