Proceedings of the 10th International Conference on Fluid Flow, Heat and Mass Transfer (FFHMT'23)
Canada – June 07-09, 2023
Paper No. 144
DOI: 10.11159/ffhmt23.144

Analysis of Local and Overall Volumetric Mass Transfer Coefficients in a Dual Coaxial Mixer Containing a Yield-pseudoplastic Fluid

Forough Sharifi[1], Ehsan Behzadfar[1], Farhad Ein-Mozaffari[1]
[1]Toronto Metropolitan University
350 Victoria Street, Toronto, Canada
Forough.sharifi@torontomu.ca; behzadfar@torontomu.ca; fmozaffa@torontomu.ca

Extended Abstract

Over the last decades, finding an ideal configuration for aerated mixing tanks containing non-Newtonian fluids has been highly demanded due to the extensive applications of these systems for a variety of purposes, including fermentation and the synthesis of antibiotics, enzymes, and chemicals [1]. Given the significance of maintaining an adequate level of dissolved oxygen concentration for cell growth and fermentation processes, the volumetric mass transfer coefficient (k_La) is an essential parameter for designing aerated mixing tanks [2,3]. Due to the broad applications of fluids with shear thinning behaviour in aerobic fermentation processes, studying the impact of design parameters and operating conditions such as the impeller type, impeller speed, aeration rate, and fluid rheological properties on volumetric mass transfer coefficient is very important [6]. On the other hand, the bubble size, which relies on the bubble coalescence and break-up phenomena, plays a vital role in the mass transfer coefficient (k_L) and interfacial area (a) [7]. Therefore, choosing an optimum mixing configuration results in enhancing the volumetric mass transfer coefficient and mixing performance.

Numerous studies have demonstrated that multiple-impeller systems outperformed single-impeller systems in terms of higher volumetric mass transfer coefficient, uniform gas dispersion, and lower shear generation per power dissipation [5, 8-9]. However, notwithstanding the advantages of multiple impellers for aerated mixing tanks, particularly for systems with an aspect ratio of more than one, recent studies revealed that employing the multiple impellers on the same shaft did not properly distribute the gas throughout the mixing systems containing highly viscous non-Newtonian fluids. In the previous studies, the use of a close clearance anchor impeller in combination with one or more central impellers for aerated mixing tanks with highly viscous fluids improved gas and liquid circulation, leading to a greater volumetric mass transfer coefficient [6, 10]. However, despite the widespread use of pseudoplastic fluids possessing yield stress in a variety of applications, a knowledge gap was identified for studying the local and overall volumetric mass transfer coefficients in coaxial mixing tanks with an aspect ratio of greater than one containing yield-pseudoplastic fluids. As a result, our research aimed at evaluation of the local and overall volumetric mass transfer coefficients in a coaxial mixing tank containing xanthan gum solutions, a yield-pseudoplastic fluid, furnished with two pitched blade impellers and an anchor.

In this study, the impact of different operating conditions such as the central impeller speed, anchor speed, rotation mode (i.e., co-rotating and counter-rotating), aeration rate and the fluid rheology was investigated on the local and overall volumetric mass transfer coefficients. Three different concentrations of xanthan gum solutions were tested and modelled as a Herschel-Buckley fluid. The local and overall volumetric mass transfer coefficients of the aerated coaxial mixer were measured experimentally using simplified dynamic pressure method. Finally, an in-depth analysis of the complex flow hydrodynamics within the mixing tank as a function of the operating parameters was done using a validated computational fluid dynamics (CFD) model.

References

[1] Garcia-Ochoa, F., & Gomez, E. (2009). Bioreactor scale-up and oxygen transfer rate in microbial processes: an overview. *Biotechnology advances*, *27*(2), 153-176.

[2] Linek, V., Kordač, M., Fujasová, M., & Moucha, T. (2004). Gas–liquid mass transfer coefficient in stirred tanks interpreted through models of idealized eddy structure of turbulence in the bubble vicinity. *Chemical Engineering and Processing: Process Intensification*, *43*(12), 1511-1517.

[3] Martín, M., Montes, F. J., & Galán, M. A. (2010). Mass transfer rates from bubbles in stirred tanks operating with viscous fluids. *Chemical engineering science*, *65*(12), 3814-3824.

[4] Gabelle, J. C., Augier, F., Carvalho, A., Rousset, R., & Morchain, J. (2011). Effect of tank size on kLa and mixing time in aerated stirred reactors with non-newtonian fluids. *The Canadian Journal of Chemical Engineering*, *89*(5), 1139-1153.

[5] Puthli, M. S., Rathod, V. K., & Pandit, A. B. (2005). Gas–liquid mass transfer studies with triple impeller system on a laboratory scale bioreactor. *Biochemical engineering journal*, *23*(1), 25-30.

[6] Jamshidzadeh, M., Ein-Mozaffari, F., & Lohi, A. (2021). Local Distribution of Oxygen Mass Transfer Coefficient in CMC Solutions in Bioreactors Furnished with Different Types of Coaxial Mixers. *Chemical Engineering Research and Design*, *174*, 213-224.

[7] Nienow, A. W., EDWARDS, M. F., & Harnby, N. (1997). *Mixing in the process industries*. Butterworth-Heinemann.

[8] Arjunwadkar, S. J., Sarvanan, K., Kulkarni, P. R., & Pandit, A. B. (1998). Gas-liquid mass transfer in dual impeller bioreactor. *Biochemical Engineering Journal*, *1*(2), 99-106.

[9] Bouaifi, M., & Roustan, M. (1998). Bubble size and mass transfer coefficients in dual-impeller agitated reactors. *The Canadian Journal of Chemical Engineering*, *76*(3), 390-397.

[10] Rahimzadeh, A., Ein-Mozaffari, F., & Lohi, A. (2022). New Insights into the Gas Dispersion and Mass Transfer in Shear-Thinning Fluids Inside an Aerated Coaxial Mixer via Analysis of Flow Hydrodynamics and Shear Environment. *Industrial & Engineering Chemistry Research*, *61*(10), 3713-3728.