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Fluid Flow Characterization of Gas Dispersion in a Yield-Pseudoplastic Biopolymer Using a Coaxial Mixer: Effect of Rotation Mode

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Extended Abstract

Gas-liquid mixing in mechanically agitated vessels is widely utilized in a variety of industrial applications, such as wastewater treatment, methane biodegradation, antibiotics and polysaccharides production, fermentation reactors, and cell culture [1,2]. The numerical simulations of these multiphase flow processes are often employed to obtain a detailed investigation of the fluid flow behavior. Computational fluid dynamics (CFD) tools enable the evaluation of local variables throughout the vessel that is particularly important for the investigation of mixing systems with non-Newtonian fluids. For instance, local fluid velocity analysis provides a better understanding of the mixing performance in a stirred vessel that supports the investigation of optimum design and operating conditions to enhance the gas-liquid mixing [3,4]. In fact, the characterization of the flow pattern determines the well-mixed regions and the oxygen-deficient areas, which directly affect the bubbles dispersion, the gas holdup, and the mass transfer between the phases. Therefore, the objective of this work is to numerically investigate the mixing performance in a coaxial mixer comprising of a pitched blade turbine and an anchor impeller in terms of the flow pattern induced by the agitation. In addition, the present work aims to determine the effect of rotation mode (co-rotation and counter-rotation) on the fluid flow of an aerated yield-pseudoplastic xanthan gum solution (1 wt%) upon varying the central impeller speed and anchor speed.

The two-phase mixing system was modelled and simulated using the Ansys Fluent software. A transient analysis was required to account for the sliding mesh rotating approach. The multiphase framework was described by the Eulerian-Eulerian approach and the mass transfer between the phases was neglected. Also, only drag force was included as an interfacial force using the Schiller-Naumann model, and a constant purged gas bubble diameter was assumed. The xanthan gum solution was defined as the continuous phase and its rheological properties were described by the Herschel-Bulkley model to incorporate the yield-pseudoplastic characteristic of the fluid. The air inlet was defined on the top surface of the circular sparger with a constant aeration rate of 10 L/min, whereas the outlet was defined on the liquid surface by specifying the ambient pressure and allowing the reverse flow of the liquid phase only. In addition, the laminar flow regime was set to account for the yield stress of the fluid. The model was validated against experimental data of gas holdup and power consumption obtained from the electrical resistance tomography technique and two torque meters, respectively. The relative error between experimental data and CFD simulation for power consumption was 8.22%, while the gas holdup error was 7.83%.

The numerical results demonstrate that the fluid flow behavior in the co-rotation and counter-rotation modes significantly differ from each other. Under the co-rotation mode, large and well-defined circulation loops were observed mainly resulting from the synergetic rotation of the impellers, which indicates an enhanced mixing performance. On the other hand, the fluid flow in the counter-rotation mode of operation promoted better mixing in the central region of the vessel. In fact, when the coaxial mixer is in counter-rotation mode, the circulation loops near the wall are disrupted, which reduces the overall velocity magnitude in that region while intensifying the shear stress and fluid flow in the central area of the vessel. The results obtained from this work corroborate that the CFD simulation is a valuable tool to be used alongside different experimental techniques in accurately designing energy-efficient aerated coaxial mixers based on the fluid flow characteristics.

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