Effect of liquid properties on O_2 mass transfer in an oscillatory flow reactor provided with smooth periodic constrictions

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Introduction

Gas-liquid contactors such as bubble columns or air lift reactor have been used to enhance gas-liquid mass transfer in chemical and biochemical processes [1]. However, these mass transfer equipment have problems associated with bad mixing, product quality, process reproducibility and scale up. To overcome these limitations oscillatory flow reactors (OFR) have been emerging. The OFR has advantages over common mass transfer equipment such as reducing reagent requirements, waste and industrial costs, efficient mixing, scale-up and ability to operate to operate at low flow rates and volumes. In OFR an efficient mixing mechanism is originated by the eddies propagation in radial and axial direction, which depends on oscillatory conditions frequency (f) and amplitude (x_0) [2]. In present work the effect of surface tension and viscosity on O_2 mass transfer in an oscillatory flow reactor provided with smooth periodic constrictions (OFR-SPC) is studied. The experiments were performed at 25 ºC, the oscillation conditions range from 1 to 4 Hz and 0.08L to 0.35L mm and the gas flow rate up to 100 cm^3/min.

Dynamic method

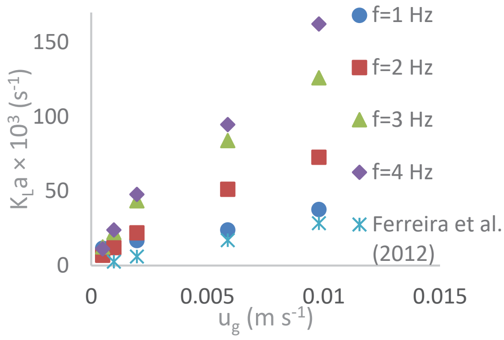
As previous works by Ferreira et al. [2] the dynamic method was used to measure the O_2 concentration with time, using an fibreoptic oxygen meter, connected to the FireSting O_2 instrument.

Test F methodology

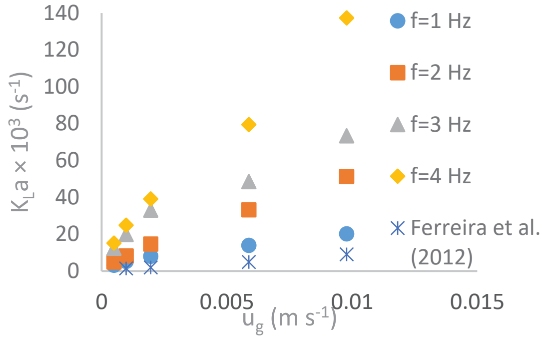
According to Mena et al. [3], there are errors to the choice in linear zone of response curve, therefore a statistical method, *Test F* was used to obtain the volumetric liquid-side mass transfer coefficient (K_La).

Results and Discussion

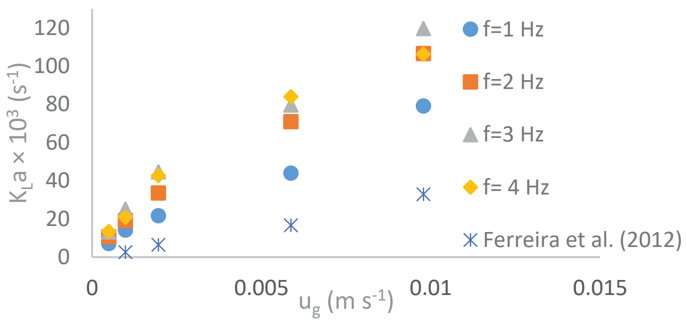
Figure 1 is presented a 2D plot of the k_La for different frequency (f), superficial gas velocity (u_g) and for highest amplitude (x_0) compared with previous work by Ferreira et al. [4] in bubble columns. The k_La increases with f, x_0 and u_g, but when f increases the k_La increases less than two-fold for low x_0. For higher amplitudes, the increase in the oscillation frequency results in an increasing less than six-fold on k_La, which may suggest that amplitude allows the eddies to move along the OFR-SPC instead frequency has a radial effect on mixing, enhancing the collisions numbers of the bubbles increasing k_La. However, for high oscillation conditions, the ethanol forms a foam, which creates a resistance to mass transfer in liquid phase, consequently decrease k_La. As the viscosity and surface tension increase k_La tends to decrease.



Distilled water



Sucrose 1.41M



Ethanol 1.37M

Figure 1. Effect of f and u_g for x_o = 0.35L mm

Conclusion

The amplitude reveals a higher increasing on k_La than frequency; An increasing of viscosity and surface tension has a negative effect on k_La; The best choice to increase k_La within OFR-SPC is to increase the mixing and the residence time of the bubbles, thereby increase f and x_0. Summarizing the OFR-SPC reveals an increasing on mass transfer rate when compared with bubble columns and air-lift reactors.

References

[1] M. S. N. Oliveira and X. Ni, Effect of hydrodynamics on mass transfer in a gas – liquid oscillatory baffled column, *Chem. Eng. J.*, vol. 99, no. 1, pp. 59–68, 2004.

[2] A. Ferreira, J. A. Teixeira, and F. Rocha, O2 mass transfer in an oscillatory flow reactor provided with smooth periodic constrictions. Individual characterization of KL and a, *Chem. Eng. J.*, vol. 262, no. 15 February 2015, pp. 499–508, 2015.

[3] P. Mena, A. Ferreira, J. A. Teixeira, and F. Rocha, Effect of some solid properties on gas – liquid mass transfer in a bubble column, *Chem. Eng. Process. Process Intensif.*, vol. 50, no. 2, pp. 181–188, 2011.

[4] A. Ferreira, G. Pereira, J. A. Teixeira, and F. Rocha, "Statistical tool combined with image analysis to characterize hydrodynamics and mass transfer in a bubble column," *Chem. Eng. J.*, vol. 180, no. 15 January 2012, pp. 216–228, 2012.