CFD Study on Hydrodynamics in Inclination-Augmented Liquid-Solid Fluidized Beds

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Liquid-solid fluidized beds find applications in a wide range of industries, including coal beneficiation, chemical processing, pharmaceutical manufacturing, biochemical technology, food processing, and wastewater treatment. Most fluidization studies so far have been conducted with traditional straight columns. The comprehension of fluidization processes in inclined systems such as the inclined fluidized beds and inclination-augmented liquid-solid fluidized (LSFB) are constrained and have not been thoroughly examined. The inclination-augmented LSFB such as the Reflux Classifier (RC) has been widely used in the mineral industries to isolate coal and mineral particles based on their size and density. Due to the intricacy of the liquid-solid flow and interfacial forces, the hydrodynamic behavior of an inclination-augmented LSFB exhibits greater complexity compared to that of a conventionally vertical fluidized bed. A two-dimensional transient model is developed to simulate the flow hydrodynamics of mono-disperse particles in an inclined augmented liquid-solid fluidized bed using the computational fluid dynamics (CFD) method. The unsteady behavior of this two-phase flow was simulated by using the Eulerian–Eulerian method coupled with the Kinetic Theory of Granular Flow model.

Firstly, a 2D CFD model was developed to perform a sensitivity analysis of the crucial CFD parameters required to effectively describe the bed hydrodynamics of an inclination-augmented LSFB, which will apply to the CFD model development of RCs on a commercial scale. There are numerous of literature available for conventional fluidized beds, and also a few have modeled inclined channels using CFD models. However, there is still no consensus on how to choose appropriate closure models and sensitive model parameters in CFD modeling of an inclination-augmented LSFB, i.e., liquid-solid fluidized bed containing an inclined section at the top. Therefore, in this work, the influences of various crucial CFD parameters like interphase drag force, lift force, solid viscosity model, particle-particle restitution coefficient, and particle-wall specularity coefficient on average are thoroughly demonstrated to realize their impact on the hydrodynamic behavior. This study suggests that for an inclination-augmented LSFB, choosing suitable drag models and taking lift force into account have a significant improvement in the model predictions.

Later, the influence of the inclination angle of the inclined augmented fluidized bed, the number of parallel inclined plates in the inclined section on the bed hydrodynamics, and solids flow characteristics were analyzed for both mono-disperse and polydisperse particles. The results were analyzed and discussed in detail in terms of average solid volume fraction, length of solid suspension, pressure drop, vorticity, lateral distribution of solid horizontal velocity, vertical velocity, and solid volume fraction. For inclination-augmented LSFB with monodisperse particles, it is found that the bed inclination imparted a significant ramification on the solid distribution in the vertical direction, and the bed pressure substantially decreased as the inclined top section gradually aligned with the vertical bottom segment, especially at the elevated liquid velocities. Similarly, in the case of polydisperse inclination-augmented LSFB, the results delineate that change in the angle of an inclined liquid-solid fluidized bed, the width of the channels, and the number of channels considerably influence the flow behavior of the complex polydisperse mixtures.

Keywords: LSFB, Reflux Classifier, Segregation, Eulerian-Eulerian model, CFD