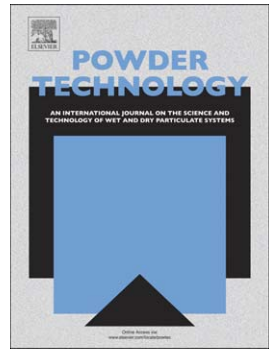

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On the limitations of 2D CFD for thin-rectangular fluidized bed simulations

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Abstract

Thin rectangular fluidized beds enable detailed optical diagnostics providing high quality data for validating numerical simulations. Because of their lower computational costs, 2D CFD continues to be employed despite the high wall surface-area to bed-volume ratio characterizing this geometric setup. 2D simulations do not resolve the gas and solids flow in the third (spanwise) direction nor the true boundary condition along the front and back walls, both of which are critical because the hydrodynamics are significantly affected by the presence these walls whose surface area is often much larger than the walls modeled in 2D analyses. Through highly-resolved simulations of three independent experimental setups, we show that 2D CFD may not capture, even qualitatively, the fluidization hydrodynamics because (a) bubble rise and coalescence mechanisms along the spanwise direction are not resolved, and (b) solids momentum and energy dissipation are under-predicted, and bubble rise velocities are over-predicted, because effects of the front and back walls are not modeled. 3D simulations with suitable wall boundary conditions predict bubbling dynamics and solids mixing in excellent agreement with experimental observations without further tuning of model parameters. Overall, we recommended that 3D numerical simulations be employed to model thin lab-scale setups for model development and validation purposes.

Keywords: Fluidized bed, 2D vs. 3D, wall boundary condition, validation, bubbling dynamics, solids circulation

Introduction

Thin rectangular fluidized beds (or pseudo-2D bed) are used extensively in experimental studies of fluidization because of their compatibility with optical techniques. Bubbles are detected and tracked using Digital image analysis (DIA) and solids-phase flow is quantified using particle image velocimetry (PIV) methods. The knowledge acquired from these studies has not only enhanced significantly our understanding of the complicated interplay between gas and particle motion during fluidization, but also offered high quality experimental data for the development and validation of physical models and computational fluid dynamics (CFD) methodologies

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