EFFECT OF DRAFT TUBE HEIGHT AND SUPERFICIAL GAS VELOCITY ON LIQUID CIRCULATION IN RECTANGULAR AIRLIFT LOOP REACTOR

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ABSTRACT

Airlift loop reactors have been used widely for production of diverse bioproducts in chemical and biotechnological industries. Liquid Circulation velocity is a unique design parameter in airlift loop reactor. The principle objective of the present work is to quantify the effect of operational and geometrical parameters on liquid circulation velocity. Experiments were performed to evaluate effect of superficial gas velocity on liquid circulation velocity which was found to increase correspondingly. This can be attributed to increased bubble population which leads to increase in total gas hold up which is driving force for liquid circulation velocity. By decreasing draft tube height, liquid circulation velocity was found to decrease which can be attributed to increase in upper clearance which leads to increased coalescence of bubbles leading to formation of large size bubbles that escape quickly from the system resulting into decreased gas hold up and thus decrease in liquid circulation velocity.

Index Terms: Rectangular Airlift Loop Reactor, Liquid Circulation Velocity, Superficial Gas Velocity, Draft Tube Height

1. INTRODUCTION

Airlift loop reactors are gas-liquid contacting devices which are of particular importance in biotechnology and chemical industries. In general, these devices consists of a pool of liquid divided by draft tube, of which riser is sparged by gas and the unsparged downcomer connected with each other at top and bottom of column. The different gas holdup in the gassed and ungassed zones results in difference of bulk densities of the fluid in these regions that causes a well-defined circulation of the liquid in the column by a gas-lift action.

The magnitude of liquid circulation velocity is one of the most important design and scale up parameters in airlift loop reactors. The velocity of liquid circulation, while itself controlled by the gas holdups in the riser and the downcomer, in turn affects these holdups by either enhancing or reducing the velocity of bubble rise. In addition, the circulation affects turbulence, the fluid-reactor wall heat transfer coefficients, the gas-liquid mass transfer and the shear forces to which micro organisms are exposed. [1]

This work deals with estimation of liquid circulation velocity in airlift loop reactor and influence of operational and geometrical parameters viz. superficial gas velocity and draft tube height on liquid circulation is investigated.

2. MATERIALS AND METHODS

In this investigation, Rectangular Airlift Loop Reactor (RALR) Fig 1 fabricated with transparent acrylic sheets had geometrical specifications as mentioned in Table 1.

<table>
<thead>
<tr>
<th>Parts</th>
<th>Specifications, cm</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>W</td>
</tr>
<tr>
<td>Outer Column</td>
<td>10.7</td>
</tr>
<tr>
<td>Draft tube - 1</td>
<td>8</td>
</tr>
<tr>
<td>Draft tube - 2</td>
<td>8</td>
</tr>
</tbody>
</table>

The draft tube was placed coaxially within the column and held using a bolting mechanism. Care was taken that the gap between the draft tube and the column was uniform on all sides throughout the length of the draft tube. The draft tube was mounted 1 cm above the sparger. Air was sparged into the column through sparger. A trapezoidal gas chamber beneath the sparger ensured the uniform distribution of air through sparger.

![Figure 1: Schematic of experimental setup of RALR](image-url)
regulator and measured using calibrated rotameters. A pH probe was located at the side of the main column by drilling a hole in it at a distance of 0.5 m from the base of column. pH probe was connected to pH meter ((Biocraft Scientific system, NIG334 coupled to a pH electrode with an automatic temperature compensation probe).

In the present investigation, the liquid circulation velocity was determined using acid tracer technique with air water system. Initially the pH of water was lowered to 2 by adding hydrochloric acid (35%w/v). The vessel was then bubbled with air for 20 min to remove any carbonate/bicarbonate species. After this treatment the liquid showed no buffering over the pH range (pH ≤ 4) of the measurements.

The pH was now raised to 4.5 by adding 12M sodium hydroxide. The acid tracer (2 ml of 35% hydrochloric acid) was added instantaneously at the top of the downcomer and the change in pH with time was recorded using pH meter. The dimensionless concentration, $C_T$ of the tracer (hydrogen ion) was calculated as follows:

$$ C_T = \frac{[H^+]_{\text{final}} - [H^+]_{\text{initial}}}{[H^+]_{\text{final}} - [H^+]_{\text{initial}}} $$

The mean liquid circulation velocity ($U_{LC}$) is defined as:

$$ U_{LC} = \frac{x_c}{t_c} $$

Where $x_c$ is circulation path length and $t_c$ is the average time for one complete recirculation. For calculation of mean liquid circulation velocity using equation (2), the value of $x_c$ was calculated from the geometry and was approximately double the length of draft tube for airlift vessel. The cycling time $t_c$ was estimated as the time interval between adjacent peaks of a tracer concentration profile. Such one prototype tracer concentration profile is shown in Fig 2.

In airlift loop reactors, the superficial gas velocity has a dominant influence on liquid circulation velocity as discussed in literature [2]. Similar pattern was also observed in the experimental data obtained in this investigation. Since the force inducing liquid circulation in RALR, i.e. gas holdup increases with increasing superficial gas velocity, this attributes to increase in liquid circulation velocity as well. Fig. 3 and Fig. 4 demonstrates the effect of superficial gas velocity on liquid circulation velocity in airlift loop reactor with two different draft tubes of heights 70 cm and 60 cm respectively.

3. RESULTS AND DISCUSSION

3.1 Effect of superficial gas velocity on liquid circulation velocity

Effect of draft tube height on liquid circulation velocity was studied by using two draft tubes of heights 60 cm and 70 cm in rectangular internal ALR. For experiments performed with draft tubes of two different heights, it can be observed from Fig 5. that there is much less deviation in liquid circulation velocity for lower values of liquid circulation velocity however, the deviation increases with increase in superficial velocities.
Although both devices show similar pattern of increasing liquid circulation velocity with increase in superficial gas velocity in Fig. 5 but the liquid circulation velocity decreases with a decrease in draft tube height from 70 cm to 60 cm. Such decrease in liquid circulation velocity can be attributed to the decrease in gas hold up of the column. As the height of draft tube decreases, it increases upper clearance of column leading to increased bubble coalescence forming large bubbles that escape out quickly from the system. This leads to decrease in gas hold up which is the driving force for liquid circulation velocity.

4. CONCLUSION

Liquid circulation velocity was determined by acid tracer technique. Liquid circulation velocity increases with increase in superficial velocity due to increase in bubble population. Also liquid circulation velocity decreases with decrease in height of draft tube attributed to increase in top clearance and hence increase in bubble coalescence forming large bubbles which escape out quickly from the system.

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