EFFECT OF PULSATING FLOW IN FCC RISER

Milinkumar T Shah*, Ranjeet P Utikar, and Vishnu K Pareek
Department of Chemical Engineering, Curtin University of Technology
Perth, WA 6845, Australia

Abstract

Gas-solid flow in fluid catalytic cracking (FCC) riser exhibits heterogeneous "core-annulus" radial profile of solids holdup, which causes poor mixing and significantly reduces performance. To overcome this shortcoming, pulsating (regular variations) gas flow can be useful in riser. In this study, impact of pulsating gas flow on gas-solid hydrodynamics and performance of FCC riser is investigated by using computational fluid dynamic (CFD) approach. Simulations of gas-solid cold-flow and reactive flow in FCC riser are performed without and with pulsating gas flow of various amplitudes and frequencies. Predictions from pulsating gas flow show improved homogeneity in radial profiles of phase holdup, concentrations and temperature.

Keywords

Riser, fluid catalytic cracking, CFD, Pulsating flow

Introduction

In an FCC, a riser is a long vertical pipe where fine catalyst is fluidized by gas flowing at high velocity. In FCC riser, mixing between gas and solids governs conversion and yields. Almost all previous studies on riser hydrodynamics have shown an existence of 'core-annulus' flow pattern, which is characterized by higher solids volume fraction (10-30% depending on the solid loading) near walls and a dilute flow at center. In FCC riser, the core-annulus flow pattern results in a narrow reaction zone with presence of both gas and catalyst, whereas significant amount of catalyst near walls and gas at center remain non-participating in reactions. Thus, enhanced mixing is desired for higher performance of FCC riser.

In dense fluidized beds, pulsating fluidization, where gas velocity fluctuates with time in regular patterns, has resulted in improved gas-solid mixing. Devahastin and Mujumdar (2001) have found that pulsating spouted bed shows superior mixing behavior at certain law frequency of pulses. Wang and Rhodes (2005) have found that both sinusoidal and square pulsations improve quality of fluidization over a wide range of pulsation amplitudes and frequencies. Hamed Bizhaem and Tabrizi (2013) have shown that pulsating airflow enhances mixing of fine cohesive particles in poly-dispersed fluidized bed. Taking lead from its desired impact in dense fluidized beds, impact of pulsating flow in riser needs to be investigated.

In this study, the effect of pulsating flow is investigated by performing 2D CFD simulations of gas-solid flow in risers with two different flow conditions, namely cold-flow (FCC catalyst-air, H = 14 m, D_t = 0.2 m, G_s = 489 kg/m^{2}s, U_g = 5.2 m/s; Knowlton et al., 1995) and reactive flow (FCC catalyst-VGO vapor and steam, H = 30 m, D_t = 1 m, G_s = 470 kg/m^{2}s, Catalyst to oil = 5.10, Steam = 5% in feed, feed inlet temp = 652 k; Derouin et al., 1997). The CFD model of this study is based on Eulerian-Eulerian gas-solid flow model, where interphase drag is modelled by using the EMMS model and reaction kinetics is modelled by using the 4-lump cracking kinetic model (Lee et al. 1989). Initially, predictions are compared with experimental data and plant data. The validated model is used to simulate

* To whom all correspondence should be addressed

different cases without and with pulsating flow of different amplitudes and frequencies.

Results and discussion

Results discussed in this abstract are from simulated cases listed in Table-1.

*Table-1. Simulated cases (*pulsating flow cases)*

		Gas velocity	Pulse frequency
Reactive-flow	Case-1	9.39 m/s	
	Case-2*	4.69-14.08 m/s	2 Hz
	Case-3*	2.34-16.43 m/s	2 Hz

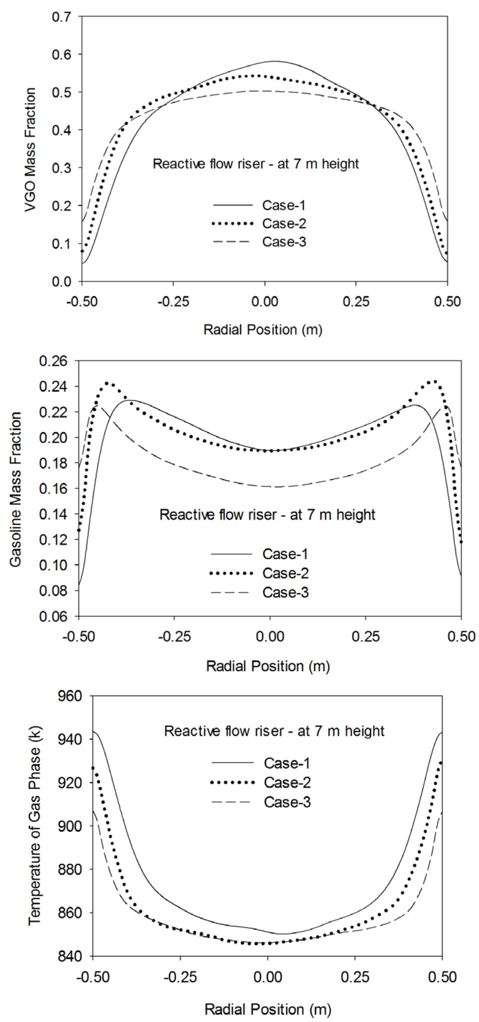

Figure 1. (a) VGO fraction Vs. radial position, (b) gasoline fraction Vs. radial position, and (c) Temperature Vs. radial position

Fig-1(a) shows predicted radial profiles of vacuum gas oil (VGO) mass fraction. Higher concentration of VGO at center and lower values near walls can be seen. This is because of the core-annulus structure, where VGO penetration in dense annular region is less. However for the pulsating flow cases, values near walls are higher than those for without pulsating flow. This suggests that penetration of VGO increases in the annular region, which is relatively less dense in pulsating flow cases (not shown in abstract). Fig-1(b) shows radial profile of gasoline mass fraction. Gasoline mass fractions are higher at some distance away from wall and center of riser. This is because reactions take place where catalyst and VGO contact or at boundaries of core and annular regions. In Fig-1(b) also, the values near walls increase with increase in amplitude of pulses. Furthermore, difference between values at wall and center of riser decrease with increase in amplitude of pulses. This also suggests that the reaction zone expanded towards the walls. However, gasoline mass fraction is significantly lower in the core region for case-3 than those in cases-1 and 2. This is attributed to lower VGO concentration in the core region as appearing in Fig-1(a). Fig-3 shows radial profiles of temperature. According to core-annular profile, higher values near wall can be attributed to higher temperature and concentration of catalyst. For cases-2 and 3, temperature values at both wall and center decreases. This can be attributed to higher heat transfer between the two phases and higher reaction rates in pulsating flow resulting in higher endothermic heat of reactions.

Conclusion

The use of pulsating gas flow gives less dense annular region with it being more penetrated by reactant. As a result, participation of annular region in reactions increases by using pulsating flow. This results in lower difference between values at wall and center, suggesting reduced heterogeneity in radial profiles. In addition to results shown here, the effect of pulsating flow on axial profiles of holdup, temperature and concentration, and time series of catalyst accumulation and mass flow rates are also analyzed.

References

Bizhaem, H.K., Tabrizi, H.B. (2013). Experimental study on hydrodynamic characteristics of gas–solid pulsed fluidized bed. *Powder Technology* 237, 14-23.

Derouin, C., Nevicato, D., Forissier, M., Wild, G., Bernard, J.-R., 1997. Hydrodynamics of riser units and their impact on FCC operation. *I&EC* 36, 4504-4515.

Devahastin, S., Mujumdar, A.S. (2001). Some hydrodynamic and mixing characteristics of a pulsed spouted bed dryer. *Powder Technology* 117, 189-197.

Knowlton, T., Geldart, D., Masten, J., King, D., 1995. Comparison of CFB hydrodynamic models, PSRI Challenge Problem Presented at the Eighth International Fluidization Conference, Tour, France.

Lee, L.S., Chen, Y.W., Huang, T.N., Pan, W.Y. (1989). Four-lump kinetic model for fluid catalytic cracking process. *The Canadian Journal of Chemical Engineering* 67, 615-619.

Wang, X., Rhodes, M. (2005). Using pulsed flow to overcome defluidization. *Chem Eng Sci* 60, 5177-5181.