Direct Determination of Granular Pressure in Liquid Fluidized Beds Using A DEM-Based Simulation Approach

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ABSTRACT

Based on Kinetic Theory of Granular Flow (KTGF), granular pressure (solid phase pressure) is defined as the force per unit area exerted on the container walls of the fluidized bed cell due to the collisions of particles (similar definition is used for a gas pressure based on the Kinetic Theory of Gases) [1]. Therefore, the total pressure of a fluidized bed is the sum of solid and liquid phase pressures [2]. The significance of the granular pressure in fluidized beds has been primarily encountered in two major contexts: theoretical models (two-fluid model) [3] and stability analysis [4].

Regardless of all the details, current models for granular pressure differ in the expression of the solid phase equation of state [5]. Therefore, several orders of magnitude and different relationships between granular pressure and volume fraction have been reported in the literature [5,6]. The aim of this study is to directly determine the granular pressure in a liquid fluidized bed based on the definition appeared in the KTGF using a DEM simulation. DEM is a numerical simulation method that can provide a detail mapping of the particle motion and interactions. To find the force acting per unit area of the fluidized bed wall, we directly computed the particle-wall collision frequency and momentum transport at the time of the collision. The reliability of this method was verified by comparing to experimental results as well as theoretical and mechanistic models.

To carry out the simulation of the fluidized bed, a one-way coupling DEM-based modelling approach was developed. The effect of liquid phase was considered through a suitable drag force model in which the slip velocity is simulated via a random fluid fluctuating velocity scheme. The random fluid fluctuating velocity follows a Gaussian Probability Distribution Function (PDF) with a certain mean and standard deviation. This random value was directly used to define the slip velocity for each particle at any given time step.

The bed was made of 8 mm glass bead particles. Initially, we validated our model by comparing the relationship between superficial fluid velocity and bed expansion against the well-known Richardson-Zaki equation [7]. The results demonstrated a good agreement of our model. The granular pressure and temperature, as well as the particle-wall collision frequency, in the liquid fluidized bed were determined for fluid velocities in the range between 0.072 and 0.320 m/s. The granular pressure exhibited a maximum (between 0.3-0.4 solid fraction) that matched the experimental measurements of Zenit et al. [6] for high inertia particles. The granular temperature also revealed a peak at a solid concentration of around 0.2 which is in line with the experimental measurements of Zivkovic et al. [8] and the model of Gervin et al. [5]. The set of the results presented in this study suggests that the approach used here is valid for obtaining the granular pressure for a wide range of volume fractions in liquid fluidized beds.

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