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DIRECT NUMERICAL SIMULATIONS OF COLLISION DYNAMICS OF WET PARTICLES

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Fluidized beds involving liquid injection have a wide industrial application ranging from physical operation, like agglomeration and coating, to chemical processes including catalytic oxidization, fluid catalytic cracking, condensed-mode polyethylene (1). The injection of the liquid results in wet particles, which behave completely different from dry particles and hence lead to much more complicated hydrodynamics of fluidized beds (2). Nevertheless, a fundamental description of the dynamics of wet particles is predominantly missing, which however is crucial for prediction of fluidization behavior effecting on the product quality.

Despite significant investigation, experimental studies of wet collisions under actual fluidization condition (e.g., low particle velocity, thin liquid layer) are virtually impossible to perform and control. Direct numerical simulations can complement experiments by providing quantitative predictions of the micro-mechanical collisional behaviour of one or more particles with well-defined and easy-controlled system parameters. Jain et al. (3) demonstrated that the experimentally observed phenomena of collision between a particle and a wet wall can be reproduced by a hybrid model combining the volume of fluid (VOF) method and the immersed boundary method (IBM). Such simulations will be extended in this work to investigate the effects of liquid layer thickness, impact velocity, particle size and surface tension on the wet restitution coefficient (e_{wet}) under normal collisions as well as oblique collisions. The motion of a solid particle is described by the IBM (Figure 1), which enforces a no-slip condition at the particle surface. Whereas, the VOF (Figure 2) describes the motion of the gas-liquid interface by a piece-wise linear reconstruction of the interface.

Figure 3 plots the trajectories of the downwards velocity of a 1.74 mm glass particle colliding on a wall covered with 400µm layer of water. A good agreement on the impact and rebound velocities is observed between the VOF/IBM simulation results and the experimental data. However, unlike the simulation results (snapshots in Figure 3), experimental measurements cannot provide all details of the collision since it happens within a very short time. In addition, numbers of simulations have been performed for investigation of the parameters beyond the critical “sticking” values under normal and oblique collisions. It is found that the normal e_{wet} increases approximately logarithmic and reaches a constant value that is smaller than the dry value when the particle impact velocity increases. On the other hand, the normal e_{wet} almost decreases linearly as the liquid layer thickness increases, but is independent of the collision angle as well as the surface tension. The tangential e_{wet} is found larger than the dry value and the minimum shifts to smaller collision angles with increasing liquid viscosity. An increase of the layer thickness however has no significant influence on the tangential e_{wet}. Finally, on the basis of all the simulation data, a phenomenological model proposed by Sutkar et al. (4) is modified to better predict the wet restitution coefficient.

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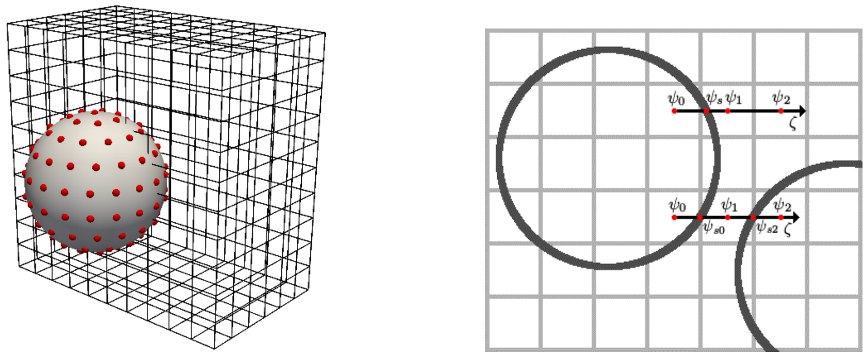

Figure 1. Schematic explanation of the IBM: (left) Representation of a solid particle by Lagrangian marker points distributed over the particle surface; (right) Incorporation of the boundary condition for a general fluid quantity ψ.

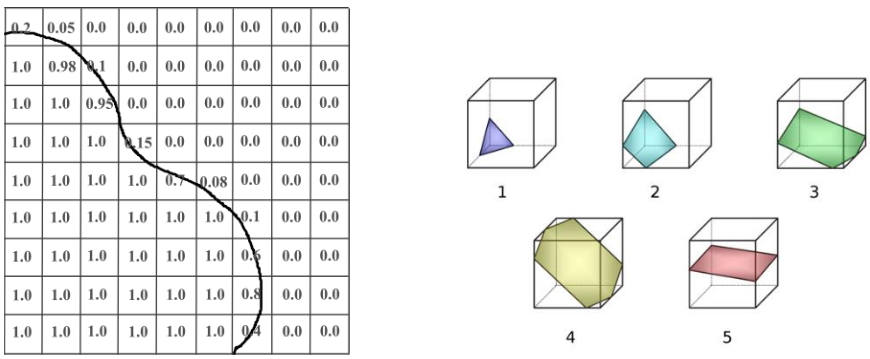

Figure 2: Schematic explanation of the VOF: (left) The value of a colour function indicates the fractional amount of the liquid present at individual grid cell; (right) Five generic types of interface configurations considered in the computation of the fluxes through the cell faces.

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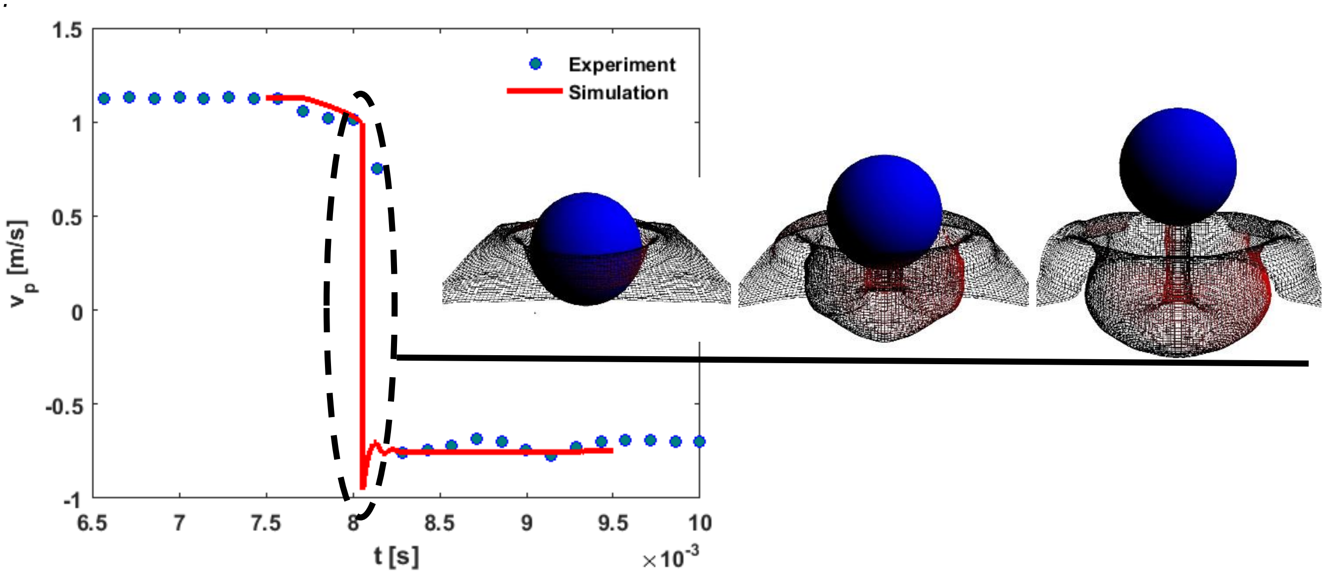

Figure 3. Trajectories of downwards velocity of a 1.74mm glass particle colliding with a wall covered by a 400µm layer of water. The symbols are experimental data, whereas the solid line shows the simulation results together with three snapshots when the particle is colliding.