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Modelling of a slurry bubble column reactor for Fischer-Tropsch synthesis

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Abstract

The slurry bubble column reactor (SBCR) is of particular interest in Fischer-Tropsch (FT) reactor modelling because of its importance to gas-to-liquids processes and the technical challenges it poses. Being one of the most important and complex Fischer-Tropsch Synthesis (FTS) systems in use today, there is a need to improve the current knowledge and understanding of the SBCR at a fundamental level, particularly the hydrodynamics of the process. Accordingly, a mathematical model of a SBCR has been developed in this work. The model is based on mass balances into which hydrodynamic, mass transfer and kinetic parameters have been incorporated. The hydrodynamic model considers two distinct phases in the SBCR, namely the gas and slurry phases with the liquid and solid phases treated as a single pseudo-homogenous phase. The gas phase in the reactor was assumed to exist in the form of distinctly large and small bubbles with each bubble class moving predominantly upwards through the center of the reactor and down near the wall respectively. Material balances were accordingly performed over three compartments including the slurry, large bubbles and small bubbles compartments. Axial dispersion was assumed in both the slurry and gas phases. The overall superficial gas velocity decrease along the axial direction was taken into account using an overall gas balance. Species material balances, hydrodynamics, kinetics and gas/liquid physicochemical property models were all coupled into a single SBCR model. The model was able to produce simulations capable of describing the fate of the reactant species, in the axial direction, in all three phases. Notably, the CO and H_2 concentrations dropped by 62.01% and 64.13% respectively in the large bubble phase. A sensitivity study revealed the negative dependence of syngas conversion on the superficial gas velocity. A positive effect on the syngas conversion was evident with an increase in reactor diameter, i.e., an increase in diameter between 6 m and 7.8 m resulted in an increase in the syngas conversion between 38.3% and 90.78%. An increase in catalyst loading (0.28 to 0.38) resulted in a decrease in the syngas conversion (93.57% to 0.704%) due mainly to the overall decrease in the bubble hold-up. The comparison of the model results with those from literature was favorable with some noticeable discrepancies resulting from the inherent differences between the models.