CFD-DEM modeling of fluidized beds with heat production : influence of the particle size distribution and heat source

CFD-DEM MODELING OF FLUIDIZED BEDS WITH HEAT PRODUCTION: INFLUENCE OF THE PARTICLE SIZE DISTRIBUTION AND HEAT SOURCE

Zizi Li*, Eindhoven University of Technology; The Netherlands
z.z.li@tue.nl
Martin van Sint Annaland, Niels G. Deen , J.A.M. Kuipers, Eindhoven University of Technology; The Netherlands

Gas-phase polyolefin polymerization processes are executed in fluidized beds. The particles often have a broad particle size distribution (PSD) due to a variety of factors (e.g. residence time distribution, initial catalyst size distribution, different rate of catalyst activity decay, etc.). The heat transfer phenomena of particles in poly-disperse beds with different particle size distributions have been numerically analyzed using an in-house developed 3-D computational fluid dynamics and discrete element model (CFD-DEM) (1). Simulations have been carried out for beds with Gaussian PSD's using three different distribution widths, viz. a narrow, medium and broad distribution (see figure 1), but with the same Sauter mean diameter (d3,2=1.2 mm). The thermal energy equation of the particles contain a heat source related to the heat of reaction. Two cases were considered: a constant volumetric heat production (*qv*, [W/m3]) and a constant heat source per particle (*Q*, [W]) to represent different systems, respectively the heat production in normal catalytic reactions and polymerization reactions. The results from the probability distribution function (PDF) of the particle temperature show that the temperature distribution in the fluidized bed is strongly affected by the width of the particle size distribution, the magnitude of the heat source and the superficial gas velocity. The results from the temperature contour show the relation between the temperature distribution and the particle size (see figure 2). It was found that small particles (fines) with high heat production cause hot spots formation in the bed, which has been frequently observed in polymerization reactors. It was also found that operating the bed with a relatively high superficial velocity cannot limit the number of particles in the high temperature region. Furthermore, snapshots of the fluidized beds demonstrate that these small particles have higher chance to be found on the top of the bed and in the vicinity of the side walls of the reactor. The former is due to minor size segregation in the vertical direction, the latter is caused by preferential particle motion.

FIGURES OF THE ABSTRACT

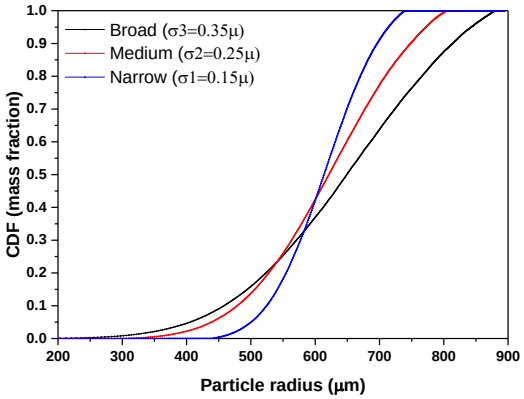

Figure 1. Particles size distribution profiles for the particle beds used in the simulations.

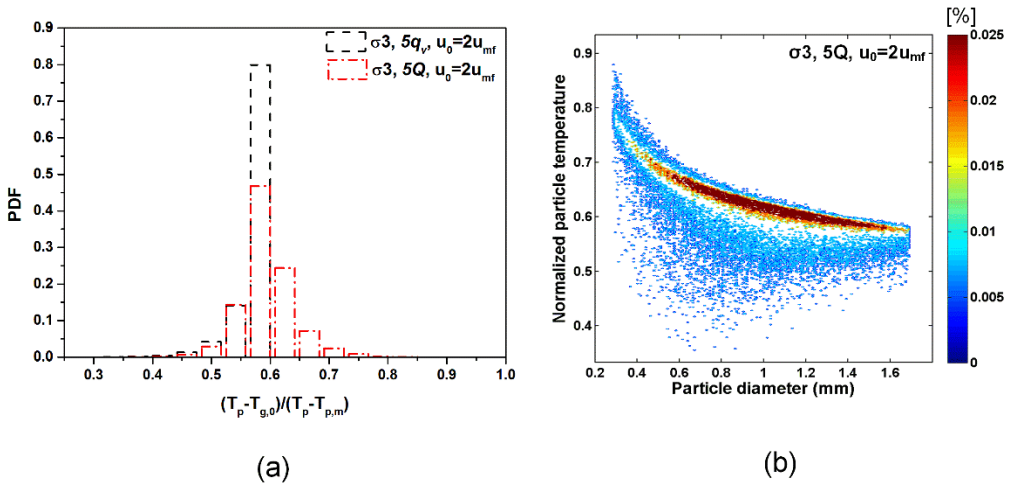

Figure 2. Particle temperature distribution in a fluidized bed with a broad PSD. (a) Normalized particle temperature PDF. The simulation conditions are with a broad PSD (σ3), gas superficial velocity 2 times of u_{mf} ($u_0=2u_{mf}$). (b) dimensionless particle temperature countour (PSD=σ3, heat producing: 5Q, $u_0=2u_{mf}$).

ACKNOWLEDGMENT
This research is part of research programs of Dutch Polymer Institute (DPI) as project #751.

REFERENCES
1. A. V. Patil, and J. A. M. Kuipers. Modeling bubble heat transfer in gas–solid fluidized beds using DEM. Chem Eng Sci., 105:121-131, 2014.