O_2 mass transfer in a planar oscillatory flow reactor-continuous mode

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Introduction

Gas-sparged stirred tanks, air-lift and bubble columns are the most commonly used devices for enhancing gas–liquid mass transfer. However, problems associated with bad mixing, scale up, product quality and process reproducibility, are typically reported. In order to overcome these limitations oscillatory flow reactors (OFR) have been studied. In the last decade a new generation of OFR has been arising, the meso-OFR. These mesoscale (milliliter) oscillatory baffled reactors have received considerable attention due to their small volume and ability to operate at low flow rates. Recently, Ferreira et al. [1] studied the influence of several geometric parameters that characterize the OFR provided with smooth period constrictions (OFR- SPC) at meso and macroscale in order to obtain the lowest mixing times. The optimized values obtained have been applied to gas-liquid [2] and crystallization systems. However, some problems related to the flow and suspension of solids have been reported. In order to overcome these issues, and prevent the deposition of solids, a new design was developed that replaces the circular cross section (Figure 1 (a)) with a rectangular cross section (Figure 1 (b)). This new generation of OFRs is known as planar OFRs. In the present work the planar OFR are used in a continuous mode. The effects of superficial gas velocities (u_G), net flow rate and the oscillatory conditions (frequency and amplitude) on the gas–liquid mass transfer process are experimentally evaluated.

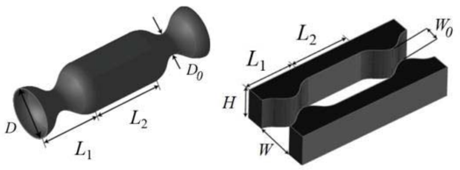
Methods

The planar OFR consists of a 3.35 m long plate-like device with approximately 111 mL made of Perspex.

The parameters that characterize each cell of the planar OFR are: W=8 mm, W_0= 1.5 mm, $L=L_1+L_2$=34 mm, H=5 mm. The experiments were performed at room temperature (20.5 ± 0.5 ºC). The fluid was oscillated by using a linear motor. Oscillation amplitudes (x_0) and frequencies (f) ranged from 0.07 to 0.34 L and 2 to 6 Hz, respectively. A single needle gas sparger was used allowing the formation of small, uniform and distinct bubbles. The superficial gas velocities, u_G, range from 2.8 to 5.4 mm/s. Two net flow rate were used: 72 mL/ min and 117 mL/min. Dissolved oxygen concentration values were measured online using an fiberoptic oxygen meter (OXR50-HS, Pyroscience), located 1.11 m from the gas sparger. Air-water O_2 mass transfer coefficient, k_La, was estimated from O_2 mass balance to the liquid stream in the reactor at initial and final steady states, using the following equation:

$$k_La = -\frac{1}{\tau} ln\left(1 - \frac{x_{O_2,out}}{x_{O_2,sat}}\right)$$

where τ is the mean residence time, $x_{O_2,out}$ and $x_{O_2,sat}$ are the oxygen concentration at the outlet and in the saturation, respectively.



(a) (b)

Figure 1. (a) OFC with pipe geometry. (b) OFC with planar geometry.

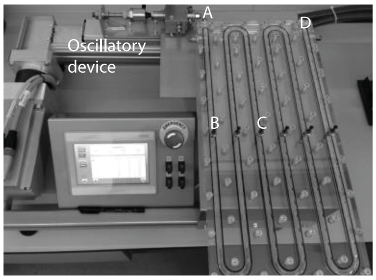
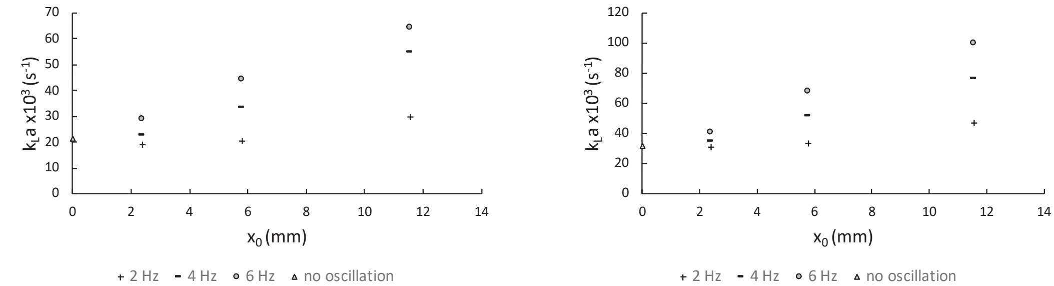


Figure 2. Experimental set-up. A-Water inlet; B- gas sparger; C – Oxygen concentration measurement; D- Water outlet.

Results and Discussion



(a) (b)

Figure 3. Effect of conditions on volumetric liquid side mass transfer coefficient in the planar OFR at constant net flow rate (72 mL/min) and: (a) u_G=2.8 mm/s; (b) u_G=5.4 mm/s.

k_La increases with both u_G and oscillatory conditions, the last ones having the highest impact on the mass transfer process. k_La increases considerably with oscillation frequency and amplitude, the amplitude having the highest effect, since the oscillation amplitude controls the length of the eddy generated along the reactor. A similar behavior and k_La results were observed by Ferreira et al. [2]. Increasing the net flow rate from 72 mL/min to 117 mL/min a 40% decrease on k_La was observed.

Conclusion

The present work opens new insights for a better understanding of mass transfer phenomena in the planar OFR and shows that this reactor can be work in continuous mode being a good compact alternative to the conventional OFR.

References

[1] Ferreira, A., Rocha, F., Teixeira, J.A.,Vicente, A., Apparatus for mixing improvement based on oscillatory flow reactors provided with smooth periodic constrictions, WO/2015/056156, 2015.

[2] Ferreira, A., Adesite, P.O., Teixeira, J.A., Rocha, F., 2017. Effect of solids on O2 mass transfer in an oscillatory flow reactor provided with smooth periodic constrictions. *Chem. Eng. Sci.* 170, 400.