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Experimental investigation on solid dispersion, power consumption and scale-up in moderate to dense solid–liquid suspensions

*Rouzbeh Jafari, Philippe A. Tanguy, Jamal Chaouki**

Chemical Engineering Department, École Polytechnique Montréal, PO Box 6079, Station. CV, Montreal, Quebec, Canada H3C 3A7

ABSTRACT

Detailed particle concentration distribution in dense solid–liquid suspension was measured by means of fiber optic probes. The effect of solid loading, impeller speed, and impeller type and clearance was investigated. Results were compared with modeling approaches to show the accuracy of sedimentation–dispersion model and its capability to describe complex phenomena taking place in dense liquid–solid mixing systems. Variation of power numbers by changing impeller clearance and solid loading were also investigated. It was shown that the impeller power number for a slurry system exhibited different trends in a moderate or dense liquid–solid system. In addition, scale-up rules to achieve the same level of homogeneity on a large scale as the laboratory scale were evaluated.

Keywords: Solid dispersion; Fiber optic; Liquid–solid; High solid loading; Mechanically agitated vessel

1. Introduction

Mechanical mixing is a common unit operation in chemical, biochemical, mineral processing and many other applications. Suspension of solid particles in a liquid is required in many processes, such as leaching, catalytic reactions, crystallization, and water treatment. According to the process, it is possible to carry out the mixing of liquid–solid system in the state of just suspended or homogeneous suspension. Homogeneous suspension, when solid phase uniformly is distributed in the stirred vessel, is difficult to attain and usually is not required in most industrial applications. Proper design of liquid–solid stirred tank reactor requires comprehensive knowledge of local solids concentration profiles in the slurry. Most published studies on liquid–solid agitated vessels have been done for characterizing just suspended condition. Other parameters related to a liquid–solid mixing system, like cloud height, solid concentration profile, power consumption and scale-up, have not been studied extensively in high concentrated systems.

Numerous methods are available for measuring local solids concentration in slurry (for example: Angst and Kraume, 2006; Ayazi Shamlou and Koutsakos, 1989; MacTaggart et al., 1993b; Spidla et al., 2005). One of the popular methods is the optical method. It has been used widely for characterizing solid distribution in agitated vessels (Ayazi Shamlou and Koutsakos, 1989; Magelli et al., 1990, 1991). This non-intrusive method is generally limited to solids concentrations less than 1–2%. This is due to the scattering and blocking of light by the solids between the source and the receiver. Other measurement methods are the sample withdrawal method and the conductivity probes. The sample withdrawal method is the simplest one and has been employed widely (Barresi and Baldi, 1987; MacTaggart et al., 1993b). The samples are taken from different locations in the vessel, and the solid phase concentration is determined. However, it is has been shown that Iso-kinetic sampling from stirred tank reactors is extremely difficult because of the complex dynamic behavior of the system (Barresi et al., 1994; MacTaggart et al., 1993b; Nasr-El-Din et al., 1996). Another method is conductivity measurement, which is based on the conductivity changes in the suspension according to the quantity of solid particles present. Most researchers have used the two-electrode conductivity probe (for example Spidla et al., 2005). However, four-electrode conductivity probe also have been applied in some studies (Considine and Considine, 1985; MacTaggart et al., 1993a; Nasr-El-Din et al.,

* Corresponding author.
E-mail addresses: rouzbeh.jafari@polymtl.ca (R. Jafari), jamal.chaouki@polymtl.ca (J. Chaouki).
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