NUMERICAL SIMULATION AND EROSION EVALUATION ON FCC RISERS USING CFD

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ABSTRACT

Allowing heavy fractions of petroleum to be converted into more profitable products, the Fluid Catalyst Cracking (FCC) process plays an important role in the oil industry. In countries like Brazil, where most of the explored crude oil composition lies on distinct long-chained hydrocarbons, this technology is essential for the economical success of a refinery.

Constituting a FCC unit, one is to find several equipments, such as: regenerators, cyclones, risers, etc... In fact, it’s along the riser where most of the cracking reactions take place. Thus, it’s of great significance to acquire detailed information on its internal behavior.

For almost every industrial plant, it’s common to associate gas-solid streams with the occurrence of the erosion phenomena. Due to the fixed interaction between the already mentioned equipments, there are few options for a FCC unit’s outline and the riser’s geometrical conformation itself ends up on accelerating the erosive process. Therefore, to verify the most likely areas to suffer deterioration along the module is another major aspect of concern.

The present work aimed to simulate, using ANSYS FLUENT software, the vertical gas-solid flow along a riser of a specific FCC Unit. Fundamentally, to achieve its purpose, the study was carried-out in 3 distinct sections:

- Transient 2D simulations to evaluate the most efficient modeling approach to physically represent the flows’ behavior. Although there is no axisymmetry in this type of flow, 2D models are known to run faster and could be used as a great initial modeling approach. For the same reason, the mesh sensitivity tests were performed in this section and the central plane profile was extended to the 3D models used in sections 2 and 3;

- Transient 3D simulation of a complete Riser, as suggested by Santos et al.[1], to capture the boundary conditions effects over the flow behavior and determine both unsteady and time-averaged profiles along the equipment;

- Steady-state 3D top geometries simulations, fed with the obtained time-averaged profiles on section 2, to evaluate erosion occurrence.
Due to the simulation complexity, some hypotheses were made: The flow was assumed biphasic (gas and catalyst) and cracking reactions terms were neglected, represented by thermal balance.

Although the existing erosion models are only available when using a Lagrangian approach, the software’s modeling guide recommends that particles fraction should not exceed 10% for this type of modeling. Assuming the “perfect sphere” model for the catalyst particles flowing along the equipment led to a 63% maximum packing limit for the dispersed phase. Thus, for a dense particle flow scenario, an Eulerian approach, coupled with the Granular Kinetic Theory for the dispersed phase, is recommended instead. This approach was used on the work developed in both sections 1 and 2, where mean particle diameter was set to the value of 67µm. Several authors, such as Rosa, have indicated this modeling to be accurate when compared to experimental data. As for turbulence contribution inside the equipment, k-ε equations were used. For all the transient cases performed, 25 [s] flow time were simulated using a 10^{-4} [s] time-step. As for convergence criteria, it was set the value of 10^{-4} (averaged residual) for all simulations.

Results have demonstrated great similarity between simulated fluid dynamics behavior and experimental data, indicating good agreement between the employed modeling and the physical aspects of the real equipment’s flow. As an example, figures 1 and 2 illustrate simulated, respectively, catalyst time-averaged profile distribution and velocity profile along the equipment. As expected from experiments, catalyst particles tend to concentrate in near-wall region, where negative velocities can also be observed indicating recirculation.

Once modeling was proved physically representative, distinct riser top geometries were tested aiming erosion process reduction. Top geometries went through steady-state simulations using averaged profiles as inlet condition. For comparison matters, the dispersed phase was modeled using Lagrangian approach and considering Rosin-Rammler’s distribution. In spite of exceeding 10% volume fraction, it was decided to use this approach because it allows the employment of erosion models. It was assumed that such approach misusage would carry the same error due to particles concentration for every top geometry and could be considered valid to compare the cases. Figure 3 illustrates most probable erosion regions for one of the simulated top geometries.
Figure 3: Most probable erosion regions in the equipment.

References


