Scientific issues in multiphase flow raised by Hanratty et al.* workshop

By Sofiane Benyahia

Fluent Inc.

* A Summary of this workshop can be found in: T.J. Hanratty et al., "Workshop findings", International J. of Multiphase Flow, 29 (2003), pp. 1047-1059

On microphysics[1]

- **Most critical scientific issues raised by this study group are not directly relevant to us:**
  - Boiling nucleation
  - Condensation and contact forces (surface tension)
  - Multiphase flow in microchannels

- **Breakup and coalescence**
  - VOF, LBM (etc) depend strongly on grid resolution
  - Need to establish theoretical and experimental criteria

- **Drag reducing polymers**
  - Mostly for gas/liquid flow. Few theoretical work conducted to understand the role of polymers in reducing drag (even at very low concentration)

[1] J.M. Delhaye and J.B. McLaughlin, “Report of study group on microphysics”, International J. of Multiphase Flow, 29 (2003), pp. 1101-1116

NETL

On computational physics[2]

- **Issues related to computational multiphase flows**
  - Multiscale phenomena (large-scale phenomena affected by small-scale processes)
  - How to best exploit the enormous amount of data generated by simulations?
  - Transient phenomena: need to follow the evolution of an enormous range of scales for a long time

- **Foreseeable future: use averaged multiphase flow equations, which need:**
  - Better closure models developed from detailed simulations such as DNS, LBM etc.
  - High accuracy, fast algorithms and computers
  - Account for phase change, rheological effects, chemical reactions, electric and magnetic fields, etc.

[2] A. Prosperetti and G. Tryggvason, “Report of study group on computational physics”, International J. of Multiphase Flow, 29 (2003), pp. 1089-1099

On disperse flow[3]

- **Dilute particle laden flow (e.g. coal combustion)**
  - Extending single-phase LES or DNS to include particles as point-force approximation. Issues:
    - Use of analytical or empirical drag law using explicit (undisturbed) relative velocity causing large particle tracking errors
    - Ignore the effect of particles on small-scale turbulence
    - Very fine grid near solid boundaries
  - Fluid-particle interaction due to drag need improvements for turbulent flows (particle-eddy interaction). Can be solved by highly resolved computations.
  - Particle-particle interactions can be important. Can be studied by numerical codes (tracking millions of particles) or particle-tracking velocimetry.
  - Turbulence and transition to turbulence modified by particles: need for detailed experiments

[3] S. Sundaresan et al., "Report of study group on disperse flow", International J. of Multiphase Flow, 29 (2003), pp. 1069-1087

On disperse flow[3] (continued)

- **Concentrated suspension (instantaneous particle collisions)**
  - Based on kinetic theory with dissipative effects in the fluid and particle collisions
    - Need for careful experiments and particle dynamic simulations to test/validate the theories
    - More work is needed to enhance our current understanding of boundary conditions
    - Theory should account for bubble deformation and bubble shape oscillation
    - Theory that include the effect of particle-size distribution (addition of fines) must be developed
  - Multiphase flows are unstable (need transient model)
    - Loss of stability can happen at small length scale (few particle diameters) and the validity of the averaged equations when gradients arise from such small scales is not clear
    - Develop coarse grid closures from statistical data acquired during fine grid simulations
    - Need non-intrusive measurements techniques with fine spatial and temporal resolutions

- **Dense systems (with enduring particle contact)**
  - Need to develop theories based on particulate-characteristics such as:
    - Cohesive inter-particle forces
    - Particle size, shape and their distribution
    - Frictional contact between particles

[3] S. Sundaresan et al., "Report of study group on disperse flow", International J. of Multiphase Flow, 29 (2003), pp. 1069-1087

On disperse flow[3] (continued)

- **Dense systems (with enduring particle contact)**
  - Role of frictional particle-particle and particle-boundary interactions:
    - Extend theories of particle angular momentum for gas/solids flow with experimental validation
    - In polydisperse systems, need models to describe segregation or mixing of particles of different size and density.
  - Several issues with MD simulations need to be resolved:
    - Parametric sensitivity
    - Handling of wall boundaries
    - Real material properties (non-spherical materials, multi-size etc.)
  - Multiscale models involving continuum and MD simulations can be tackled within 5-10 years

[3] S. Sundaresan et al., "Report of study group on disperse flow", International J. of Multiphase Flow, 29 (2003), pp. 1069-1087

On flow regimes[4]

- **Mainly for gas-liquid flows, which recognizes two major approaches:**
  - Steady fully-developed adiabatic flows
    - Lack of validity of current models (rate of droplets entrainment to walls, the effect of wall heat flux on entrainment of deposition of droplets etc.)
    - Need to understand (from first principles) slug formation and flow transition from disperse to slugging
    - Phase distribution in bubbly flows need improvements on how bubbles are formed at the inlet
  - Mixing flows
    - Modeling issues occur because of topological changes occur at relatively sharp spatial regions

[4] T.G. Theofanous and T.J. Hanratty, “Report of study group on flow regimes in multifluid flow”, International J. of Multiphase Flow, 29 (2003), pp. 1061-1068

Concluding remarks

- **Many important issues were raised by the workshop, but few clues were given on how to solve them.**
- **Most relevant issue to us were raised by the study group on disperse flow**
- **We can choose and expand on the most relevant issues that will be addressed in our workshop**