

CFD SIMULATION OF FLUID CATALYTIC CRACKING IN A ROTATING FLUIDIZED BED IN A STATIC GEOMETRY

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Summary

The application of a rotating fluidized bed in a static geometry for fluid catalytic cracking is evaluated by means of CFD simulations using an Eulerian-Eulerian model and the Kinetic Theory of Granular Flow. The reactions are described by a 10-lump model. First, the reaction kinetics is based on currently allowable catalyst activity. Typical reactor dimensions required are derived and an evaluation of the process intensification potential is made, based on a comparison with riser technology. Next, the possibility of using a higher cracking temperature, or a more active catalyst is evaluated.

Keywords

Process Intensification, Fluidization, Fluid Catalytic Cracking (FCC), Computational Fluid Dynamics (CFD).

Introduction

Rotating fluidized beds in a static geometry (RFB-SG) have been recently developed.¹⁻³ The rotational motion of the bed is generated by the tangential injection of the fluidization gas in the fluidization chamber via multiple slots.

In a RFB-SG, the particle bed height is of the order of centimeters, compared to the order of meters or tenths of meters in conventional fluidized beds or risers. The radial gas velocities can be comparable to the axial gas velocities in risers, or much higher. However, because of the negligible radial motion of the particles in RFB-SGs, the gas-solid slip velocity can be much higher than in conventional fluidized beds or risers. This is advantageous for gas-solid mass and heat transfer.² The combination of small bed heights and high radial gas velocities causes the gas phase residence time in RFB-SGs to be easily one to two orders of magnitude smaller than in conventional fluidized beds or in risers. When used as a reactor, this may be limiting the conversion of gas phase reactants. To compensate for the smaller gas phase residence times, RFB-SGs offer particle bed densities about one order of magnitude higher than those in risers. Furthermore, High-G fluidization was shown to improve the particle bed uniformity, bubbling being suppressed. As such, bypassing of solids (catalyst) by the gas, encountered in conventional fluidized beds, can be avoided in RFB-SGs and the gas solid contact improved. Finally, the improved particle bed mixing and related uniformity may allow the use of higher reaction temperatures and/or a more active catalyst.

To evaluate the impact of the different above mentioned factors and the process intensification potential of RFB-SG type reactors, CFD simulations with the Kinetic Theory of Granular Flow are used. The fluid catalytic cracking (FCC) process is simulated because it is the most important industrial process using fluidized bed, more particular, riser technology and because of the amount of data available in the literature. First, the intrinsic process intensification potential of RFB-SGs is evaluated, that is, using the same catalyst and kinetics used in the riser simulations.⁴ Next, operation at higher cracking temperatures and the use of a more active catalyst are evaluated.

Results and Discussion

CFD simulations using the Eulerian-Eulerian approach with the Kinetic Theory of Granular Flow and a 10-lump reaction model confirm the potential of rotating fluidized beds in static geometry for the intensification of the fluid catalytic cracking process (Figures 1 and 2). Using the conventional catalyst and cracking temperature, process intensification factors of 50 are easily reached. The gasoline selectivity is also slightly higher. Increasing the cracking temperature increases the Gas Oil conversion nearly proportionally, but decreases the gasoline selectivity. Adapting the particle bed height to its optimum to prevent significant overcracking of produced gasoline,

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increasing the catalyst activity increases the Gas Oil conversion, although less than proportionally, but still decreases the gasoline selectivity. The demonstration of the intrinsic process intensification potential of rotating fluidized beds in a static geometry on the FCC process no doubt justifies a further investigation.

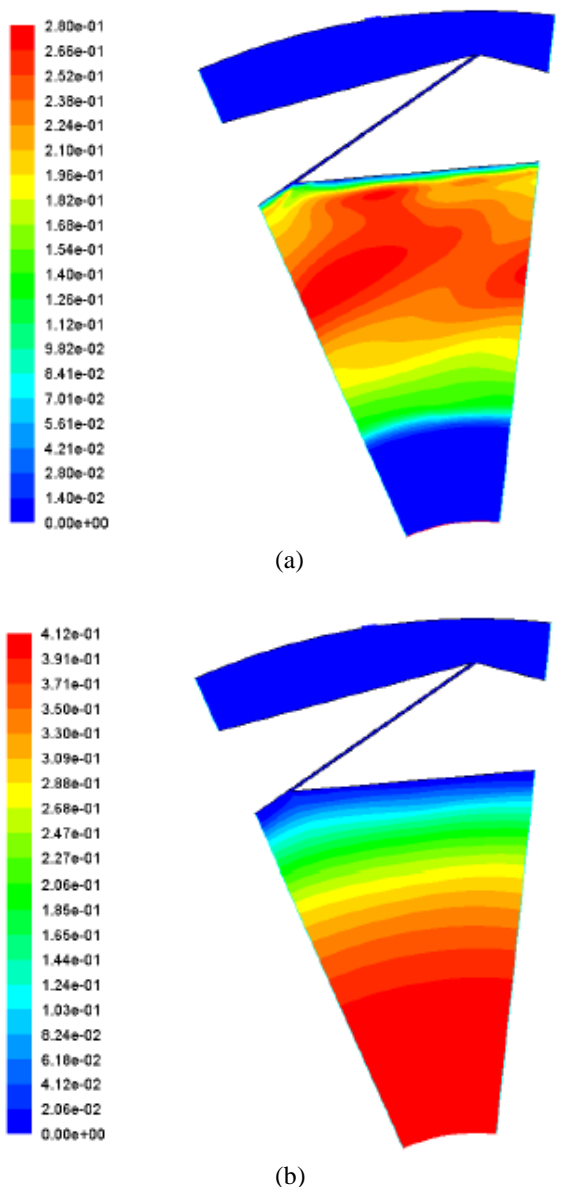


Figure 1: Typical contours plots of the (a) solids volume fraction and (b) gasoline conversion in a RFB-SG.

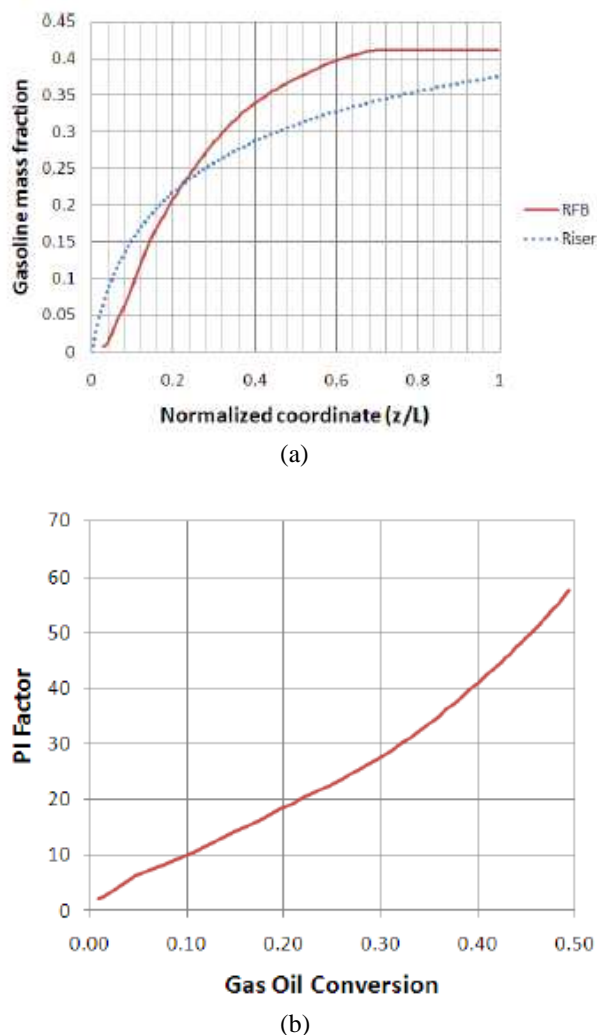


Figure 2: Comparison of FCC in a RFB-SG and in a riser reactor. RFB-SG with conventional catalyst and cracking temperature. (a) Gasoline mass fraction versus normalized coordinate. (b) Process Intensification factor as a function of the Gas Oil conversion.

References

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