Effect of various parameters on bubble formation due to a single jet pulse in two-dimensional coarse-particle fluidized beds

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Abstract

A soft-sphere discrete particle model based on re-arrangement of the gas phase governing equations has been developed to investigate the formation of a single bubble due to a central jet pulse in two-dimensional coarse-particle fluidized beds. A comprehensive study is made on the influence of bed width, particle properties and jet velocity on the bubble characteristics. The bubble grows heterogeneously when its diameter reaches one third of the bed width and elongates rapidly when its transverse size exceeds about one half of the bed width. At a given superficial velocity, a bed with a larger width leads to a decrease of gas leakage of the bubble. The influence of particle density and particle size on the bubble characteristics can be considered as the effect of the minimum fluidization velocity, which is consistent with the results obtained by two-fluid model in literature. In the presence of wall restrictions, bubble grows into an egg shape rather than an elliptical shape at detachment time when the superficial velocity is higher than the minimum fluidization velocity. Besides, a thin layer in dilute regime is observed near the top of the bed at a larger jet velocity. A bed of finer particles tends to form this layer more easily.

1. Introduction

Fluidized beds are widely used in chemical industry for a variety of processes such as drying, coating, granulation, combustion, oxidation, and chlorination to name only a few. The flow behavior in fluidized bed is very complicated as a result of fluid–particle and particle–particle interactions. Heterogeneity, the coexistence of regions of strongly contrasting particle concentration is deemed an intrinsic feature of gas–solid fluidization systems. Among those heterogeneous flow structures, bubbling is one of the most prominent, observed in dense gas–solid fluidized beds. When the particle bed is expanded beyond the point where homogeneities first occur, sharply defined regions of very low particle concentration or bubbles form and rise through the bed with a speed that depends on their size. The bubble dynamics may have dominant effects on the operation performance of those processes taking place in fluidized bed in terms of, for instance, the efficiency of heat and mass transfer.

There have been extensive researches on the dynamics and mechanism of bubble formation in gas–particle systems. Earlier researches mainly focused on empirical and theoretical analysis. Several approximate models based on some assumptions were proposed. Assuming that the particle motion is irrotational, Davidson and Schuler [1] applied the potential flow theory and Darcy’s law and presented firstly a theoretical solution to the problem of a single bubble rising in an unbounded fluidized bed. They predicted the existence of a zero-velocity cloud which was verified by later experimental observations. With the assumption of no gas exchange between bubble and surrounding emulsion phase, Harrison and Leung [2] adopted the model by Davidson and Schuler and acquired a correlation of the bubble volume at detachment to the gas flow rate through the orifice. It was shown later in the experiments by Nguyen and Leung [3] and Rowe et al. [4] there is a considerable gas leakage into the emulsion phase during the process of bubble formation. Subsequently, researchers started to take internal gas leakage into account. Similar to Zenz’s [5] treatment, Yang et al. [6] developed a model based on the assumption that gas leaks from bubble into emulsion phase at a superficial velocity equal to the minimum fluidization velocity. This model is semi-empirical because it takes a necessary input of the experimental observed bubble frequency. Caram and Hsu [7] applied Darcy’s law to obtain an expression for the superficial gas leakage velocity at the bubble boundary and established an improved theoretical model. The aforementioned models focused on the prediction of bubble volume and formation time. The bubble rise velocity used in these models mainly depends on the empirical formula given by

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