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CFD Modeling of Gas Dispersion in Yield-Pseudoplastic Solutions Driven by Coaxial Mixers: Effect of Rotating Approach

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Extended Abstract

The gas-liquid dispersion in mechanically agitated vessels is extensively investigated in the literature due to its various industrial applications [1-3]. The effectiveness of these multiphase systems depends on the equipment design, operating conditions, and physical properties of the phases' components. In fact, the significant effect of the process variables' interaction on the mixing performance and the complex phase interaction are challenging aspects that hamper the formulation of generalized outcomes. Therefore, a thorough fluid flow analysis of the stirred vessel is a valuable process characterization enabled through computational fluid dynamics (CFD) that facilitates a comprehensive investigation of the mixing effectiveness. Although the CFD modeling of aerated stirred vessels has been addressed in previous studies [4, 5], a lack of available data on the sensitivity of the model with respect to the rotating approaches for coaxial mixers containing yield-pseudoplastic fluids is evident. Coaxial mixers are comprised of an upper shaft in which the impeller rotates at a higher speed and a lower shaft attached to a low-speed impeller, and such configuration requires the definition of two independent rotating regions. In view of the rising complexity observed in these aerated mixing systems, extended model verification and validation concerning the simulation approaches are required. Therefore, this work aims to investigate the numerical model of the gas dispersion in shear-thinning fluids possessing yield stress in an anchor-PBT coaxial mixer using the Multiple Reference Frame (MRF) and Sliding Mesh (SM) rotating approaches.

Ansys Fluent software was utilized to model the gas dispersion through a ring sparger in a xanthan gum solution inside a 50 L anchor-PBT coaxial mixer. The Eulerian-Eulerian approach was employed, in which the rheological properties of the continuous phase were determined experimentally and characterized by the Hershel-Bulkley model. The fixed air flow rate (0.8 vvm) was defined at the upper surface of the sparger, and the bubble size was defined at a constant value of 6 mm. The Schiller-Naumann model was used to calculate the drag coefficient incorporated in the gas-liquid momentum transfer, whereas the virtual and lift forces were neglected due to their minimal influence in the aerated stirred vessel. Furthermore, the RNG k-ε model was adopted to describe the turbulent mixing flow regime. Finally, the rotating approaches were defined for a central impeller speed of 500 rpm under the upward pumping mode and an anchor impeller speed of 40 rpm in the co-rotating mode.

Similar flow patterns and air volume fraction profiles were obtained from both rotating frames, which agreed with the findings from Cappello et al. [5] for gas dispersion in pseudoplastic fluids using single shaft stirred vessels. The CPU time observed for the Multiple Reference Frame was four times smaller than that for the Sliding Mesh. In fact, the higher computational efficiency of the MRF approach leads to considerable advantages for this complex mixing system since additional model features, such as the coupling of population balance equations, should be included in future works for an accurate prediction of the bubble sizes. Moreover, the more efficient CFD modeling benefits the analysis of scaled-up mixing vessels, which needs to be solved in a feasible amount of time.

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