THE THREE-DIMENSIONAL SIMULATION OF VORTEX ON THE BOTTOM OF A PARTICLE IN GAS-LIQUID TWO-PHASE FLOW

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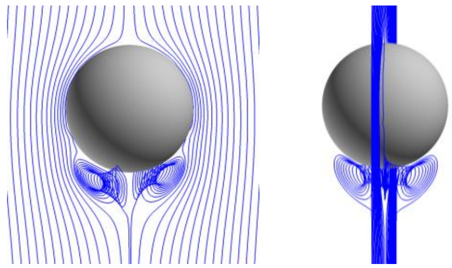
The sophisticated industrial applications demand deep knowledge of local flow hydrodynamics on a particle surface in fixed bed reactors in order to improve process efficiency, particularly micro- (or particle-) scale of gas-liquid two-phase flow, which the study of vortex on the bottom of a particle is much more meaningful. The three-dimensional numerical simulations of gas-liquid two phase flow passing a spherical particle were investigated using Computational Fluid Dynamics (CFD) methodology with the volume of fluid (VOF) method. The effects of gas velocity, liquid velocity, liquid-solid contact angle, surface tension coefficient, and liquid viscosity on the interface status of fluid flow were presented in this paper. The simulation conditions were particle diameters of 10mm, water and air as liquid and gas respectively, droplet size 4mm, and an atmospheric pressure.

Results show that the droplet movement and gas streamlines are greatly dependent on the air flow conditions and the liquid physical conditions. To better observe the flow field around the liquid droplet, the 3D plot is drawn for the contact angle of 50° with the gas velocity of 1.0m/s at the time instant of 0.015s as shown in Figure 1. Vortices are produced on the bottom of a particle known as Von Kármán vortex street, which have the opposite direction of rotation and the double row arrangement vortex. In addition, vortices are found to be more obvious and farer from the particle at higher gas and/or liquid velocities, and the droplet moves faster with the increasing gas velocity (0.2m/s-2.0m/s) and liquid velocity (0.24m/s-0.465m/s). Moreover, the generated vortices can be clearly observed at downstream of particle, and the droplet shape varies with the flow time. Vortex radius changes from 0.5mm to 2.5mm with the time going at the gas velocity 0.5m/s and liquid velocity 0.24m/s. The liquid-solid contact angle between 40° and 80° mainly affects particle surface wettability, which results in the different droplet shape and flow gas streamlines. At the beginning, the shape of the droplet is spherical and thereafter it changes to appropriate shape according to the surface properties and the contact angle. When the liquid-solid contact angle is 50°, vortex is comparatively density which radius is only 0.5mm initially, and then changes to 3.5mm approximately with an increase of the flow time.

Meanwhile, the surface tension can affect the contractile properties and the gas streamlines. With increasing the surface tension coefficient, vortices produced at the same time are density initially, and then change to rarefaction tardily. And the radius of vortex firstly increases to 3mm, then decreases until the droplet leaving the particle surface at the surface tension coefficient of 35dyn/cm. Viscosity is generally one important parameter of the fluid properties. However, it is also shown that as compared to the above factors, the influence of liquid viscosity is negligible in this simulation.



(a) (b)

Figure 1. Streamlines around the particle with gas velocity of 0.5m/s and liquid velocity of 0.24m/s at the time instant of 0.015s.

REFERENCES

[1] Al-Dahhan M H, Larachi F, Dudukovic M P, et al. High-pressure trickle-bed reactors: A Review. Industrial and Engineering Chemistry Research, 1997, 36: 3292-3314.

[2] Bittagopal Mondal, Kui Jiao, Xianguo Li, Three-dimensional simulation of water droplet movement in PEM fuel cell flow channels with hydrophilic surfaces, Int. J. Energy Res. 2011;35:1200-1212.

[3] May J. Cheah, Ioannis G. Kevrekidis, Jay B. Benziger, Water Slug Formation and Motion in Gas Flow Channels: The Effects of Geometry, Surface Wettability, And Gravity, Langmuir 2013, 29, 9918-9934.

[4] Wei Du, Dongsheng Feng, Jian Xu, Weisheng Wei, Computational Fluid Dynamics Modeling of Gas-Liquid Two-Phase Flow around a Spherical Particle. Chemical Engineering Technology, 2013, 36 (5), 840-850.