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Short communication

Performance of airlift contactors with baffles

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Abstract

This work investigated the effect of baffles on hydrodynamics and gas–liquid mass transfer in an internal-loop airlift contactor (ALC). It was found that the introduction of baffles reduced liquid circulating velocity in the system. The riser gas holdup in the baffled contactor was found to be higher than the unbaffled, but due to the lower liquid circulation, the use of baffles resulted in a decreased downcomer gas holdup. The overall gas holdup and the rate of gas–liquid mass transfer were not significantly influenced by the presence of the baffles.

Keywords: Airlift contactor; Internal-loop airlift contactor; Baffle; Gas–liquid mass transfer; Hydrodynamic behavior

1. Introduction

Airlift contactors (ALCs) have outstanding advantages over stirred tanks due to their simple construction, low power consumption, and low shear force. However, numerous numbers of work indicated that gas–liquid mass transfer (k_La) in the ALC was comparatively lower than that in bubble columns (BCs) [1–5]. Several mechanisms have been proposed to improve the gas–liquid mass transfer rate in the ALC, for instance, a two split cylinder airlift tower [6], a double draft tube system [7], a multiple draft tubes ALC [5], and a modified draft tube ALC such as a perforated draft tube [8], and a semipermeable draft tube [9]; all of which had reported successful outcomes. Comprehensive reviews of the current state of knowledge on the ALCs were presented in [10,11].

One common alternative for the modification of ALCs was to insert baffle-plates into the riser to obstruct the flows of liquid and gas bubbles. An example of this configuration includes the system proposed by Lin et al. [12] who installed slanted baffles in a tower cycling fermentor. Lin et al. [12] observed from the experiment that the presence of baffles enhanced the k_La value, and concluded that baffles broke large air bubbles into smaller ones and, hence, increased the specific gas–liquid interfacial area (a). Moreover, baffles facilitated turbulent conditions which provided relatively high value of mass transfer coefficient (k_L). Stejskal and Potucek [13] investigated gas–liquid mass transfer in an internal-loop ALC with a motionless mixer placed in the riser. The report indicated that the motionless mixer increased a residence time of bubbles in the system resulting in an enhancement of "a" and also the gas–liquid mass transfer coefficient. Perforated plates was introduced into a BC and an internal-loop ALC by Zhao et al. [14]. It was reported that the gas–liquid mass transfer rate depended on the trade-off between an increase in "a" (due to the breakup of bubble at perforated plates) and a decrease in "k_L" (due to lower liquid velocity). Chen et al. [15] introduced mesh baffle-plates into a rectangular ALC and reported that, at low superficial gas velocity, the system performance was not different from a BC. However, at high superficial gas velocity, the mesh baffle-plates broke large bubbles into small ones. This resulted in higher k_La in the proposed ALC than that in the BC.

It is clear that the baffled ALC is significant as a potential alternative system for the ALC due to their simple design and construction than other configurations. However, the influence of baffles on the performance of the ALC is still not thoroughly understood, and the reported results were sometimes contradicted. It was the objective of this work to therefore investigate the behavior of the ALC when baffles were inserted into the riser.

2. Experimental

The ALC employed in this work was made of clear acrylic plastic in which it was possible to observe the on-going

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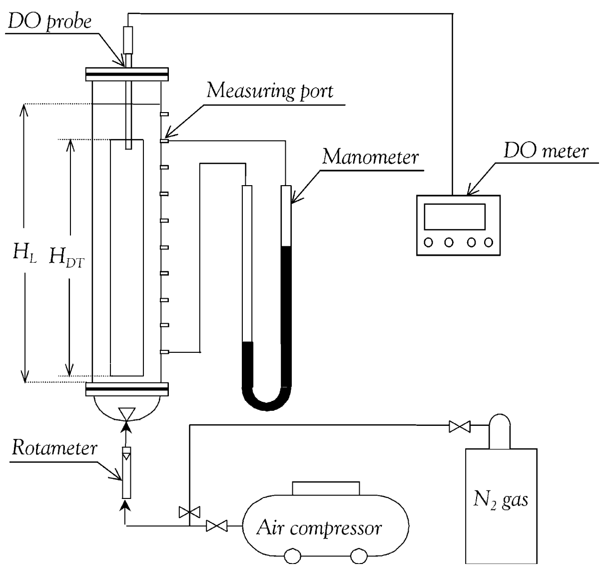

Fig. 1. Experimental setup of the ALC.

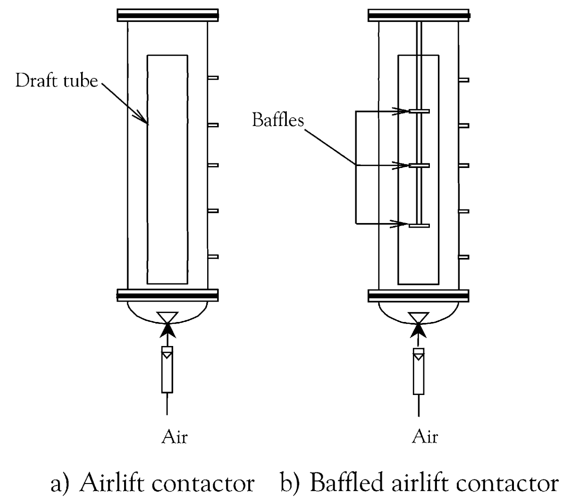

Fig. 2. The configuration of the ALCs employed in this work.

Table 1
Dimensions of the employed ALCs

Column diameter, D (cm)	13.7
Draft tube diameter, D_{DT} (cm)	9.3
Unaerated liquid height, H_L (cm)	104.5
Draft tube height, H_{DT} (cm)	100
Nominal volume, V (l)	16

phenomena. Attached to the outer column of the ALC were a series of measuring ports (Fig. 1) for pressure drop measurement. The measuring ports also allowed easy injection of color tracer for the liquid velocity measurement. Air was sparged into the contactor by an air compressor and air flow rate was controlled by a calibrated rotameter. Details of gas holdups, liquid velocity and mass transfer measurements were provided in Appendices A–C.

Two ALCs were used (Fig. 2), a conventional draft tube configuration (ALC) and an identical device installed with baffles in the riser (ALC-B). The various dimensions of the reactors were identical (Table 1) with the A_d/A_r ratio being unity in both cases. The draft tube of the ALC-B contained three perforated baffle-plates (plate diameter = 6.5 cm; hole diameter = 3 mm; 8 holes per plate). Both reactors were sparged through identical perforated pipe ring

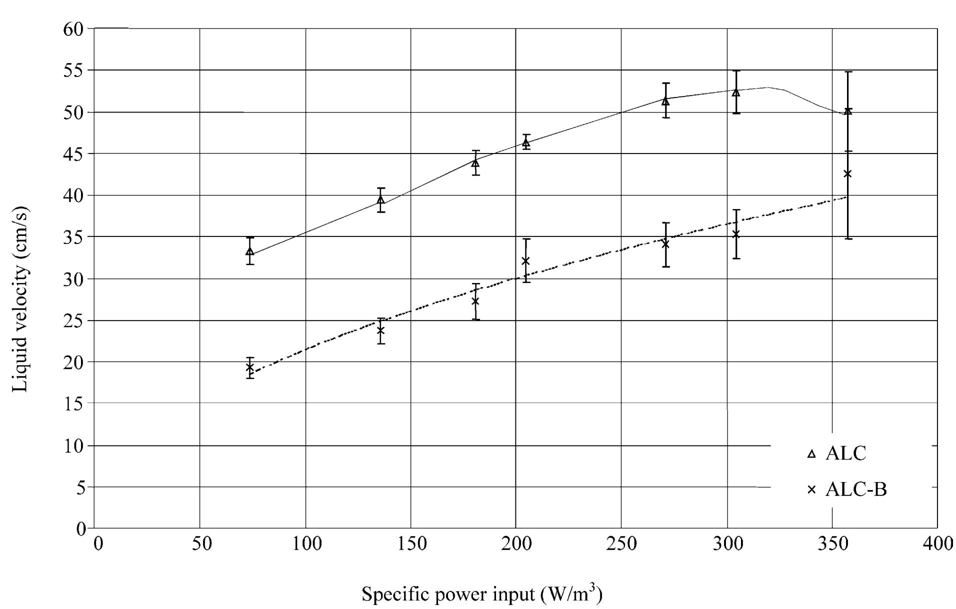

Fig. 3. Relationship between liquid velocity and power input in various configurations of ALCs.

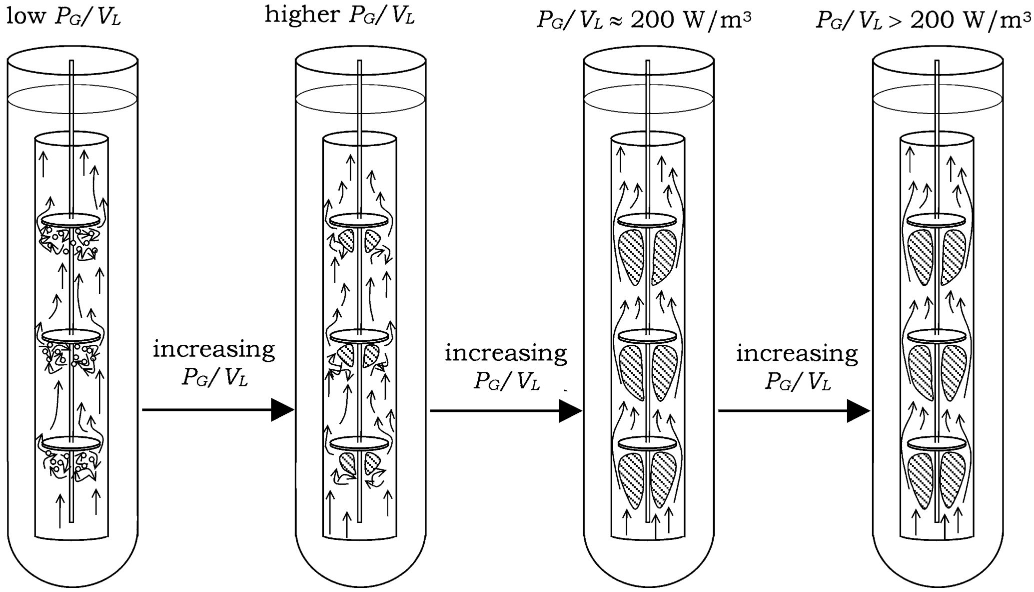

Fig. 4. The mechanism of dead zones in the ALC-B.

spargers (14 holes, 1 mm hole diameter). The specific power input ranged from 73 to 357 W/m^3, which corresponds to superficial gas velocity from 1 to 5.3 cm/s, respectively.

3. Results and discussion

The effect of baffles on liquid velocity in the ALC is depicted in Fig. 3. It was found that an introduction of baffles into the riser caused a marked decrease in the liquid velocity. This was because baffles obstructed a flow of liquid and, in effect, increased resistance to liquid flow. It was found in the same figure that, in the baffled contactor, the liquid velocity continued to increase with the increasing power input. This was because the development of stagnant regions underneath the baffles streamlined the flow path. In contrast, the liquid velocity in the ALC no longer depended on the specific power input for $P_G/V_L > 270$ W/m^3

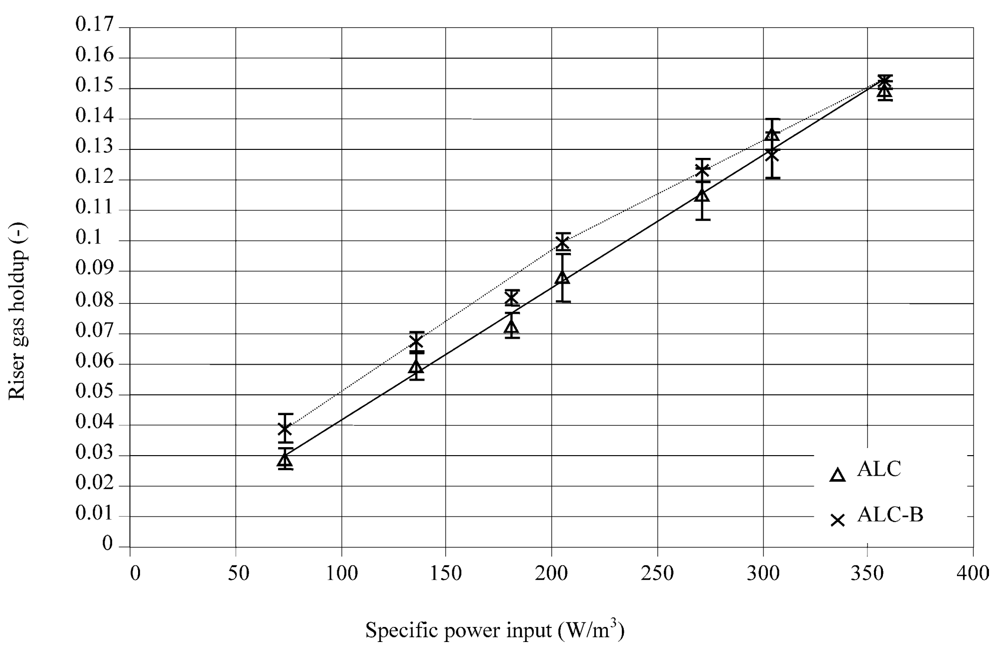

Fig. 5. Relationship between riser gas holdup and power input in various configurations of ALCs.

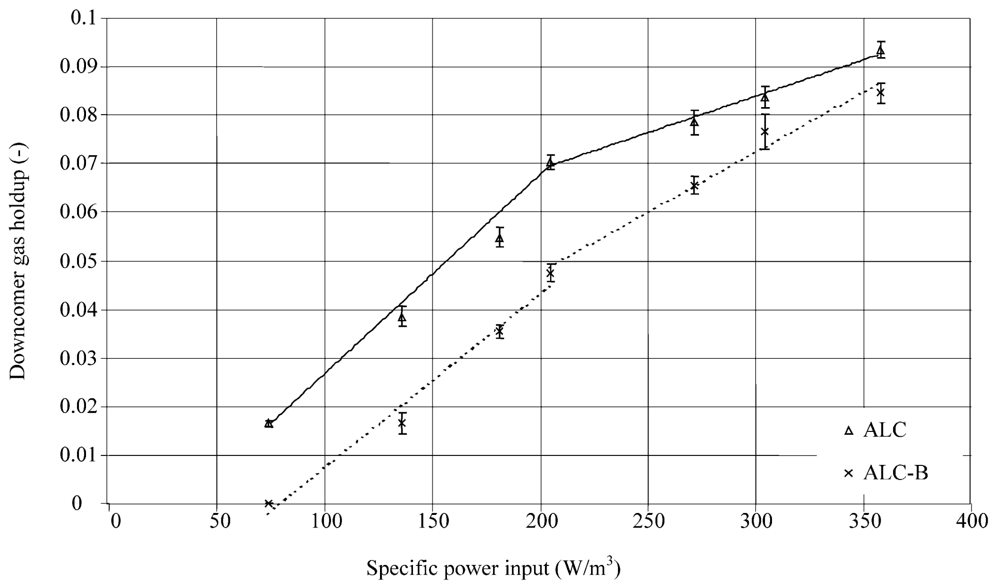

Fig. 6. Relationship between downcomer gas holdup and power input in various configurations of ALCs.

(superficial gas velocity >4 cm/s). The development of the stagnant regions beneath the baffles is shown in Fig. 4 for various of values of the specific power input.

The use of baffles resulted in slight enhancement of the riser gas holdup relative to the configuration without the baffles (Fig. 5). A possible explanation of the holdup enhancement was the reduced effective rise velocity of the bubbles because of the baffles. On the other hand, the higher liquid velocity in the ALC without baffles (Fig. 3) dragged more bubbles into the downcomer which resulted in a higher downcomer gas holdup than the baffled contactor (Fig. 6). It is interesting to note that, for the conditions of experiment employed in this work, the baffles had negligible effect on the overall gas holdup (Fig. 7) because the relatively higher holdup in the riser zone was compensated by reduced gas holdup in the downcomer.

The $k_L a$ was negligibly influenced by the presence of the baffles (Fig. 8) because the overall gas holdup (Fig. 7) and consequently the gas–liquid interfacial area were barely affected.

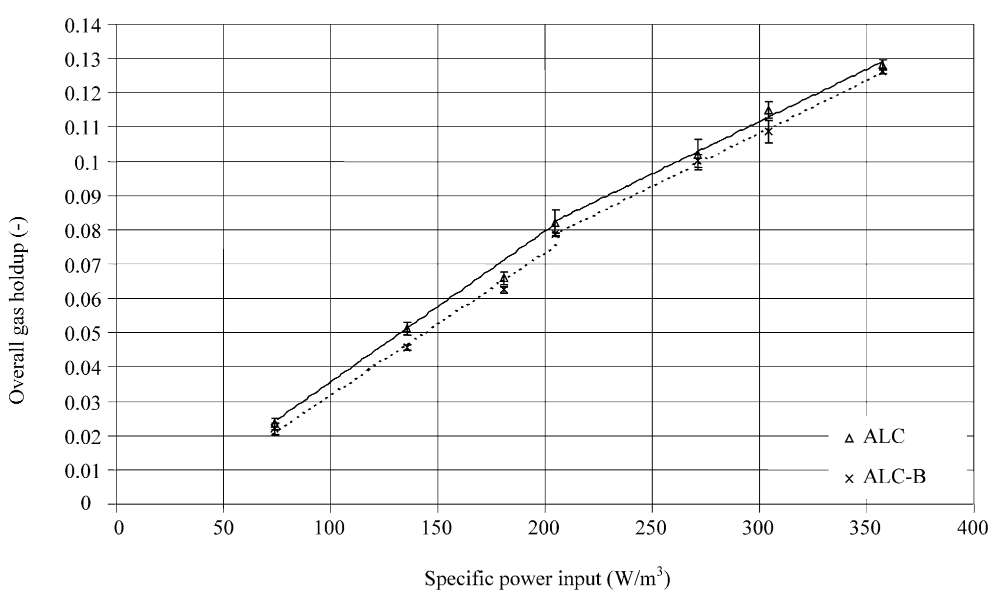

Fig. 7. Relationship between overall gas holdup and power input in various configurations of ALCs.

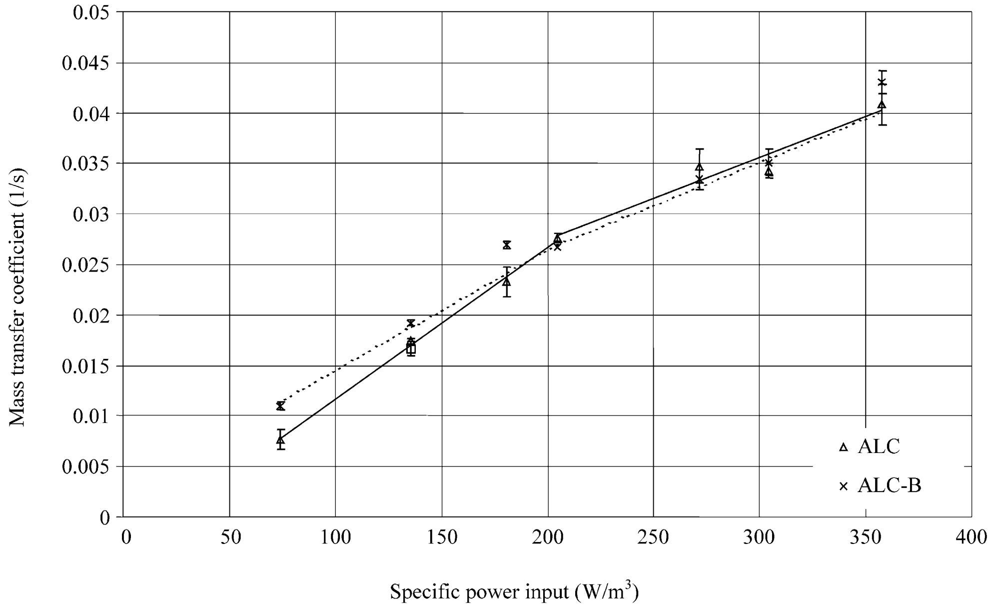

Fig. 8. Relationship between mass transfer coefficient and power input in various configurations of ALCs.

4. Conclusion

Installation of cross-sectional baffles in an ALC reduces the rate of liquid circulation compared to the unbaffled configuration. The perforated plate baffles installed in the riser may significantly enhance the gas holdup in the riser zone; however, because of reduced liquid circulation, the use of baffles causes a reduction in the gas holdup in the downcomer. As a consequence of these effects, the baffles have barely any influence on the overall gas holdup and on the volumetric gas–liquid mass transfer coefficient.

Appendix A. Measurement of gas holdups

The overall gas holdup was estimated using the volume expansion method where the overall gas holdup, ε_{Go}, was calculated from the dispersion height, H_D, and the unaerated liquid height, H_L.

$$\varepsilon_{Go} = \frac{H_D - H_L}{H_D} \tag{A.1}$$

Gas holdup in the downcomer, ε_{Gd}, and in the gas separator, ε_{Gs}, were measured using manometer, and the riser gas holdup, ε_{Gr}, was calculated from the following equation:

$$\varepsilon_{Go} = \frac{H_{DT} A_r \varepsilon_{Gr} + H_{DT} A_d \varepsilon_{Gd}}{H_D(A_r + A_d)} + \frac{(H_D - H_{DT})(A_d + A_r)\varepsilon_{Gs}}{H_D(A_r + A_d)} \tag{A.2}$$

where H_{DT}, A_r, and A_d are the height of draft tube, the cross-sectional areas in riser and downcomer, respectively.

Appendix B. Measurement of liquid velocities

To measure the liquid velocities in the riser and downcomer, the color tracer was injected rapidly via the measuring ports of the column. The average times in riser and downcomer, t_r and t_d, were measured as the time the tracer required to travel between the two points in the column. The riser and downcomer liquid velocities, V_{L_r} and V_{L_d}, were then obtained from:

$$V_{L_r} = \frac{L_r}{t_r} \tag{B.1}$$

$$V_{L_d} = \frac{L_d}{t_d} \tag{B.2}$$

where L_r and L_d are the distance where tracer pass through between the measuring ports in the riser and downcomer, respectively.

Appendix C. Measurement of volumetric mass transfer coefficient

O_2 mass transfer was measured using the dynamic method. The DO meter (Jenway model 9300) was located in the riser to measure changes in DO in the dispersion, and the value of $k_L a$ was calculated from integrating the following mass transfer equation:

$$\frac{dC}{dt} = k_L a(C^* - C) \tag{C.1}$$

where C is the bulk concentration of dissolved oxygen and C^* the saturated concentration of dissolved oxygen. If C^*

is assumed constant (which is a reasonable assumption for small scale systems), Eq. (C.1) can be integrated to

$$\ln(1-\bar{C}) = -k_{\mathrm{L}}at \quad \text{(C.2)}$$

where

$$\bar{C} = \frac{C - C_0}{C^* - C_0} \quad \text{(C.3)}$$

and C_0 is the initial concentration of dissolved oxygen.

Appendix D. Specific power input

Specific power input can be estimated from Eq. (D.1) (see [16] for further detail).

$$\frac{P_{\mathrm{G}}}{V_{\mathrm{L}}} = \frac{\rho_{\mathrm{L}} g Q_{\mathrm{G}}}{A_{\mathrm{r}} + A_{\mathrm{d}}} \quad \text{(D.1)}$$

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