Effect of particle diameter on agglomeration dynamics in multiphase turbulent channel flows

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ABSTRACT

Densely dispersed particle-laden fluid systems are ubiquitous in nature and industry, such as atmospheric transport, blood drop forensics and mineral processing. In particular, the nuclear industry depends on a comprehensive understanding of the particle-scale and system-scale processes associated with such flows in order to predict the long-term behaviour of waste suspension slurries. At high particle-fluid volume fractions, the dynamics of both phases are governed by interparticle collisions, which in most cases can lead to particle-particle adhesion or agglomeration due to electrokinetic interactions. The ability to understand and predict the resultant flow effects due to this behaviour would be invaluable in optimising present transport systems and developing future, more efficient ones.

Recent advances in computational performance allows for extremely accurate prediction of the continuous phase via direct numerical simulation (DNS). Alongside this, Lagrangian particle tracking (LPT) provides a promising tool for which the discrete solid phase trajectories are calculated. Other mechanisms such as particle-fluid momentum feedback and interparticle collisions are also important for flows with high mass-fraction. This work uses the above techniques in the form of a fully coupled DNS-LPT solver[1] in conjunction with a collision energy-based deterministic agglomeration algorithm[2] to determine the effect of particle diameter on the aggregation properties of a wall-bounded particle-laden channel flow at shear Reynolds number, $Re_\tau=180$.

Three primary particle diameters are considered of relevance to the nuclear industry resembling 200μm - 400μm calcite particles dispersed in water, with a Hamaker constant of 3.8×10^{-20}J. The simulations are initialized with randomly dispersed particles of numbers calculated to ensure a constant volume fraction $\Phi_P = 10^{-3}$. Analysis is focused on elucidating the various mechanisms for both collision and agglomeration throughout the wall-normal channel flow regions over time as well as determining the role of particle-turbulence interaction on aggregation dynamics.

Results indicate a decrease in particle agglomeration efficiency as diameter is increased, which provides for a reduction in agglomeration rate at large time scales as the particles begin to aggregate and the mean agglomerate diameter increases. Further to this, the normalized number of collisions is similar in all simulations, with the smallest particles showing a slightly increased collision rate. Arguments associated with energy dispersed in collisions are presented to substantiate this claim. Collision rates across the channel are approximately constant with a slight increase close to the walls which, when normalized by the total number of primary particles, are actually favoured by smaller particles. Analysis will be used to correlate particle behaviour in each region of the channel flow with subsequent collision and agglomeration rates. For instance, the mean energy dispersed in collisions can be compared to the mean angle of collision, a behaviour which varies throughout the channel. This information provides important knowledge surrounding the aggregation dynamics in different types of turbulence.

REFERENCES

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