An Experimental Study of Fluid and Solids Velocity Characteristics in Dilute Solid-Liquid Stirred Tanks

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Abstract

The work is aimed at investigating the turbulent hydrodynamics of solid-liquid stirred tanks with particular attention to the effects of the dispersed phase on the turbulence levels of the continuous phase. Among the different aspects of interest for equipment design and process control in solid-liquid mixing, many open issues concern the turbulent characteristics of the two-phase flow and the capability to predict them by appropriate theoretical considerations or computational models. Very recently, advanced experimental techniques for the collection of detailed local information on turbulent solid-liquid stirred tanks have started being adopted. The experimental data collected in this work are aimed at adding information relevant to different solid-liquid systems and stirred tank geometries with respect to the previously investigated conditions. They may be also adopted as a useful benchmark for CFD modelling validation of solid-liquid stirred tanks.

The experiments were performed by a two-phase Particle Image Velocimetry technique similar to that already applied to the investigation of gas-liquid and liquid-liquid systems in our previous works. The experiments were carried out in a fully baffled standard geometry vessel (T=23.2 cm, H=T) stirred by a standard Rushton turbine (D=T/3, C=T/3). Water and glass beads were used as the liquid and solid phases, respectively. The effect of particle size on the liquid turbulence levels was investigated by adopting two different glass mean sizes (d_p=774μm and d_p=115μm) and the particle contents was increased stepwise from zero (single phase system) up to 0.2 vol. % with the bigger particles and up to 0.1 % with the smaller one, the difference being due to the different optical behavior of the two suspensions. The rotational speed was fixed at 850 rpm, that is above the 'just suspended' condition evaluated with the well-known Zwietering correlation, and fully turbulent flow regime was attained in all cases, being the rotational Reynolds number $Re=8.77\cdot10^4$.

Although the effect of turbulence modulation is modest as the system is very dilute, for both the r.m.s. velocity components it exhibits a clear trend for both particle sizes and at increasing particle volumetric fraction: the smaller particles produce turbulence dampening relative to single phase conditions, while the bigger particles augment the fluctuating velocity components. Moreover, even for the very limited variations of particle concentration investigated, the results clearly indicate that the turbulence modulation is more pronounced, the higher the particle concentration is.

From preliminary interpretation of the results, based on the ratio between the particle diameter and the integral length scale of the continuous phase, our data agree with the Gore and Crowe findings [Gore, R.A., Crowe, C.T. 1989. Effect of particle size on modulating turbulent intensity. Int. J. Multiphase Flow, **15**, 279-285] relevant to pipe flow and free jets.

keywords: solid-liquid, turbulence modulation, particle size, Particle Image Velocimetry

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