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Improving the dynamic performance of continuous-flow mixing of pseudoplastic fluids possessing yield stress using Maxblend impeller

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ABSTRACT

The strategic approach of this article is to characterize the continuous-flow mixing of pseudoplastic fluids possessing yield stress in a stirred reactor with the Maxblend impeller. Dynamic experiments were carried out through the frequency-modulated random binary input of a brine solution to determine the extent of non-ideal flows. Mixing quality was determined on the basis of the extent of channeling and fully mixed volume. The effects of important parameters such as impeller speed (25–500 rpm), absence of baffles, fluid rheology (0.5–1.5%), fluid flow rate (3.20–14.17 L min^{-1}), and the locations of inlet/outlet on the dynamic performance of the continuous-flow mixing vessel were explored. The performance of the Maxblend impeller was then compared to the performances of various types of impellers such as close-clearance (an anchor), axial-flow (a Lightnin A320), and radial-flow (a Scaba 6SRGT) impellers. It was found when the channeling approached zero and the fully mixed volume approached the total fluid volume in the vessel, the power drawn by the A320 impeller and the Scaba impeller were about 2.9 and 4.3 times greater than that of the Maxblend impeller. Thus, the Maxblend impeller was able to drastically improve the performance of continuous-flow mixing with huge power savings. The mixing quality was further improved by optimizing the impeller speed, decreasing the fluid flow rate, decreasing the fluid concentration, and using bottom inlet- top outlet configuration. The flow non-ideality of the mixing system increased in the absence of the baffles. Thus, better mixing quality and more energy savings can be achieved by employing the findings of this study.

Keywords: Maxblend impeller; Mixing dynamics; Continuous-flow mixing; Yield stress; Non-ideal flows; Close-clearance impellers

1. Introduction

Most of the chemical and allied process industries frequently use a mixing operation to increase the degree of homogeneity of a property such as viscosity, colour, concentration, and temperature (Chhabra and Richardson, 2008). These industries often involve non-Newtonian fluids with yield stress; namely, pulp suspension, food substances such as ketchup and mayonnaise, paint, cement, pigment slurries, certain polymer and biopolymer solutions, and wastewater sludge (Etchells et al., 1987). The mixing of non-Newtonian fluids is more challenging than the mixing of Newtonian fluids because of the complex rheology of non-Newtonian fluids (Sue and Holland, 1968). Agitation of pseudoplastic fluid with yield stress results in the formation of a cavern (the well mixed region) around the impeller and stagnant region far from the impeller where the shear stresses are below the yield stress (Amanullah et al., 1997). This condition leads to a poor quality of heat and mass transfer and so do the end products. Therefore, it is always desirable to eliminate such stagnant regions in the mixing of non-Newtonian fluids. An appropriate choice of impellers, which always provide good mixing under varying hydrodynamic conditions, is of vital importance. Various types of impeller such as axial-flow, radial-flow, and close-clearance impellers are available nowadays; however, among them close-clearance impellers are generally

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