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# Visualization of reactive and non-reactive mixing processes in a stirred tank using planar laser induced fluorescence (PLIF) technique

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ABSTRACT

A comprehensive study on the liquid mixing with/without instantaneous reactions was conducted using planar laser induced fluorescence (PLIF) technique, where a novel reactive PLIF technique was adopted to quantitatively visualize the dynamic variation of the concentration of fluorescence dye due to signal quenching by a Fenton reaction. The factors (e.g., tracer injection direction, tracer injection position, impeller speed) influencing the reactive and non-reactive mixing processes were investigated, and the mixing performances were characterized by non-reactive mixing times ($\tau_{95}$ and $\tau_{99}$), and reactive mixing time ($\theta_{99}$), respectively. The experimental results from the 2-D measurements of liquid mixing behavior emphasized the significance of the understanding on the spatio-temporal mixing patterns: not only did the tracer injection position affect the mixing performances in the stirred tank, but also the sampling position to monitor the mixing status would lead to a large difference in evaluating the mixing performance. For the stirred tank with fast reactions, the reactive mixing performance had a strong interplay with the non-reactive mixing.



*Keywords:* Stirred tank; Reactive mixing; Non-reactive mixing; Planar laser induced fluorescence (PLIF); Visualization

## 1. Introduction

The liquids mixing in a stirred tank has drawn more and more attention due to their wide applications in the chemical, pharmaceutical and biochemical industries, where the mixing performance is generally appraised by the mixing time, i.e., the time to reach the liquid homogeneity of the bulk liquid after the injection of a tracer pulse. In the past, most of the literature concentrated on the liquids mixing processes without reaction (i.e., non-reactive mixing), while little attention focused on the reactive mixing processes to understand the mixing mechanisms through detailed measurements. For the reactive mixing processes, a deep understanding of the effect of liquids mixing performance on the chemical reaction is of vital importance to the their appraisal and design. Though non-reactive mixing processes have been studied using various methods, the new trend is to visualize the mixing details in space, and even the reactive mixing processes, by using non-intrusive advanced measurement techniques.

The probe techniques in terms of thermometry (Kramers et al., 1953; Biggs, 1963) and conductivity (Hoogendoorn and Den, 1967) have been applied to measure the non-reactive mixing. However, in addition to the relatively poor precision, the probes in these techniques also impact the flow field to some extent. A liquid crystal thermographic technique was developed to visualize the transient mixing characteristics in a stirred tank, while the measurement depended much on the temperature calibration (Lee and Yianneskis, 1997). Other techniques such as pH and coloration–decoloration were also used by some researchers (Merchuk et al., 1998; Fabrice and Christian, 2003; Delaplace et al., 2004; Cabaret et al., 2007). The 3-D electrical resistance tomography (ERT) was employed to capture the fast acid–alkali reaction in a 2.3 $m^3$ plant-scale stirred vessel (Wabo et al., 2004); a 3-D UV light pattern visualization was applied to stirred bioreactors (Alvarez et al.,

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