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Comparative Numerical Simulations of Reaction-Coupled Annular and Free-Bubbling Fluidized Beds Performance

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Abstract : An annular fluidized bed (AFB) is gaining extensive application in the process industry due to its efficient gas-solids contacting. But a direct evaluation of its reaction performance is still lacking. In this paper, comparative 3D Euler–Lagrange multiphase-particle-in-cell (MP-PIC) computations are performed to assess the reaction performance of AFB relative to a bubbling fluidized bed (BFB) in an FCC regeneration process. By using the energy-minimization multi-scale (EMMS) drag model with a suitable heterogeneity index, the MP-PIC simulation predicts the typical fountain region in AFB and solids holdup of BFB, which is consistent with an experiment. Coke combustion rate, flue gas and temperature profile are utilized as the performance indicators, while related bed hydrodynamics are explored to account for the different performance under varying superficial gas velocities (0.5 m/s, 0.6 m/s, and 0.7 m/s). Simulation results indicate that the burning rates of coke and its species are relatively the same in both beds, albeit marginal increase in BFB. Similarly, the shape and evolution time of flue gas (CO, CO_2, H_2O and O_2) curves are indistinguishable but match the coke combustion rates. However, AFB has high proclivity to high temperature-gradient as higher gas and solids temperatures are predicted in the freeboard. Moreover, for both beds, the effect of superficial gas velocity is only conspicuous on the temperature but negligible on combustion efficiency and effluent gas emissions due to constant gas volumetric flow rate and bed loading criteria. Cross-flow of solids from the annulus to the spout region as well as the high primary gas in the AFB directly assume the underlying mechanisms for its unique gas-solids hydrodynamics (pressure, solids holdup, velocity, mass flux) and local spatial homogeneity, which in turn influence the reactor performance. Overall, the study portrays AFB as a cheap alternative reactor to BFB for catalyst regeneration.

Keywords : annular fluidized bed, bubbling fluidized bed, coke combustion, flue gas, fountaining, CFD, MP-PIC, hydrodynamics, FCC regeneration
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