Challenge Problem for Model Validation[1]

Engineering and modeling are synonymous with each other. We need models to simplify the world into manageable components because if you can´t manage it, you can´t control it. The problem is that the models are dependent on assumptions and simplifications. Thus, all models are wrong. It is the validation process that enables a model to be useful. The problem is that for complicated models such as those used to describe granular-fluid systems such as gasifiers, combustors, fluidized reactors, and circulating fluidized bed reactors; experimental data is in high demand. Thus, Particulate Solid Research, Inc. (PSRI) and the National Energy Technology Laboratory (NETL) are teaming up to provide the most comprehensive granular-fluid challenge problem yet.

The first challenge problem was based on PSRI´s 0.2-meter ID by 22-meter riser with an L-valve configuration. The materials were FCC catalyst powder (US 260 equilibrium powder) with a particle density of 1714 kg/m^3 and median particle size of 76 microns and sand with a particle density of 2644 kg/m^3 and median particle size of 175 microns. Air at room temperature and pressures was used as the lifting gas. The six test conditions were used for the FCC catalyst material and four test conditions were used for the sand material.

Ten modeling results were submitted and were based on either compartment or hydrodynamic models. The results were presented at Fluidization VIII in Tours, France [Laguerie, 1995]. Not all the result encompassed all the test cases. Some modeled only the FCC catalyst powder cases and some modelers did not model the acceleration region. None of the results captured the high pressure drop at the top of the riser due to the round elbow exit. Many models predicted fully developed flow, but none of the test cases were in that regime. Also, most models did not capture the axial pressure profile. Many models provided a shallower decrease of density with height. In addition, many models did not show the upflow of solids at the wall for the high solids mass flux case. Some models, however, did capture a hump in the solids flux profile at the 70% of the radius for high mass solids fluxes.

Six years later, PSRI issued another riser challenge problem. Data were collected from the same unit except the entrance region was reconfigured for an angled standpipe. Also, a fluidized bed region was added to the bottom to help provide a more symmetric radial profile. As with the first challenge problem, the same two types of materials were used: FCC catalyst powder and sand.

The results of the second challenge problem were presented at Fluidization X in Beijing, China [Kwauk, 2001]. Thirteen sets of modeling results responded to the challenge. As before, some modeled all the test cases, but most only modeled selected parts. Modeling results were still unable to fully capture the axial and radial profiles. Radial profiles for the solids flux and particle velocity were also poorly captured. Percentage error ranged from 77 to 334%.

The high error for the modeling results for both challenge problems stem from several factors. First, there is still only a limited amount of CFB data available to validate modeling concepts. The constitutive equations developed for riser flow are only as accurate as the quality and quantity of data available. Additional work is still needed in the area. Second, researchers must often assume uniform boundary

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conditions at the bottom of the riser. This is rarely the case in any riser application. The inlet boundary condition needs to be captured at the most predictable part of the CFB which is the slide valve. Fluxes are high at the slide valve, and a uniform boundary condition may be appropriate. Also, the path from the slide valve to the riser entrance will help minimize any error of making a uniform boundary condition assumption. Third, many modelers assumed that the first few seconds (on the order of 10 to 30 seconds) of startup are sufficient to match the steady state results from experiments. In addition, averaging of the modeling results is only done over a few seconds whereas in the experiments it is done over minutes.

NETL, in collaboration with PSRI, has generated a third Challenge Problem from data generated in NETL's circulating fluidized bed and PSRI's bubbling fluid bed. The results are to be presented at the Circulating Fluid Bed X to be held in Sun River Valley, Oregon, USA in May, 2011 (www.cfb10.org). You are hereby invited to predict the data with your hydrodynamic model. The third challenge problem will be designed to overcome the limitations of the first two challenge problems. Physical properties will include minimum fluidization and bubbling velocities and bed densities. The first step in model validation should include capturing the minimum fluidization and bubbling velocities and bed densities. Modelers will be asked to submit modeling results based on the experimental description alone. After which, the data will be released and the modelers will have a second chance to provide modeling results. Both sets of results will be presented at CFB X. A description of the experimental unit used to obtain the hydrodynamic data, material parameters, and test conditions/parameters can be found at https://mfix.netl.doe.gov.

We realize that there is not a lot of time remaining until papers are due for the CFB X conference, but your first set of results must arrive by e-mail or computer disk by October 30, 2010. All modeling results will be handled confidentially up and until CFB X. Model input results will be assigned a random model number so that contributors can track the performance of their results anonymously. Experimental results and validation criteria will be made available on the MFIX website November 1, 2010. Any feedback, new simulations or comments on these results and criteria will only be considered for up to January 1, 2011.

PSRI and NETL have been working hard to provide test cases that best encompass the challenges in granular-fluid hydrodynamics. We are excited by the prospect that some of the new modeling efforts will show. However, the goal of the third challenge problem is not to rank the models but to learn what does and does not work for this application and to grow from those lessons.

References

1. Laguerie, C., Large, J.F., Fluidization VIII Workshop, Tours, France, May 14-19, 1995.
2. Kwauk, M., Li, J., Yang, W-C., Fluidization X Workshop, Beijing, People Republic of China, May 20-25, 2001.