Multiphase Flow Research Needs

Tim O'Hern
Sandia National Laboratories, Albuquerque, NM

Here are a few of my thoughts on research needs in multiphase flows. I have tried to focus on dilute gas-solid flows but many of the needs have a lot of overlap with dense gas-solid flows and even gas-liquid and liquid-solid flows.

- Experiments at multiple scales (at least two different scales). Generally small scale experiments are better for control and experimental accessibility and repeatability while large scale experiments provide the link to industrial conditions and are needed to verify that the same physical phenomena are occurring at both scales. Example: Dynamic pressure measurements around the perimeter of a large fluidized bed show circumferential variations related to local defluidization, etc. Such variations are not always detectable, if present, in lab-scale fluidized beds. On the other hand, the simple lab-scale experiments may not be of direct industrial relevance but they can be well characterized and (ideally) measured, so there is clearly a need for both types of experiments. Additionally, scale-up is one of the greatest challenges in multiphase flows. Achieving the same flow conditions in a series of well-planned scaled facilities, and measuring with identical diagnostics, would provide the most direct scale-up data available.

- Experiments that include simplified chemical reactions, e.g., ozone decomposition. Most experimental data in the literature were acquired under "cold-flow" (no chemical reaction) conditions. Such experiments are generally easier to run and replicate, and can tell a lot about multiphase hydrodynamics. However, many multiphase flow applications have temperature, pressure, phase change, and/or other chemical reaction effects which can be dominant but are not seen in cold-flow experiments.

- Calibration of multiphase diagnostics. Diagnostics in multiphase flows can be complicated by different instrument response to each phase and to changes in the phase distribution. Unlike single phase flows, it is very difficult to generate a flow of known conditions that can be used to calibrate multiphase diagnostics. This is, of course, because the flow patterns can be different even for identical flow rates of each phase. For this reason, most multiphase diagnostic calibration is done by comparing the results of different diagnostics. More such work is needed. The results will be extremely valuable in showing the often complex link between acquired data and the flow conditions at the measurement location.

- Noninvasive diagnostics: Multiphase flows and turbulent flows are the two outstanding problems in fluid mechanics. Turbulent multiphase flows are obviously a great challenge. Diagnostics are needed to measure turbulent characteristics of the gas and solids motion, for example using ultrasonics, radioactive particle tracking, etc. Successful validation and implementation of such diagnostics will require dedicated effort. As per the calibration bullet above, validation of new techniques must be done in a well-characterized facility under well-controlled test conditions, with other diagnostics acquiring calibration data simultaneously.

- Segregation data over a wide range of operating conditions. Segregation occurs in many gas-solid flows but most of the data in the literature are for very simple conditions, for example, passage of a single bubble through a bed. A well-characterized series of experiments on particle segregation due to size and density differences over a broad range of operating conditions is needed to provide data needed to test computational and analytical models.

- Cluster formation in CFBs: How formed, effect of clusters on bulk flow viscosity and pressure drop. Requires combined experimental and computational/modeling effort.

- Experimental needs: Good test facilities and good diagnostics already exist and have been operated for years. While there is some need for improvements and upgrades, I would like to see experimental programs with sufficient funding to allow the facilities and the diagnostics to be operated nearly full time for a few years. Small programs suffer from the time needed to get facilities and diagnostics up and running, particularly in multiphase flows.

- Experimental facilities with the capability to run fully characterized experiments including not only the flow properties being studied but also initial and boundary conditions, particle size distributions and its changes with time, etc. The facilities should be able to provide validation data over a broad range of conditions. Experimental data are often not too useful for developing and/or validating models because key data are missing, for example the inlet or boundary conditions at which the experiment was performed. I propose that any new program involving multiphase modeling or experiments require close and frequent interaction between the experimental and modeling/computational groups. As an example, we ran a large series of experiments at Sandia National Laboratories designed to acquire data to validate computational models of turbulent pool fires. While the detailed data sets acquired in large fires were useful for understanding the fluid physics, they could only be used for computational validation when the inlet and boundary conditions were carefully controlled and monitored.