Topic: CFD Modeling and Experiments in a Bubbling Fluidized Bed Reactor for Biomass Gasification

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ABSTRACT

This research consists of two main parts: the experimental investigation of rubber woodchip gasification and computational fluid dynamic (CFD) simulation of a bubbling fluidized bed gasifier (BFBG), the main device used for gasification experiments. The objective of the gasification experiment is to investigate the potential of utilizing high-moisture (27% moisture content) biomass fuel by mixing with plastic waste (High Density Polyethylene type). For the gasification model simulation, the CFD codes were developed using FLUENT on three-dimensional computational domains to investigate the hydrodynamic behaviors of the BFBG. The Euler-Euler approach with KTGF was applied. The input parameters and the optional model selections were studied and validated under cold flow (ambient temperature and non-reactive considered) conditions by comparing the simulation with the experimental results of a downscale BFB made of acrylic. The hydrodynamic behaviors especially inside bed zone of the BFBG were investigated comparing the non-simplified (actual configuration) and simplified air distributor under both cold flow condition and elevated temperature (hot sand with heat transfer and non-reactive considered) condition.

The results of the gasification experiments showed a significant improvement of gasification performance from mixing the high-moisture (27% M.C.) rubber woodchip with plastic waste (SPB). Even at 10% mixing ratio, the HHV of the product gas increased by about 50% and 25% compared to the case of high-moisture rubber woodchip (27% moisture) and pre-dried rubber woodchip (8% moisture), respectively. At 20% mixing ratio, the HHV of product gas increased from 3.85 to 6.06 MJ/Nm^3. The carbon conversion efficiency was significantly improved to reach the level of the pre-dried rubber woodchip when mixing with 20% SPB. Moreover, increasing ER could also effectively increase the carbon conversion efficiency for all feedstocks. These experimental results indicate that the co-gasification with plastic waste can be considered as a promising solution for utilizing high-moisture biomass and effective way for plastic waste management is an additional benefit.

Comparing the non-simplified and simplified air distributor models, which were simulated under cold flow conditions, the results show that their hydrodynamic behaviors, i.e. bubble formation and motion inside bed zone, gas-solid flow pattern, bed expansion ratio, and profiles of absolute pressure along the height of bed zone, were different. More fluctuations were observed, and the loops of bubble formation and motion were also faster in a non-simplified air distributor model. The gas-solid flow patterns in the simplified air distributor model were different from those in the non-simplified air distributor model, as there were large-size vortexes in the lower part of the bed in the simplified air distributor model, while the gas-solid flow mainly occurred around the nozzles in the non-simplified air distributor model, resulting in large-size of vortexes in upper part of the bed. For the bed expansion ratio, it was 1.33 and 1.16 for non-simplified and simplified air distributor model, respectively. The difference of these comparison bed expansion ratios indicated that the expansion height of fluidized bed obtained from simplified air distributor model was underestimated as compared to the non-simplified air distributor model which was closer to the actual BFBG. The profiles of absolute pressure along the height of bed zone in simplified air distributor model was different from that in non-simplified air distributor model as the absolute pressure at each height in simplified air distributor model was nearly constant, while fluctuations were clearly observed in non-simplified air distributor model, especially in upper zone of the bed. In addition, in both non-simplified and simplified air distributor model, the pressure drop across the bed resulted from the simulation under elevated temperature condition was lower and the bubbles formed rose to the bed surface faster than that obtained from the simulation under cold flow condition. The main reasons are the decrease in air density and dynamic pressure with increasing temperature.

Keyword: CFD; Three-dimensional model; Simulation; Bubbling Fluidized Bed; Biomass Gasification