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Experimental study on instantaneous pressure fluctuation time series in the novel tank agitated by multiple horizontal jets

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ABSTRACT

The Novel Circulating Jet Tank (CJT) agitated by multiple horizontal jets has become an alternative to the bottom-entering mechanical stirred tank in chemical process industries. In order to characterize the coupled interaction between the rectangular baffles and the tank wall, the pressure fluctuations in the novel tank of 0.4 m diameter are measured using high speed acquisition system. The time series of instantaneous pressure in the jet mixing zone are investigated at different radial, circumferential and axial positions under different Reynolds numbers. Time-frequency and energy characteristics of the instantaneous pressure are analyzed and evaluated with the Hilbert–Huang Transform and marginal spectrum. Experimental results indicate that the spatial distributions of instantaneous pressure fluctuation amplitudes increase with the increasing Reynolds numbers. The first order inherent frequencies of power spectrums are lower than 5 Hz. The relationship between power spectral density and frequency accords with power-law attenuation. The scaling exponents range from 0.5 to 1.15 which indicates the existence of fractal characteristics in the pressure fluctuation time series. Compared with the corresponding normal distributions, the probability distribution functions and χ^2 hypothesis tests of the pressure fluctuations have been obtained. The deviations from the normal distribution are quantitatively analyzed based on skewness and flatness.

Keywords: Instantaneous pressure; Hilbert spectral analysis; Probability density functions; Flatness; Skewness

1. Introduction

Mixing is one of the common unit operations employed in chemical and allied industries. It can be achieved using mechanical mixers, fluid jet mixers, static mixers or pipe line with tees. Jet mixing can be described as a fast-moving stream of liquid being injected into a slow-moving or stationary liquid (Amiri et al., 2011; Dehkordi and Savari, 2011; Monclova and Forney, 1995; Sundararaj and Selladurai, 2010). It has no moving parts as in conventional agitators. So maintenance costs are low. Jet mixers are easy to install when compared with impellers (Maruyama et al., 1982; Mathpati et al., 2009; Ranade and Joshi, 1989; Wasewar, 2006). Therefore, jet mixers become an alternative to impellers and are widely used for blending the inhibitor into the monomer storage tank to stop violent runway exothermic polymerization reactions, for bio-chemical applications and in fast competitive consecutive reactions (Patwardhan and Gaikwad, 2003; Zughbi, 2006; Zughbi and Ahmad, 2005; Zughbi and Rakib, 2004). Jet mixers are more appropriate for mixing processes involving chemically sensitive liquids (Kandakure et al., 2009; Rahimi and Parvareh, 2007; Simon and Fonade, 1993). Furthermore, jet mixing inside a slot has the potential to be applied for cooling in various components in gas turbines (Wang et al., 2000).

In the past few years, some efforts on computational fluid dynamics and experimental studies of mixing in fluid-jet-agitated tanks have been made (Gavi et al., 2007; Parvareh et al., 2009; Patwardhan and Gaikwad, 2003; Raja et al., 2007; Zughbi, 2006; Zughbi and Ahmad, 2005). Ranade (1996) investigated the flow patterns using standard κ–ε turbulent model and predicted that results of the mixing time in a cylindrical vessel, agitated by one or two side entering, horizontal jets

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