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Hydrodynamics and Mixing Characteristics of a Multiphase Coaxial Mixing Tank: Design and Scalability Study

Ali Rahimzadeh, Farhad Ein-Mozaffari, Ali Lohi
Department of Chemical engineering, Toronto Metropolitan University, Toronto, Canada
Email: ali.rahimzadeh@ryerson.ca

Extended Abstract

The effectiveness of the gas dispersion inside a mixing vessel is significantly influenced by the multiphase flow pattern created by the mixing process [1]. However, investigating the hydrodynamics and shear rate attained by an aerated mixing tank is very challenging, specifically for those dealing with complex fluid rheology [2]. Coaxial mixers consisting of a central impeller and an anchor impeller have shown a promising performance in eliminating the poor mixing zones inside the mixing tank [3]. Studying hydrodynamics of gas dispersion in a coaxial mixer filled with a non-Newtonian fluid has recently attracted tremendous attention. This is due to the fact that it is quite impossible to scale-up a coaxial mixer without having a thorough understanding of the gas-liquid hydrodynamics. The flow regime generated by an aerated mixing system furnished with two concurrently rotating impellers is too complicated to fully understand. Therefore, in this study the computational fluid dynamics (CFD) coupled with a population balance model was developed to assess the performance of the coaxial mixer in terms of gas hold-up profile, power consumption, energy dissipation rate distribution, mass transfer coefficient, and impeller torque fluctuation. The sliding mesh technique was used to model the rotation of both impellers. Furthermore, the quadrature momentum balance model was considered to take the polydispersity of the gas phase into account. Extensive sets of experiments were carried out to validate the developed numerical model. The mixing characteristics of the coaxial mixer were explored experimentally through the use of electrical resistance tomography and dynamic gassing-in methods at various impeller types, impeller speeds, pumping directions, and aeration rates, and fluid rheologies. The results obtained from the CFD model showed that by enhancing the uniformity of the energy dissipation rate throughout the mixing vessel the impeller torque fluctuation reduced. In addition, it was found that the mass transfer coefficient achieved by the coaxial mixer was highly dependent on the dissolved oxygen measuring location. In fact, the mass transfer coefficient at the impeller swept region was higher than that obtained at regions away from the central impeller. It was discovered that the coaxial mixer's pumping capability and flow regime were affected by the accumulation of gas phase close to the central impeller. Importantly, the data obtained from the numerical model revealed that the flow regime attained by the coaxial mixer at higher central impeller speeds was not in favour of achieving a higher gas hold-up value. Finally, the proposed model was thoroughly examined, and novel strategies for scalability of the coaxial mixer in terms of the mass transfer coefficient, specific power consumption, and multiphase-flow hydrodynamics were developed.

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