RADIOTRACER METHODS, CFD AND SCALE-UP:
CURRENT STATUS AND FUTURE TRENDS

Shantanu Roy*
Department of Chemical Engineering, Indian Institute of Technology (IIT) – Delhi,
New Delhi 110016, India

Abstract
Radiotracer techniques are widely used for measurement of hydrodynamic parameters, troubleshooting and process optimization in industrial reactors. Radioactive Particle Tracking (RPT) methods have been popular in the laboratory investigations. Both have been used to validate respective-scale CFD models to partial success. This talk summarizes a history of such developments and the current state of this art and science, with a perspective towards the future and how these investigations may help augment scale-up methods.

Keywords
Radiotracer, residence time distributions (RTD), radioactive particle tracking (RPT), flow measurements, CFD, scale-up

The design and scale-up of chemical reactors is a problem of continuing interest to chemical and process engineers. While many problems and challenges in the design and scale-up of multiphase reactors have been addressed, the emergence of novel (and typically difficult) feedstocks as well as the need to reduce the environmental footprint of process units continues to open and evolve new challenges in this field. Many of these challenges relate to the inherently complex and scale-dependent nature of these dispersed multiphase flows. Other transport effects in reactors, in turn, get determined by the nature of these flows.

Radiotracer techniques are widely used for measurement of hydrodynamic parameters, troubleshooting and process optimization in full-scale industrial reactors because of their many advantages such as high detection sensitivity, on-line detection and availability of a wide range of compatible radiotracers for various applications and utility in harsh industrial environments. Built on the legacy of classical reactor engineering and residence time distribution (RTD) theory, radiotracer imaging involves the injection of radioactive material in a suitable physico-chemical form similar to that of the process material. The passage of these radiotracers in their sojourn through the system of interest is monitored at strategically selected locations using radiation detectors. In spite of their widespread use in the industry, radiotracer techniques have several limitations in their interpretation, not often widely discussed, and thus their use for scale-up and scale-down of multiphase flow reactors and validation Computational Fluid Dynamic (CFD) models is limited.

The other end of the spectrum of radiation-based imaging techniques is represented by single-particle radiotracing methods, such as Radioactive Particle Tracking (RPT), Positron Emission Particle Tracking

* To whom all correspondence should be addressed
(PEPT) and X-Ray Particle Velocimetry (XPTV). For instance, RPT, which has been widely discussed in the open literature, is based on the principle of following a single gamma-ray emitting tracer particle through its many realizations in the process vessel of interest, and then back-projecting the photon counts time series to yield a Lagrangian velocity time series. From the latter information, many flow quantities of interest are evaluated, including ensemble averaged profiles of velocity, turbulence and flow regime information, and dispersion coefficients. In that sense such techniques come close to other “optical” velocity measurement methods like PIV and LDA. Such single particle radiotracer data thus yields rich databases for benchmarking CFD models, but the issues related to both experimenting with such techniques at large scales and well as having grid-converged CFD models at large scales essentially limits such validation research to small-scale laboratory systems.

This presentation will dwell on the challenges in “bridging this gap” in radiotracer techniques between these scales.

The crucial question to answer is how we can “link” experimental techniques for hydrodynamics applicable at laboratory, pilot plant and industrial scales, just as in recent years such a hierarchy of “multi-scale” models has been professed and popularized in the CFD space (for instance linking sub-grid scale Lattice Boltzmann models (LBM), discrete element models (DEM), Euler-Euler models, and phenomenological reactor models). The arguments will be presented with the help of some cases studies, specifically the application to gas-solid flows in fluidized gasification reactors.