Experimental Investigation of the Mixing of Shear Thinning Fluids with Yield Stress with a Side-entering impeller

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Abstract

Stirred vessels and agitated reactors are frequently used to prepare and store suspensions of poly-disperse slurries (e.g. water sludge, paints, particulate food mixtures, emulsions, and paper pulp suspensions). These suspensions are generally non-Newtonian: shear thinning and display an apparent yield stress. In mixing operations, this creates caverns (regions of active motion) around the impellers with the cavern size affecting the quality of mixing attained. Though ubiquitous, these systems are still poorly understood mainly due to the complex rheology of these fluids and the lack of available and affordable measurement techniques able to see through such opaque systems. Advanced optical techniques like LDV and PIV available for the diagnosis of fluid flows rely on the transparency of the fluid investigated, therefore model fluids, typically polymer solutions must be used when applying these techniques to advance our understanding in this area.

In this work we have used PIV to investigate details of the flow of shear thinning fluids with an apparent yield stress (modeled by aqueous carbopol solutions) in a laboratory-scale vessel axially agitated with a side-entering impeller. The geometrical configuration of this vessel was derived from the scale down of industrial systems for agitation of paper pulp suspensions (Gomez et al., 2010), and it is a common configuration in numerous process industries including petroleum and foods.

The PIV measurements obtained have provided detailed information on the flow field and the degree of fluid mixing inside the caverns formed around the impeller. The effect of rheological parameters (τ_y and k and n) and operational parameters (impeller speed and clearance from the wall) on the shape and size of the caverns has been investigated. Cavern models based on either a force balance (Amanullah et al., 1998; Elson et al., 1986; Hui et al., 2009)or a minimum velocity at the cavern edge (Amanullah et al., 1998) have been modified in order to account for the interaction between the cavern and the rectangular vessel walls and their predictions have been evaluated against the PIV data obtained.

keywords: Particle image velocimetry, non-Newtonian mixing, yield stress, cavern volume, side-entering impellers

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