Experimental validation of gas-solid fluidized bed models by S-statistic

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Two main approaches are available for simulating gas-solid fluidized beds: two fluid model (TFM) which is an Eulerian-Eulerian approach and combined computational fluid dynamics and discrete element method (CFD-DEM) model which is a Lagrangian-Euilerian approach. In this study, the simulation results of these two approaches in a 2D fluidized bed were compared with the experimental data of pressure fluctuations through a chaotic statistical test and also by comparing the energy of different structures in the gas-solid system (van Ommen et al., 2000). Identification of multi-scale structures in a fluidized bed (i.e., macro, meso and micro- scales) was performed through calculation of their energy contributions to the total energy of the pressure signal. This helps to interpret different scales of phenomena in the fluidized bed. The S-statistic method was used to validate simulation results at different scales.

Experiments were carried out in a column made of a Plexiglas pipe of 15 cm inner diameter and 2 m height. Sand particle with mean size of 600 μm and particle density of 2650 kg/m^3 with a static bed height of 15 cm were used in the experiments. The TFM simulations were performed using the transient Eulerian-Granular model (Kumar and Natarajan, 2009). Momentum exchange coefficients were calculated using Syamlal-O'Brien drag function and the kinetic energy loss during inter-particle collisions was specified by setting the restitution coefficient to 0.95. The CFD-DEM simulations were obtained by the program developed by Norouzi et al. (2011). Based on this model, the motion of the gas phase was determined by a set of volume-averaged Navier-Stokes and continuity equations and the motion of each individual particle was obtained by soft sphere approach. The equations describing the motions of solid and gas phases are coupled together through porosity and solid-gas momentum exchange. These equations were solved simultaneously to represent the fluidized bed hydrodynamics. Figure 1 shows the contour of sand volume fraction for both simulated case at the superficial gas velocity of 0.65 m/s (~3U_{mf}).

Pressure fluctuation for various superficial gas velocities was obtained for experimental setup as well as both TFM and CFD-DEM approaches. The measured signals were used to construct attractors and an enhanced monitoring method so called S-statistic established to compare these attractors. Figure 2 shows the S values calculated using the experimental signals (considered as the reference time series) and the corresponding signals of the CFD-DEM code obtained at the same operating conditions. It can be seen in this figure that the S value is always less than 3 during the whole period of the reference time series for various superficial gas velocity. Therefore, it can be concluded that the CFD-DEM code can predict the hydrodynamics of the fluidized bed correctly. To find out the main source of discrepancies between the model and the experiment, wavelet transform was applied to decompose pressure time series into three frequency bands corresponding to micro-, meso- and macro-structures and the Parseval's theorem has been used to determine the energy of the signals over these frequency ranges and validation of both models was examined in all these three structures.

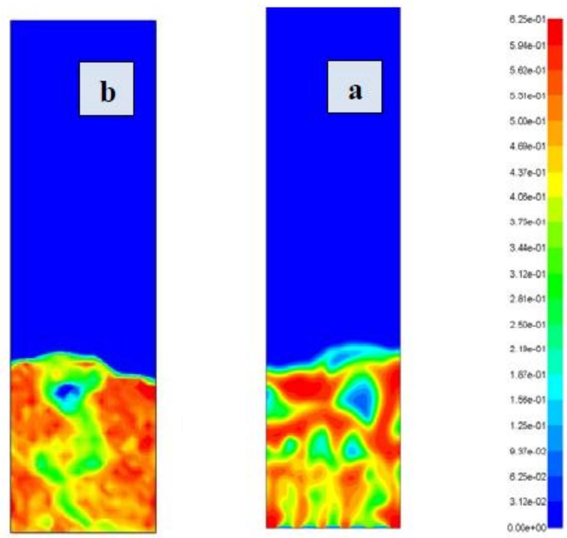

Figure 1. Contour of sand volume fraction; (a) Eulerian-Eulerian approach; (b) Lagrangian-Euilerian approach.

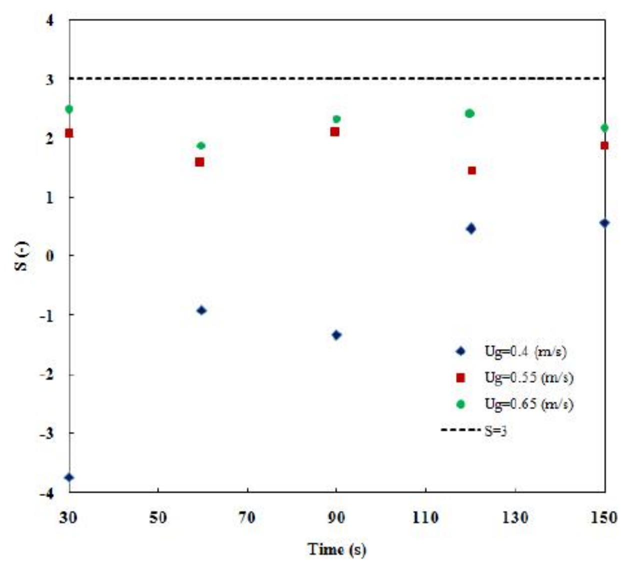

Figure 2. The estimated S from the comparison between model and experiment at bed aspect ratio 1 for three different superficial gas velocities.

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