Hydrodynamic behavior of a bubbling fluidized bed gasifier under elevated temperature: CFD simulation

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Abstract:
A bubbling fluidized bed gasifier model was developed to investigate the hydrodynamic behavior inside bed zone at an elevated temperature. Compared to the behavior under ambient temperature condition, the pressure drop across the bed resulted from the simulation at elevated temperature, i.e. 800°C, was lower and the bubbles formed rose to the bed surface faster. The main reasons were the decrease in air density and dynamic pressure with increasing temperature.

Keywords: *CFD simulation; Bubbling fluidized bed gasifier; Three-dimensional model; Elevated temperature; Heat transfer*

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1. Introduction

To successfully design and operate a gasification system, understanding of the system characteristics upon biomass gasification is essential. So far, both experimental studies of factors affecting biomass gasification in various reactor configurations model simulations to predict what happen inside the reactor in both macro and micro level have been carried out (e.g. Kaneko et al., 1999; Rhodes et al., 2001; Kafui et al., 2002; Kuwagi and Hoiro, 2002; Limtrakul et al., 2003; Wang and Rhodes, 2003; Cooper and Coronella 2005; Huilin et al. 2007, Yu at el., 2007). Computational fluid dynamics (CFD) codes were developed to explain the thermodynamics and hydrodynamics behavior. In the cold flow (ambient temperature and non-reactive considered) study, the hydrodynamic behavior was mostly investigated using a two-dimensional model and the effect of heat transfer was not taken into consideration. In this study, a three-dimensional model of a bubbling fluidized bed gasifier (BFBG) was developed to investigate the hydrodynamic behavior inside bed zone at 800°C, a typical temperature found in BFBG operation, with comparison to the simulation results obtained at ambient temperature condition.

2. Methodology

A three-dimensional model was created using a commercially available CFD code FLUENT and set up following the dimension of the BFBG which was previously developed in this laboratory (Kaewluan and Pipatmanomai, 2011). The BFBG has an internal diameter of 300 mm and a height of 2,500 mm from the air distributor level with a wall thickness of 150 mm for thermal insulation. The air distributor is the nozzle-type, which consists of 9 closed-end nozzles. Each of them has 42 air distributing holes with 3 mm of diameter and 60 degree downward inclination as seen in Fig. 1. The simulation was carried out under both ambient temperature condition (30°C) and elevated temperature condition (800°C, a typical temperature found in BFBG operation). The ambient air (as gasification medium) was set as gas phase with a velocity inlet of 3.8137 m/s and silica sand (as bed material) was set as solid phase and was patched to have an initial height at 300 mm. The silica sand was patched with temperature of 800°C and the model of "Energy" in Solution Setup step was turned on to allow heat transfer from solid phase to gas phase for the case of simulation under elevated temperature. Then, the hydrodynamic behavior inside bed zone resulted from the simulation under ambient and elevated temperature condition was compared.

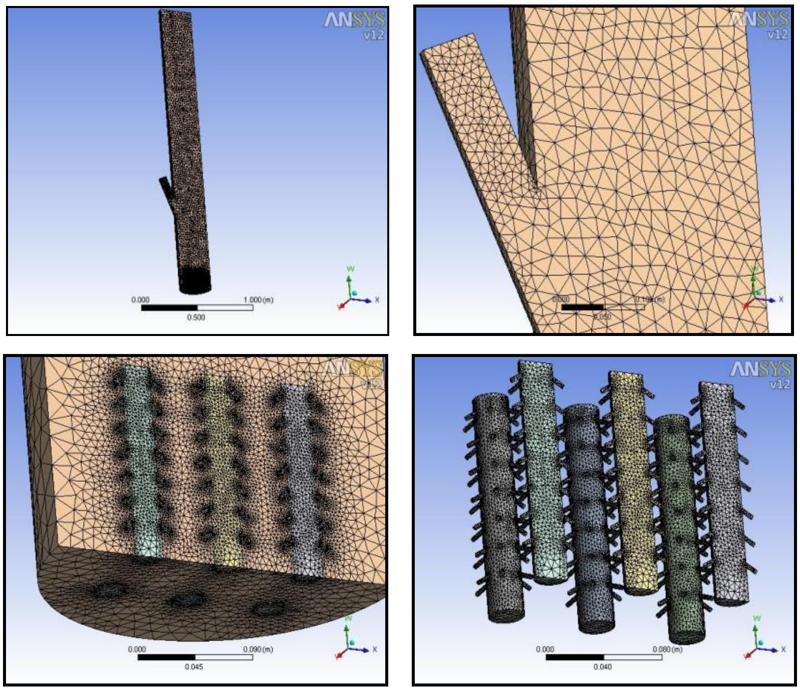

Fig. 1 The symmetrical 3-D section of BFBG model and zoom in on the feeding pipe and air distributor part.

3. Results and discussion

There was found that the bubbles which occurred under elevated temperature condition moved up to the bed surface faster than that occurred under ambient temperature condition as presented in Fig. 2. This is because the density of any gas, including air, decrease as the temperature increase. With this less density, the molecules of air move further apart and easily move up toward the bed surface.

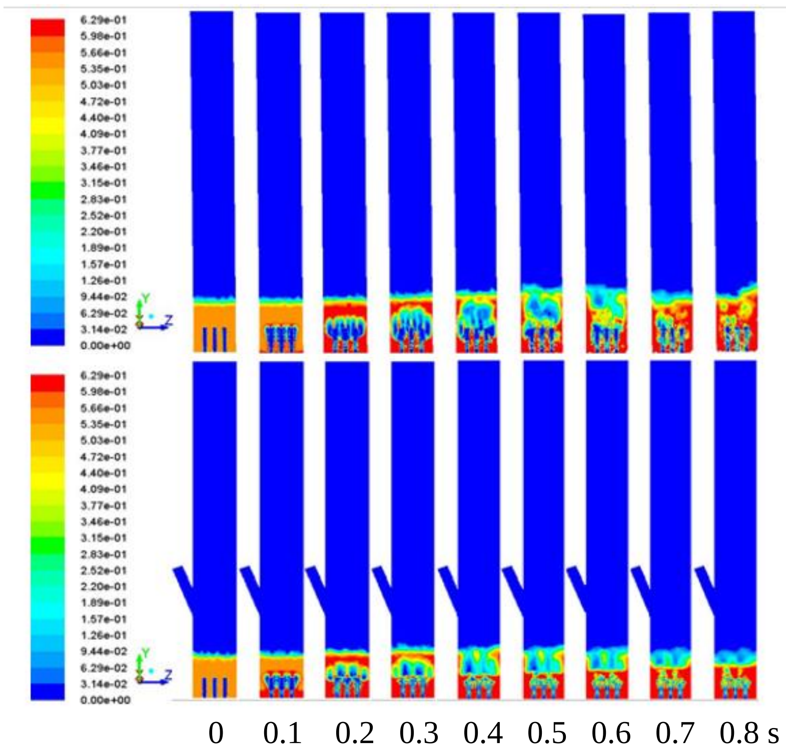

Fig. 2 Comparison the contour of solid volume fraction resulted from ambient temperature condition (top) and elevated temperature condition (below).

Furthermore, simulation under elevated temperature condition also shows the lower pressure drop across the bed when compared to that resulted from the simulation under ambient temperature condition as presented in Fig. 3. This is because the higher temperature decreases the gas density which in turn creates a lower dynamic pressure resulting in the lower pressure drop. Similar behavior was found in the study by Gimbun et al. (2005).

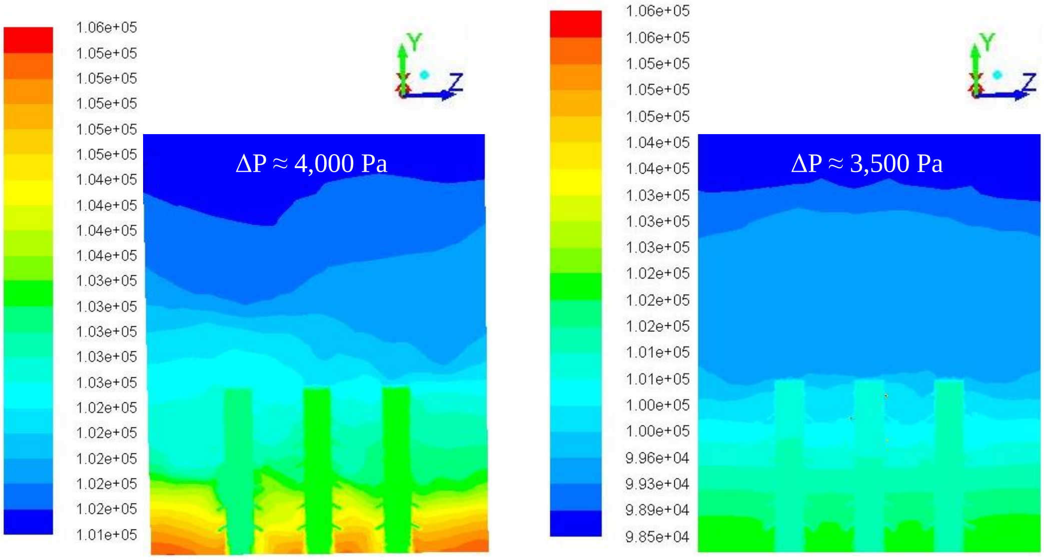

Fig. 3 Comparison the contour of absolute pressure resulted from ambient temperature condition (left) and elevated temperature condition (right).

4. Conclusion

The hydrodynamic behavior inside the bed zone of a BFBG was investigated by CFD simulation based on a developed 3-D model. The results evidently show that the hydrodynamic behavior under elevated temperature was somewhat different from that at ambient temperature condition. Under the condition at 800°C, the pressure drop across the bed was lower and the bubbles formed rose to the bed surface faster. The decrease in air density and dynamic pressure with increasing temperature plays the major effect and the extent of which must be taken into consideration for further BFBG study under reactive flow condition.

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