Gas interchange between bubble and emulsion phases in a 2D fluidized bed as revealed by two-fluid model simulations

F. Hernández-Jiménez a,⇑, A. Gómez-García a, D. Santana a, A. Acosta-Iborra a

aUniversidad Carlos III of Madrid, Department of Thermal and Fluid Engineering, Av. de la Universidad, 30, 28911 Leganés, Madrid, Spain

HIGHLIGHTS

► Gas interchange in fluidized beds is characterized using two-fluid model simulations.
► For an isolated bubble, the simulations reproduce the potential flow theory.
► For bubbling regime, the potential flow underpredicts the simulated gas interchange.
► A novel model for 2D bubbles is proposed for bubbling regime.

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ABSTRACT

Using two-fluid model simulations, the present work aims at characterizing the interchange due to gas advection between the emulsion phase and bubbles in fully bubbling beds of Geldart group B particles that are fluidized with air. In the studied beds the bubbles are slow, which means that the advection transport of gas through the bubble boundary is the main mechanism of gas interchange. In an initial verification step, the pressure distribution and the gas interchange coefficient for isolated bubbles obtained in the two-fluid simulation are compared with the classical potential flow theory of fluidized beds, providing concordant results. In a second step, the work analyzes the gas interchange in fully bubbling beds and the effects of the superficial velocity, bed height, and particle diameter on the interchange coefficient and the crossflow ratio. The results indicate that both the interchange coefficient and the crossflow ratio in bubbling beds are about two times those predicted by the potential theory of isolated bubbles. A corrected model for the gas interchange is proposed based on the introduction of the gas throughflow into the classical potential flow theory. As a consequence, the gas interchange coefficient in the corrected model is a function of the superficial gas velocity instead of the minimum fluidization velocity.

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1. Introduction

Fluidized beds have many relevant applications in industry, including, for example, fluid catalytic cracking (FCC), gasification, combustion of solid fuels, and Fischer–Tropsch synthesis [1]. Despite the fact that fluidized beds have been used in industry since the 1920s and good progress has been made in the experimental and simulation analysis of these systems, some aspects of fluidized bed dynamics are still far from fully understood.

Especially crucial for the understanding and control of fluidized bed combustors, gasifiers, and other reactors, is the characterization of the gas interchange between the emulsion of particles (i.e. the dense phase) and large voids (i.e. bubbles) in the bed. Simultaneous measurement of both the gas and the particle velocities in real beds entails serious difficulties that have not been satisfactorily solved at present. Thus, detailed numerical modeling of the bubbling process constitutes a valuable tool that can provide complete information of the gas dynamics within the fluidized bed.