Dynamic flow structure in multiphase systems using single radio-labelled particle tracking

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Mobile particulate systems are of general interest in the multiphase reactor engineering community, owing to their wide applicability as reactors and separators in the petroleum refining and downstream process industry. The flow pattern in these "real-world" systems is considerably more complex than what may be achieved in sanitized laboratory environments; consequently rigorous theoretical treatment of the flow in such systems is as yet elusive. This limitation poses a cap on predictive scale-up of such industrial vessels, whose design is primarily based on average flow rates, or more recently, on profiles of velocity and volume fraction of the phases [1]. The fluctuations in the flow, generally multi-scale is nature, are not characterized well and thus that information is not incorporated into design and scale-up protocols today.

Radioactive Particle Tracking (RPT) ([2], [3]) has become popular in recent decades as a method for probing the velocity fields in opaque, multiphase systems non-invasively. The basic idea in this method is to track the motion of a single tracer particle (made radioactive by incorporation of a suitable isotope) over many realizations of the flow, and then deriving ergodic means of the velocity profiles, RMS velocities, etc. In the past (e.g. [2]), most of the data treatment of RPT was done by projecting the data onto an Eulerian grid, since that was thought to be most useful from a reactor engineering perspective and also as validation data for CFD and other models.

In this presentation, the focus will be on RPT data treatment using the theory of non-linear dynamical systems. The time-series of the tracer location, which is of Lagrangian nature, serves as a "signature" of the flow pattern and indeed, the flow regime that exists in the multiphase system. Using the theory of non-linear dynamics ([4], [5]), distinct parameters that characterize the flow (such as Kolomogorov entropy) are evaluated, and their physical interpretation vis-a-vis the flow pattern and the underlying forces, is discussed. As examples, a gas-liquid system (air- water bubble column) and a gas-solid system (unary and binary fluidized bed) are taken.

References

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