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Insights into Particle Dispersion, Agglomeration and Deposition in Turbulent Channel Flow

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Abstract : The work described in this paper was undertaken to gain insight into fundamental aspects of turbulent gas-particle flows with relevance to processes employed in a wide range of applications, such as oil and gas flow assurance in pipes, powder dispersion from dry powder inhalers, and particle resuspension in nuclear waste ponds, to name but a few. In particular, the influence of particle interaction and fluid phase behavior in turbulent flow on particle dispersion in a horizontal channel is investigated. The mathematical modeling technique used is based on the large eddy simulation (LES) methodology embodied in the commercial CFD code FLUENT, with flow solutions provided by this approach coupled to a second commercial code, EDEM, based on the discrete element method (DEM) which is used for the prediction of particle motion and interaction. The results generated by LES for the fluid phase have been validated against direct numerical simulations (DNS) for three different channel flows with shear Reynolds numbers, Reτ = 150, 300 and 590. Overall, the LES shows good agreement, with mean velocities and normal and shear stresses matching those of the DNS in both magnitude and position. The research work has focused on the prediction of those conditions favoring particle aggregation and deposition within turbulent flows. Simulations have been carried out to investigate the effects of particle size, density and concentration on particle agglomeration. Furthermore, particles with different surface properties have been simulated in three channel flows with different levels of flow turbulence, achieved by increasing the Reynolds number of the flow. The simulations mimic the conditions of two-phase, fluid-solid flows frequently encountered in domestic, commercial and industrial applications, for example, air conditioning and refrigeration units, heat exchangers, oil and gas suction and pressure lines. The particle size, density, surface energy and volume fractions selected are 45.6, 102 and 150 μm, 250, 1000 and 2159 kg m-3, 50, 500, and 5000 mJ m-2 and 7.84 × 10-6, 2.8 × 10-5, and 1 × 10-4, respectively; such particle properties are associated with particles found in soil, as well as metals and oxides prevalent in turbulent bounded fluid-solid flows due to erosion and corrosion of inner pipe walls. It has been found that the turbulence structure of the flow dominates the motion of the particles, creating particle-particle interactions, with most of these interactions taking place at locations close to the channel walls and in regions of high turbulence where their agglomeration is aided both by the high levels of turbulence and the high concentration of particles. A positive relationship between particle surface energy, concentration, size and density, and agglomeration was observed. Moreover, the results derived for the three Reynolds numbers considered show that the rate of agglomeration is strongly influenced for high surface energy particles by, and increases with, the intensity of the flow turbulence. In contrast, for lower surface energy particles, the rate of agglomeration diminishes with an increase in flow turbulence intensity.

Keywords : agglomeration, channel flow, DEM, LES, turbulence
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