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Short communication

Effect of scale on entrainment in stirred tanks

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ABSTRACT

In the present work, surface turbulence characteristics at the onset of entrainment in air water system have been investigated. For the present study, shear type entrainment in stirred tanks has been considered. Experiments have been performed in stirred tanks with different scales for different types and sizes of impellers. The results of the work reveal that radial RMS, axial RMS velocities and turbulent kinetic energy showed similar magnitudes at onset even at different scales. The RMS velocities as well as TKE magnitudes did not vary with type or size of impellers. Local energy dissipation rates have been estimated from autocorrelation function of fluctuating velocity. Very low magnitudes of local energy dissipation rates at onset have been observed.

Keywords: Shear type entrainment; Surface turbulence; Stirred tanks; UVP; Autocorrelation; Turbulent kinetic energy

1. Introduction

Entrainment of gas in liquids has generated momentous interest over the years predominantly because it is commonly observed in various engineering applications. It is important to characterize the underlying fluid mechanics causing entrainment. Based upon nature of flow, entrainment mechanisms have been classified as shear type, vortex type and liquid fall type. When surface velocities are large, shearing action makes the interface unstable, producing surface waves which lead to entrainment of gas near the free surface.

Several researchers have attempted to correlate the onset of gas entrainment with operating parameters, geometry of the system (Baum and Cook, 1975; Bin, 1988; Madarame and Chiba, 1990; Bhattacharya et al., 2007; Mali and Patwardhan, 2009; etc.). Present study focuses on interfacial turbulence characteristics associated with shear type entrainment observed in stirred tanks. A brief review of the literature on similar studies has been presented in the following section.

Initial studies on gas entrainment in baffled stirred vessels focused on mass transfer and effect of parameters such as impeller type, submergence on aeration rates. Later studies concentrated on effect of fluid properties and tank geometry on onset of entrainment. Clark and Vermeulen (1964) reported visual observations of the liquid surface under the conditions of surface aeration in baffled stirred tanks. As per their observations, region of high shear occurred on the liquid surface due to the combination of flows in opposing directions. First, the impeller discharge flow and second the flow rebounded off the baffles. The liquid surface appeared oscillatory. These oscillations formed small waves on the surface, trapping small quantities of gas, which were subsequently carried into bulk of the liquid. Sverak and Hruby (1981) proposed a semi empirical correlation for critical impeller speed for surface aeration. They compared the bubble formation at the surface with formation of a non rotational vortex when fluid is sucked into a thin vertical tube placed just below the liquid surface. Greaves and Kobbaccy (1981) investigated the mechanism of air entrainment in stirred tanks. They correlated the critical impeller speed for the onset of gas entrainment with the impeller type, impeller location, impeller size and geometry of the tank. They observed that formation of surface vortices was largely governed by interfacial turbulence. These vortices entrapped the gas bubbles. Entrainment of gas into liquid occurred when downward velocity of liquid increased above the terminal rise velocity of gas bubbles. Bhattacharya et al. (2007) conducted experiments on stirred tanks with up pumping and down pumping pitched blade turbines to

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