CFD SIMULATION OF FLUID-PARTICLE AND PARTICLE-PARTICLE INTERACTION IN PACKED AND FLUIDISED BEDS

G.R. Kumar REDDY and J.B. JOSHI
Institute of Chemical Technology, Matunga, Mumbai-400 019, INDIA

ABSTRACT
Solid-liquid fluidized beds are used widely in industry for hydrometallurgical, catalytic cracking, ion exchange, adsorption, crystallisation, sedimentation, and particle classification. In each of these operations, size and density distribution of particles is present and influence bed expansion, particle segregation and overall motion of both liquid and particles. It is these properties that govern heat and mass transfer and reaction rates and determine bed volume and residence time requirements.

This study investigates experimentally and computationally a number of phenomena underlying the behaviour of fixed and fluidised beds. Both instantaneous and time-average velocity measurements have been performed in a refractive index matched bed to obtain local energy dissipation rates. A commercially available CFD code (FLUENT) was used to simulate bed composition, liquid flow rate and end effects on fluid-particle drag across fixed beds. Computationally, a number of phenomena underlying the behaviour of fixed and fluidised beds was explored. The FLUENT analysis was extended to binary particle size systems to explore the behaviour of segregation and intermixing. Binary mixtures with ratio of terminal settling velocity range 1.2-3.2 and Reynolds number from 0.33 to 2080 were investigated. The computational model was in good agreement with experimental observations and predicted the layer inversion phenomena due to different size and density as well as the critical velocity at which the complete mixing of the two particle species occurred.

DIRECT NUMERICAL SIMULATION (DNS)
A DNS code was developed to model the fluid flow around a freely falling sphere. Briefly, the code is a non-Lagrangian multiplier based fictitious-domain method as described by Veeramani et al. (2007). Simulations were performed in the range 1<Re<210, with excellent agreement with published experimental values for the separation angle (θ) and the normalized wake length (L/dₚ). For Re=200, it was found the wake generated by the freely falling sphere was identical to that of a fixed sphere. At Re=210, a double threaded wake was observed, resembling the experimental observations of Magarvey and MacLatchy (1961). Computationally, the instability in the wake gave rise to a lift force resulting in the rotation and lateral migration of the sphere. Under these conditions the lift coefficient for the freely falling sphere was 1.8 times greater than that for the fixed sphere.

The DNS modelling was extended to multi-particle (9, 27, 100, 180 and 245) systems to examine the influence of hindrance on the wake dynamics, settling velocity and drag coefficient of individual spherical particles. A moving reference frame was used at the center of mass of each sphere along the flow direction so that the finely resolved grid region was retained for each instant in time. It was found that the time averaged settling velocity of an individual particle decreased with an increase in the number of particles surrounding it, and resulted in a decrease in the swarm velocity. For the simulation involving 245 particles the predicted bed voidage was in...
good agreement with the Richardson and Zaki (1954) correlation.

Finally, the drag coefficient and suspension viscosity computed for the DNS simulations have been compared with published experimental results (e.g. de Kruij et al., 1985; Gibilaro et al., 2007) and models (e.g. Einstein, 1906; Frankel and Acrivos, 1967). At low solids concentration, the suspension viscosity models were similar and in good agreement with the DNS simulations. At solids concentrations above about 10 percent there was wide variation between the models, with the DNS simulations matching closely the work of Frankel and Acrivos (1967). The DNS modelling has shown that suspension behaviour can be correctly predicted without introducing the notion of suspension viscosity once the force interactions between particles has been properly resolved.

REFERENCES


