# INVESTIGATION OF MULTIPHASE REACTORS USING RADIOACTIVE PARTICLE TRACKING

by

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# CERTIFICATE

This is to certify that the thesis entitled '***Investigation of Multiphase Reactors by Using Radioactive Particle Tracking***' being submitted by **Mr. Rajesh Kumar Upadhyay** to the Indian Institute of Technology, Delhi for award of Doctor of Philosophy is a record of bonafide research work carried out by him under my guidance and supervision in conformity with the rules and regulations of Indian Institute of Technology, Delhi.

The research report and results presented in this thesis have not been submitted, in part or full, to any other University or Institute for the award of any degree or diploma.

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# Abstract

In this work, a next generation Radioactive Particle Tracking Technique (RPT) test facility, which is a unique non-invasive methodology for measuring velocity fields and mixing patterns in multiphase vessels, has been designed and installed. In the RPT technique, a single radioactive particle (which is a gamma ray emitter) is used as the marker of the phase whose velocity field is to be mapped. The tracer particle motion is interrogated by an array of scintillation detectors which are strategically placed around the vessel of interest. Subsequently, the Lagrangian trace of this particle is used to decipher the instantaneous position time series of any "typical" fluid element and from that the instantaneous velocity time series. From this information, a rich database of flow quantities such as mean velocity fields, kinetic energies of the turbulence and other parameters that represent the prevailing flow regimes and flow characteristics can be extracted.

Work as part of this thesis research encompasses various aspects of the implementation of and investigations with RPT. The first part of the thesis relates to the implementation of the current RPT setup, and ways in which this unit improves upon the earlier work is reported. In continuation, protocol for *a priori* design of the RPT experiments has been presented with experimental work on a specially designed experimental setup. Theoretical claims made earlier (Roy et al. (2002)) regarding experimental design for a given configuration and flow system have been experimentally verified. Various reconstruction algorithms have been tested and most favorable algorithm for RPT implementation is identified. Error analysis is also performed.

In the subsequent chapter of this thesis, RPT has been used to study gas-liquid flows in 2D laboratory scale bubble columns. Two objectives are met in this study. First, the results of newly developed RPT setup is benchmarked against a literature-reported Laser Doppler anemometry (LDA) (which is a widely accepted flow measurement method) results, studied in rectangular cross-section bubble column. In addition, the effect of column aspect ratio on flow structure is investigated. Three different aspect ratios of the column are investigated for a wide range of air flow rate. It is found that the plume oscillation and time averaged symmetry description of liquid velocity profile is valid only for certain set of aspect ratio and air flow rate.

Next, a large part of this work is on implementation of RPT for investigating of binary fluidized beds. In this, RPT has been performed with two tracer particles, for tracking either solids that make up the binary bed. The effect of variations in size and density of particles, or both size and density of particles is investigated. This work has been performed extensively at various operating conditions and various compositions of the binary bed. The study has resulted in some very revealing conclusions, most important amongst them being the crucial role played by particle-particle collisions in polydisperse fluidized bed behavior.

Finally, *on-site* implementation of RPT technique on a pilot-plant has been attempted for the first time, and a pilot-plant bio-reactor has been investigated. As part of this study, significant modifications to existing RPT software and hardware was done to meet the logistical challenges posed by this effort. The flow pattern in the vessel of choice is reported, and recommendations suggested by the industrial RPT investigation are presented.

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