CFD-DEM modeling of the solid motion in a liquid-solid fluidized bed and comparison with results from Radioactive Particle Tracking

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Highlights

- RPT results used to validate CFD-DEM simulation of a liquid-solid fluidized bed
- Solid velocity and holdup profiles properly predicted by CFD-DEM
- Liquid distribution in the entrance influences simulation results

1. Introduction

Liquid-solid fluidized beds are used particularly for bioprocesses and mineral processing. Their internal dynamics largely affects the output of the processes performed in them. This dynamics is complex and difficult to characterize, arising from the strong interaction between the moving phases, and the difficulties in studying the motion of fluids and suspended solids in a non-intrusive way. Hence, the ability of properly representing and predicting the liquid-solid fluidized bed dynamics will support establishing appropriate rules for design and operation control [1].

Measurement techniques that completely unveil the suspended particles motion in a fluidized bed have been developed in the past decade. The thorough information arising from them allows validation of detailed models aiming at describing this motion [2, 3]. The objective of this work is to compare experimental results obtained with the Radioactive Particle Tracking (RPT) technique in a pilot-scale device, with those predicted by a Computational Fluid Dynamics – Discrete Element Method (CFD-DEM) model performed with the CFDEM coupling software [4].

2. Methods

The fluidization of 4 mm diameter calcium alginate spheres suspended by the flow of an aqueous solution of $CaCl_2$ (0.2 M) in a 0.1 m internal diameter and 1.2 m height column is examined. The tracer used to track the solid has similar size, density, texture and wettability as the suspended gel particles. It is prepared by embedding a tiny piece of gold in an alginate bead similar to the rest of the particles in the bed [5]. The gold is previously activated by neutron bombardment in the RA1 reactor of the National Commission of Atomic Energy (CNEA) in Argentina, giving ^{198}Au of around 50 μCi. The tracer path is continuously followed by 16 scintillation detectors located around the bed. The obtained experimental trajectory is then used for determining observables of the solid motion, like velocities and turbulence features, thus providing a complete panorama of the suspended particles motion.

The CFD-DEM model is based on a strategy used to calculate the exchange of momentum between the fluid and solid phases. It allows obtaining, for a given instant, the velocities and pressures of the fluid in each computational cell, and the positions and velocities of all the particles in the cell. Equations (1) and (2) are used to match the momentum exchange.

$$m_i \, \mathrm{d}\boldsymbol{v}_i/\mathrm{d}t = \boldsymbol{f}_{pf,i} + \sum_{j=1}^{k_c} (\boldsymbol{f}_{c,ij} + \boldsymbol{f}_{d,ij}) + m_i \boldsymbol{g} \qquad \text{(solid phase)} \qquad (1)$$

$$[\partial(\rho_f \varepsilon_f \boldsymbol{u})/\partial t + \nabla\cdot(\rho_f \varepsilon_f \boldsymbol{uu})] = -\nabla\cdot p - \boldsymbol{F}_{pf} + \nabla\cdot \boldsymbol{\tau} + \rho_f \varepsilon_f \boldsymbol{g} \quad \text{(fluid phase)} \quad (2)$$

Where ρ_f is the fluid density, ε_f is the volume fraction of the fluid, ξ is the fluid stress tensor, $\mathbf{F}_{pf}$ is the volumetric particle-fluid interaction force, which is related to the particle-fluid interaction force $\boldsymbol{f}_{pf}$, p is the local mean fluid pressure, $\boldsymbol{\tau}$ is related to the stress tensor, $\boldsymbol{g}$ is the acceleration of gravity, m_i and $\boldsymbol{v}_i$ are the mass and velocity of particle i, k_c is the number of particles in interaction with particle i, $\boldsymbol{f}_{c,ij}$ is the inter particle elastic force and $\boldsymbol{f}_{d,ij}$ is the viscous damping force [6].

3. Results and discussion

Figure 1 shows an example of the comparison between the experimental and simulation outputs. The experimental radial profile of axial velocities (left) is satisfactorily predicted by the simulation close to the wall, and it is underestimated in the center. The simulation matches the general trend of the experimental radial profile of solid holdup (right) although it is less steeped close to the wall. It is worthwhile mentioning that the profiles calculated from the simulation sensibly depend on the liquid distribution in the entrance; hence, this effect is particularly studied.

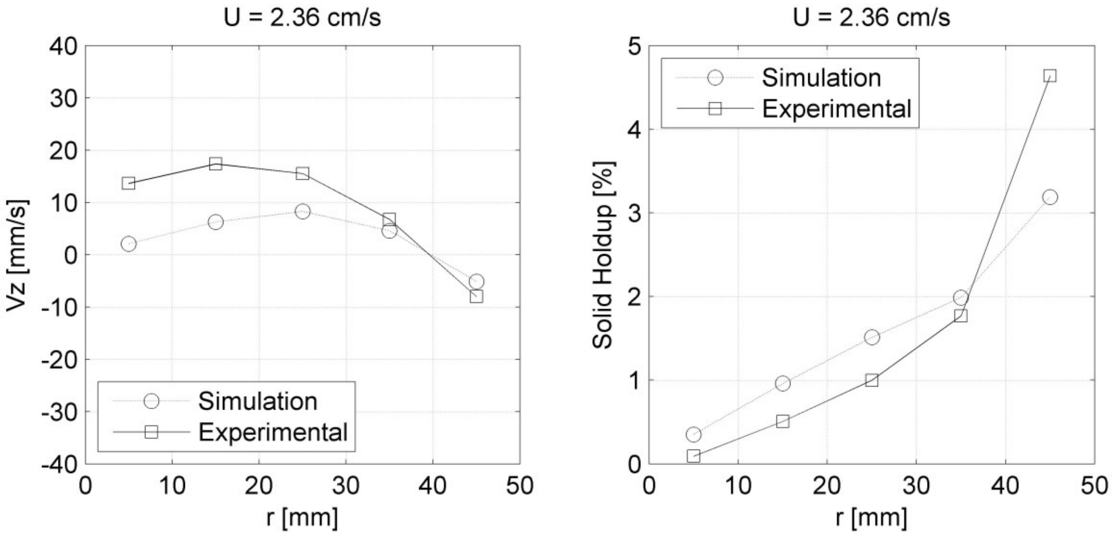

Figure 1. Comparison between the experimental and simulated radial profiles of axial velocities (left) and solid holdups (right).

4. Conclusions

RPT data are used to validate the simulation of a liquid-solid fluidized bed using the CFD-DEM method. The ability of the simulation to provide reasonable estimations of observables of interest for phenomenological models is disclosed. Particularly, the bed expansion, solid distribution, time averaged velocity fields and turbulence maps are obtained and compared with the experimental outputs. The influence of the liquid distribution and particles size distribution on the profiles obtained by simulation is studied.

References

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Keywords
Radioactive Particle Tracking; CFD-DEM simulations; Liquid-solid fluidized bed