144r A Multi-Fluid Model of Superheated Fast-Fluidized Beds Based on Cluster Characteristics

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In FCC, hydrocracking reactions take place in the gas phase. Liquid feedings atomized through nozzles have to be evaporated first. The heat for this evaporation comes from superheated catalysts and gas flows. The vapor concentrations play the role of driving the hydrocracking reactions. Without evaporation, the amount of feeding put in the riser will not affect the production rate. Therefore, the evaporation rates of droplets in riser control the reaction rates, e. g. production rates in FCC. A series of experimental data related to evaporation rates in circulating fluidized beds (CFB) has been published. It has been noticed that the data presented much smaller rates than the numerical results predicted by a model with direct heat transfer between superheated particles and droplets. The study described in this paper showed that one of the causes of such small evaporation rates was clustering of catalyst particles.

An important feature of particle-gas flow in FCC is the tendency for the particles to form aggregate clusters. This phenomenon increases the effective diameter of the interfacial geometry of solid phases up one or two orders of magnitude. This paper shows that the clustering can cause the interfacial drag down about two or three orders of magnitude for a catalyst flow with local average solid fraction > 0.1. Without taking into account the effect of clustering on interfacial interaction, it would be very difficult to predict the hydrodynamic behaviors of three-phase flows. An ensemble-averaging model for cluster and gas has been developed. This paper has extended it to a model for three phases, cluster, gas and droplets. Besides the hydrodynamic effect, clustering affects the heat transfer between superheated particles and droplets dramatically. Evaporation of droplets on a superheated solid surface is accomplished by the mechanism of film boiling, instead of pool boiling. This phenomenon greatly reduces the contact area of solid and droplet depended on the degree of superheating. Furthermore, clustering processes exclude droplets outside clusters so that most particles remaining in clusters have no chance to contact droplets for Laten heat evaporation. As a result, evaporation rates over a riser are generally recognized as being strongly governed by the presence and behavior of clusters. Furthermore, the evaporation process, which changes both temperatures and physical properties of gas phase, has a corresponding effect on diameters of cluster. Without a proper description of the clustering process, a numerical model could not give an accurate enough prediction of both hydrodynamic parameters and reaction rates for a new design or revamp. Clustering of catalyst particles has been one of several major challenges for a numerical tool. This paper gives a set of constitutive relations to describe this comprehensive heat transfer phenomenon and close the three-phase model.

Predictions based on this new mode are shown to be in good agreement with experimental measurements for axial variation of evaporation rates with different solid mass fluxes, gas velocities and liquid feed rates.