FPM modeling of particulate flows with thermal convection

Z. L. Zhang[1, 2], and †*M.B. Liu[1, 2]

[1] BIC-ESAT, College of Engineering, Peking University, Beijing 100871, China
[2] State Key Laboratory for Turbulence and Complex Systems, Department of Mechanics and Engineering Science, Peking University, Beijing 100871, China

*Presenting author: mbliu@pku.edu.cn
†Corresponding author: mbliu@pku.edu.cn

Abstract

Particulate flows with thermal convection are very complex and quite challenging to simulate numerically using grid-based methods as frequent generation and deformation of computational grid is required in many cases when the particle boundaries are complex and move with time. Meshfree and particle methods have special advantages in modeling fluid flows with moving boundaries. However, there are very few reports on meshfree modeling of fluid flow with thermal convection. The studies on how natural or mixed heat convection influences the sedimentation of the particle in a nonisothermal flow are even more limited. In this paper, a finite particle method with particle shifting technique (FPM-PST) is developed to study the dynamics of nonisothermal cylindrical particles in particulate flows. The momentum and energy transfer equations are solved to compute the effects of heat transfers. Different particulate flow tests with thermal convection are conducted using the FPM-PST along with the Finite Element Fictitious Boundary Method (FE-FBM) for comparison. It is demonstrated that FPM can achieve much higher accuracy than conventional SPH in modeling particulate flow without or with heat transfers. PST is also very important as it improves the stability of the computation and helps to avoid possible voids at high Reyleigh numbers which may lead to the breakdown of the simulation. The FPM-PST simulation results show a good comparison with the results obtained by FE-FBM. It can be concluded that FPM-PST provides a new alternative with high accuracy and stability in modeling particulate flows with thermal convection. It is also observed that heat advection between hotter particles and fluid causes the drag coefficient of particles to significantly increase at relatively low Reynolds numbers, and the buoyancy currents induced by the hotter particles reverse the drafting-kissing-tumbling (DKT) motion of the particles or suppress it altogether.

Keywords: smoothed particle hydrodynamics (SPH), Finite particle method (FPM), Finite element fictitious boundary method (FE-FBM), Particle shifting technology (PST), Particulate flow, Thermal convection

Reference:

Liu MB, Liu GR (2010) Smoothed particle hydrodynamics (SPH): an overview and recent developments. Archives of Computational Methods in Engineering 17:25-76.

Zhang ZL, Chang JZ, Liu MB (2018) A decoupled finite particle method for modeling incompressible flows with free surfaces. Applied Mathematical Modelling (Accepted).