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ABSTRACT

Bubble column fluid dynamics: a multi-scale perspective

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When a gas phase is injected into a liquid phase, it generates a complex and intriguing fluid dynamic phenomenon. This lack of understanding, which poses challenges in the design and operation of multiphase reactors, is partly due to the absence of a definitive classification of flow regimes. Since pioneering research in the 1980s, it has been recognized that the "global scale" is influenced by the "local scale," with the interaction between these scales manifesting in various flow regimes. Specifically, the "bubble scale" (i.e., the motion of individual bubbles) affects the medium scale (i.e., turbulent eddies that transport the dispersed phase) and the large scale (i.e., circulation cells and central plume oscillations) characteristics, which define the "reactor scale." Unfortunately, a precise and analytical description of the connections between the "local scale" parameters and their scaling up to the "reactor scale" across different flow regimes remains elusive. Various studies have proposed different definitions of flow patterns and experimentally obtained some global and local flow properties, but a physically based description of these flow patterns is still lacking. Is there a theory that can determine, a priori, the boundaries of different flow regimes (and thus the flow regime for a given set of boundary conditions, phases, and system design)? In this lecture, drawing from a comprehensive dataset collected over recent years of research, a new theory is proposed. This theory redefines the current approach to bubble columns and is based on the following premise: the fluid dynamics in gas-liquid bubble columns can be interpreted through a general relationship, built upon five flow regime transitions, between two global fluid dynamic parameters (Figure 1).

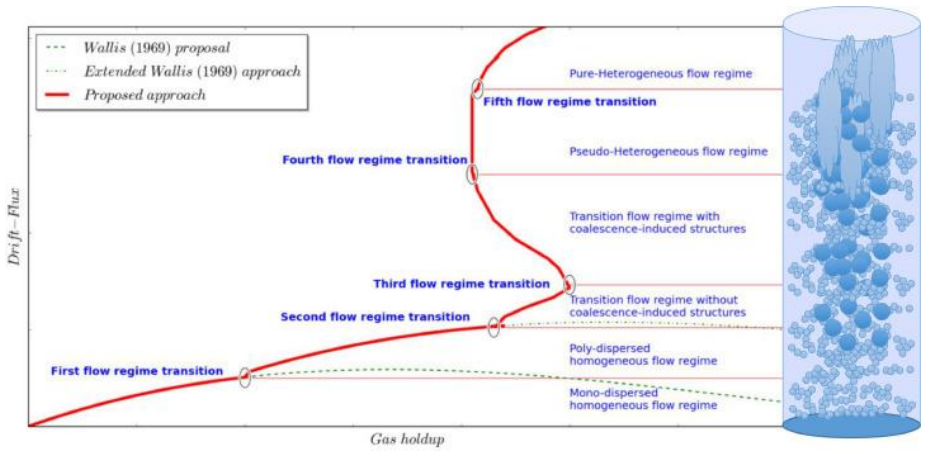

Figure 1. Anatomy of bubble column flow regime and flow regime transitions. In the graphical representation of bubble column, on the right, each vertical position represents a time-averaged condition for a fixed drift-flux value