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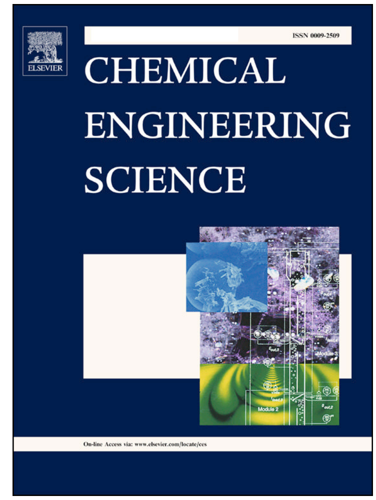

Detailed analysis of recent drag models using multiple cases of mono-disperse fluidized beds with Geldart-B and Geldart-D particles

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Detailed analysis of recent drag models using multiple cases of mono-disperse fluidized beds with Geldart-B and Geldart-D particles

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Abstract

In gas-solid flows, the drag force experienced by solid particles plays a significant role in determining the fluid dynamics of the system. Although several drag models have been proposed over the years, Gidaspow(1994) and Beetstra(2007) models are the ones that are still most commonly used. There is a lack of availability of work that gauges the capabilities of the newer models that have been developed over the past decade. Hence, this work utilizes three experimental configurations of fluidized beds to compare the performance of recent drag models proposed by Cello et al.(2010), Tenneti et al.(2011), Rong et al.(2013), Tang et al.(2016), and compares them with the drag models by Gidaspow(1994) and Beetstra et al.(2007). Euler-Euler (EE) or Two Fluid Model (TFM) simulations have been conducted for mono-disperse gas-solid fluidized beds containing Geldart-D particles corresponding to two experimental configurations and Geldart-B particles corresponding to one experimental configuration; all these configurations have been found in the literature. The temporal evolution of the ensemble-averaged particle height, time-averaged vertical particle velocity, temporal variation of the bubble diameter, time-averaged void-fraction distribution across the bed, and the time taken for computation are used as the variables for comparisons. It is observed that the drag models by Tenneti et al.(2011), Rong et al.(2013), and Gidaspow(1994) ensure appreciable performance for Geldart-D particles; for Geldart-B particles, the models by Tenneti et al.(2011) and Gidaspow(1994) exhibit satisfactory performance. The models by Beetstra et al.(2007) and Cello et al.(2010) are able to give appreciable performance only in predicting the bubble evolution, and even that at very early time instants, when the maximum solid volume fraction in the bed is about 0.60 (which is smaller than the maximum packing limit of 0.63). Taking both the computational time and solution accuracy into consideration, the model by Tenneti et al.(2011) seems to be the optimal choice for the considered cases, which is closely followed by the model of Gidaspow et al.(1994). The User Defined Functions (UDFs) and another code used for this work are included as Supplementary/Supporting Material.

Keywords: Fluidized Bed, Gas-Solid Flow, Drag Model Validation, Two Fluid Model(TFM), Momentum exchange, Numerical simulation

1. Introduction

Fluidized beds are often chosen as a test case to study the predictability of drag models that can also be used to describe several other more complex systems having gas flows laden with solid particles (Obligado et al., 2014) or gas-bubble two-phase flows. These include the formation and transportation of sand dunes (Desiree and Jurgen, 2016), dusty flows over vehicles, effects of volcanic ash, flow control using particles (Teh and Johansen, 2016), and many others. This is because it is more feasible to obtain experimental data for two phase flows in fluidized beds by using laboratory-scale experiments than in the other aforementioned scenarios, and the contribution of particle drag can, more or less, be studied in detail without considering the influence of other phenomena like chemical reactions (Schulze et al., 2017), phase change, mass transfer, etc. Apart from that, it can also directly help to develop better models capable of predicting large-scale industrial fluidized beds with complex physical and chemical processes (Dierich et al., 2018) that are extensively used in chemical, petroleum, mining, pharmaceutical, and energy industries for processes such as fluid catalytic cracking, gasification (Wittig et al., 2017), particle drying, coating, roasting, heat exchange, and many more.

Fluidized beds allow a high rate of interaction between phases by ensuring a high area of contact between the two, thereby resulting in high reaction and heat transfer rates between phases (Luna et al., 2017; Gupta and Sathiyamoorthy, 1998; Kunii, 1991; Oka, 2003; Schreiber et al., 2011; Zimmermann and Taghipour, 2005; Loha et al., 2012). The performance of such systems can be enhanced

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