AN EXPERIMENTAL STUDY ON THE AIRLIFT PACKED COLUMN WITH ADJUSTABLE HEIGHT AND MANY AIR INJECTION POINTS

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ABSTRACT

A setup consisting of a glass packed with calibrated glass rings has been achieved. It operates on the principle of an air lift pump with several air jet nozzles. It was designed for heat and mass transfer operations. Performances of this system were determined by measuring the displaced water flow rates for different submersion ratios and various air flow rates. The study shows that the proposed system has high performances and large environmental industry applications.

Keywords: air-lift pump, packed column, performance

1. INTRODUCTION

Using two machines: compressor and pump to feed a packed column with air and water is energy intensive. The two machines can be replaced by only one called air lift pump. An airlifting system is mainly composed of a submerged riser tube in which compressed air is injected at the base. The buoyancy produced by air bubbles suspended in the fluid causes a pumping action.

Many researchers have showed that the airlift pump is more energy efficient for low-head conditions than centrifugal or other standard pumps (Lee et al., 1997; Kumar et al., 2003; Oh, 2000). The air lift pump is made with a minimum of parts, so it requires low maintenance costs.
The airlift pump system is used in the sewage treatment and aquaculture ponds (Parker et al., 1987), in the petrochemical industry (Baker, 1954) and so on.

The research in the airlift pump field has received considerable attention for not only the pumping efficiency, but also aeration, sludge displacement (William et al., 1994; Yoon et al., 1997; Barrut et al., 2011), Carbon dioxide degassing in fresh and saline water (Damian Moran, 2010), etc. However, these studies are interested primarily in the effects of operating conditions on the performance of the air lift pumps.

Many researchers have studied the effect of design characteristics on the air lift pumps efficiency (G.J. Parker, 1980, Reinenmann, 1987; Oh, 1992; Khalil et al., 1999; Yoon et al., 2000; CHO Nam-Cheol et al., 2009). However these investigations show that the packed column operating on the principle of air lift pump has not yet attracted much attention.

Packed column are used in many environmental fields like extraction by liquid solvent, distillation and gas cleaning. They offer a large contact area and good separation efficiency. The Rashig rings are known by high void fraction which causes low pressure drop. The up flow of gas-liquid mixture through a packed bed offers a large opportunity for liquid distribution and packing particles wettability (Trambouze, 1999). The heat and mass transfer efficiency of the packed column depend on the packed bed height.

The purpose of this study is to obtain basic information on the characteristics of the airlift packed column with adjustable height. We propose a new airlift pump system using multiple air injection points distributed over the air column height to improve both the liquid flow rate and the total head.

2. MATERIALS AND METHODS

2.1. Experimental system

The experiments were performed on a vertical cylindrical column made up in three glass tubes 0.072 m diameter and 0.4 m length. The total height of the column and the packed bed are 1.2 m and 1.0 m respectively. The characteristics of the solid packing are shown in Table 1. The column is provided with equidistant pressure sensors in order to measure the local pressure at different heights. Four polypropylene disc diffusers, with 67 circular pores of 5 mm each, are arranged at the ends of the glass tubes. They have a double role: first they change the fluid flow direction, second they prevent the exit of solid packing out of tube. The air jet nozzle is integrated into the disc diffuser.

At the input of the column, a swirl chamber, stainless steel, is designed for the injection of water and air. At a height equal to 1.02 m of the column, water is recycled through a down comer and the air continues its path to the cyclone. Water droplets separated at the cyclone are routed to the swirl chamber. A make-up of water is placed to keep a constant liquid level in the down comer.

The tests carried out in ambient conditions. The compressor used has a power of 2Kw, Michelin type and 25 liters of tank, provided with a flow controller valve. The air flow meter is air float type; brand Tubux whose measuring range is between 0 and 25 m³ / h and the uncertainty of 4%.
The setup is designed in a manner that the amount of water evaporated will be replaced, automatically, by the same amount of liquid water issued from the tank (7).

The packed column will be used in chemical engineering operations where heat and mass transfer are involved. The efficiency of these operations depends, mainly, on the liquid flow rate. In this experiment we will be interested to the basic parameters which influence the liquid flow rate.

<table>
<thead>
<tr>
<th>Table 1: Physical characteristics of the packing</th>
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<tbody>
<tr>
<td><strong>Type of solid</strong></td>
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<tr>
<td>Density : ( \rho_S )</td>
</tr>
<tr>
<td>Average diameter: ( d_p )</td>
</tr>
<tr>
<td>Average length : ( l_p )</td>
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<tr>
<td>fixed bed porosity: ( \varepsilon )</td>
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<tr>
<td>Form Factor: ( \phi_p )</td>
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2.2 Airlift pump system

The air from the compressor can be injected in one or three points of the riser. Some valves are placed for air flow rate modification. The height of the packed column is adjustable by adding or removing of glass tubes of diameter 0.072 and 0.4m length to the riser.

2.3 Experimental procedure

Two adjustable variables are: the submersion ratio, \( Sr \), and the air flow rate, \( QG \) (m\(^3\)/h). But this later can be injected in the bottom or in the middle of the column. The only measured parameter is the liquid flow rate. In the first we will measure the influence of the gas flow rate injected only in the bottom and the submersion ration on the liquid flow rate. In the second time, we will experiment the influence of the number of air injections points on the liquid flow rate.

The submerged depth, \( Zs \), is in the range 0.4 - 0.7 m; the total head (\( Ha \)) is in the range 1m; air flow rate (\( QG \)) is in the range: 0.5-1.8 m\(^3\) /h.

3 RESULTS AND DISCUSSION

3.1 Submergence ratio

Submergence ratio (\( Sr \)) is the ratio of the length of the tube submerged in the water per total length of the vertical tube.

\[
Sr = \frac{Zs}{Ha} \quad (1)
\]

Where, \( Zs \) is the submerged depth, \( Ha \) is the total head. According to Cho-Nam-Cheol, the limits of \( Sr \) are 40% -90%. If \( Zs \) equal to \( Ha \) that means there ‘is no lifting, But if \( Sr \) is low means that \( Zs \) is low and the lifting head is high.
3.2 Water flow rate

The water flow rate is measured by calibrated liquid flow meter. The error of this instrument is below 5%. We measure liquid flow rate for each submersion ratio (Sr) value with different gas flow rate and one or three air injection points.

The experimental results are shown in fig.2, 3, 4 and 5.

Fig.1. Experimental set up
(1)Riser, (2) down comer, (3) buffer tank, (4) cyclone, (5) compressor, (6) water flow meter, (7) water make up, (8), (9) Air flow meter, (10) Temperature control

Fig.2. Effect of the Gas flow rate, submersion ratio and the number of the air injection nozzles on the water flow rate
Fig. 3. Effect of the gas flow rate, submersion ratio and the number of the air injection nozzles on the water flow rate

Fig. 4. Effect of the gas flow rate, submersion ratio and the number of the air injection nozzles on the water flow rate

Fig. 5. Effect of the gas flow rate, submersion ratio and the number of the air injection nozzles on the water flow rate
The curves illustrated by fig. 2, 3, 4 and 5 show that the liquid flow rate increases when the submersion ratio (Sr), gas flow rate and the number of air injection nozzles increase. It is known that the liquid flow rate decreases with the increase of total head value. This explained by friction energy degradation.

According to Merchuk et al., Circulation of liquid and gas is facilitated by the difference in gas hold up between the riser and the down comer, which creates a pressure difference at the bottom of the equipment:

$$\Delta P_b = \rho_L g (\varepsilon_R - \varepsilon_D)$$

(2)

Where $\Delta P_b$ is the pressure difference, $\rho_L$ is the density of the liquid (the density of the gas is considered to be negligible), $g$ is the gravitational constant, and $\varepsilon_R$ and $\varepsilon_D$ are the fractional gas holdup of the riser and down comer, respectively. The pressure difference forces the fluid from the bottom of the down comer toward the riser, generating fluid circulation. Since $\varepsilon_R$ and $\varepsilon_D$ are both average values integrated along the height of the packed column.

Generally, the global gas hold up, $\varepsilon_G$, is defined as follows:

$$\varepsilon_G = \frac{V_G}{V_G + V_L + V_S}$$

(3)

Where:

$V_G$, $V_L$ and $V_S$ are the Volume of Gas, Liquid and Solid respectively.

The average density of the fluid mixture in the riser is given by the following equation (Trambouze, 1999):

$$\bar{\rho} = \rho_L \varepsilon_L + \rho_G \varepsilon_G$$

(4)

With:

$\varepsilon_L$ : Liquid hold up

$\varepsilon_G$ and $\rho_G$ are the hold up and density of the gas.

Gas hold up and liquid hold up are linked by the following relation:

$$\varepsilon_L + \varepsilon_G + \varepsilon_S = 1$$

(5)

$\varepsilon_S$ is the volume fraction of packing.

So, if the gas flows rate increases then the Gas volume and the gas hold up, $\varepsilon_G$. The pressure difference, $\Delta P_b$, increases and the average density of the mixture fluid decreases, then the liquid flow rate increases immediately. Therefore, the gas hold up must have a high value for a high liquid flow rate value. For this purpose we propose many air injection points. This proposition can maintain both high values of liquid flow rate and total head because the liquid flow rate is proportional to the gas holdup and the total head can be insured by the use of several air jet nozzles.
4 CONCLUSIONS

In the present paper, experiments were conducted on an air lift packed column using one or three air jet nozzles. From the above mentioned results and discussion, the following conclusions are obtained.

1. The use of many air jet nozzles placed in different levels of the column can increase both the total head and the liquid flow rate.
2. The average fluid mixture density decreases and can be maintained in a low value when the number of air jet nozzles used is high.
3. The height of the packed column can be adjusted by adding or removing tubes with heat and mass transfer efficiency needed. So the number of air jet nozzle used can also be adjusted.
4. The use of several air jet nozzles can improve the air lift pump efficiency because the quantity of consumed air can reduced.

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REFERENCES