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Advanced Measurement Techniques for Enabling Multiphase Reactors and Flow Systems for Sustainable and Cleaner Processes

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Editorial

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Multiphase reactors (bubble/slurry bubble columns, packed beds, fluidized and circulating beds, etc.) and multiphase flow systems (blenders/mixers, separators, conveyers, heat exchanges, flow in pipes, etc.), have found extensive applications in every industrial processes related to energy, environmental, water and variety of products processes. These systems in general and multiphase reactors in particular are complex, as they can take various configurations and types based on the way the phases contact each other and interact. Their design, scale-up, proper operation and performance prediction are challenging tasks due to the lack of their understanding as result of the complex interactions among phases. In addition, the complexity increases with the presence of internals that affect the hydrodynamics, mixing, transports (mass and heat), reactions and hence, the performance of these reactors and flows. Therefore, advanced techniques that integrate measurements in a novel way of various hydrodynamic and transport parameters are required including high-energy gamma ray photons based techniques to advance the needed fundamental understanding of these systems and their proper operation by visualization and providing an effective diagnostic means for troubleshooting. Achieving these will enable multiphase reactors and flow systems to be integral parts of sustainable process design and for developing and operating sustainable and cleaner processes. Furthermore, computational fluid dynamics (CFD) have found increased use in industry to simulate, design and scale up of these multiphase reactors and flow systems. Due to their complexity, most (if not all) of the used models, closures, parameters in the CFD to simulate these systems have not been based on proper physics or first principles. Accordingly, advanced measurement techniques, facilities and methodologies are needed to provide the detailed local hydrodynamics parameters in order to reliably benchmark CFD simulation results for validation.

To achieve these we have developed in our Multiphase Flows and Reactors Engineering and Applications Laboratory, mFReal, such needed sophisticated measurement techniques, facilities and methodologies and we verified and utilized them for studies related to various complex reactors and flow systems such as single phase with complex geometry and gas–liquid, gas–solid, gas–liquid–solid, liquid–solid, liquid–liquid systems that cover a wide range of processes. These measurement techniques are as follows. I) Radioisotopes based measurement techniques: 1. Two radioactive particle tracking (RPT) single and multiple particles, for 3D flow field, velocity and turbulent parameters, 2. Dual source gamma ray tomography (DSCT), and 3. Gamma ray densitometry (GRD) for phases' distribution and flow pattern identification. II) Non-radioisotopes based measurement techniques: 1. Four-point optical fiber probes for bubble dynamics, 2. Optical fiber probes for two phase flow in packed beds for local gas and liquid velocities and saturations and their fluctuations, 3. Non-invasive and invasive heat transfer probes for heat transfer coefficients, 4. Combination of bubble dynamics and heat transfer probes, 5. Optical probes for solids dynamics that measure simultaneously solids velocity and holdups and their fluctuations. 6. Hot wire anemometry for local gas and liquid velocities, 7. Integration of hot wire anemometry, heat transfer probes and temperature measurements, 8. Gas tracer dynamics, 9. Liquid tracer dynamics, 10. Optical probe for local mass transfer coefficient, 11. Gas tracer technique for global mass transfer coefficient, 12. High precision pressure transducers, 13. Slurry and basket reactors for catalyst testing and kinetics, and others. These techniques have been implemented on a wide range of bench, laboratory and pilot plant scales of rigs and experimental setups of multiphase reactors and flow systems operated at room to high pressure and temperature conditions. They have been augmented with sophisticated mathematical algorithms and programs that have been developed in our laboratory for data gathering, processing and image reconstruction. The utilization of these techniques is complemented by our advanced modeling, scale-up methodologies and computations capabilities. Also statistical methods, artificial neural network and chaotic analyses have been developed and used to further analyze the obtained results for flow pattern identification and for mechanistic approaches that we have developed for scale-up methodologies of these complex multiphase flow systems. In addition, validation of CFD simulations, models and closures for various types of multiphase reactors and flow systems have been conducted both in our laboratory and in collaboration with various research laboratories and centers.

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