Gas Hold-up Characteristics of an External Loop Airlift Contactor

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Abstract

Conventional airlift contactor (UT-ALC) was modified to improve its performance. The modified system (CDT-ALC) was tested for gas hold-up characteristics. Hydrodynamic environment depends on gas hold-up. New system reported 50 % higher gas hold-up. Linear relation between superficial gas velocity and fractional gas hold-up were developed from experimental data for both the reactors.

1. Introduction

Gas hold-up is one of the most important parameter characterizing hydrodynamics of bubble column. It has two fold applications. On one hand, gas hold-up in two phase systems gives the volume fraction of the phases present in the reactor and hence their residence time. On the other hand, the gas hold-up in conjugation with the knowledge of mean bubble diameter d_{VS} allows the determination of interfacial area and thus leads to the mass transfer rate between the gas and liquid phase. Gas hold-up mainly depends on the superficial gas velocity and often is very sensitive to the physical properties of the liquid.[1, 2]. Reactor geometry is also an important parameter which influence gas hold-up [3]

The dependence of the gas hold-up on superficial gas velocity is generally of the form

$$\varepsilon_G \propto U_G^{\,n} \quad \text{--------------------} \ (1)$$

The value of ‘n’ depends on the flow regime. For bubbly flow regime value of ‘n’ varies from 0.7 to 1.2 [4] .

In the churn turbulent or the transition region the effect of U_G is less pronounced and the exponent “n” takes values from 0.4 to 0.7. The log-log plots of gas hold-up against gas velocity measured by various authors for air water system is available in literature. [5]. The bubble flow regime at low gas velocities is not very pronounced and the transition from bubble flow to the churn turbulent flow can not be easily described. Although the data obtained in column with diameter varying from 0.075 to 5.5 m the values of hold-up match with each other indicating the relative unimportant of column diameter. A large number of correlations for gas hold-up have been proposed in the literature.

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2. Experimental

Conventional external loop uniform tube airlift contactor (UT-ALC) was modified. The riser part was replaced by an irregular geometry in the form of a converging-diverging tube. The modified system was named as Converging-diverging tube airlift Contactor (CDT-ALC).

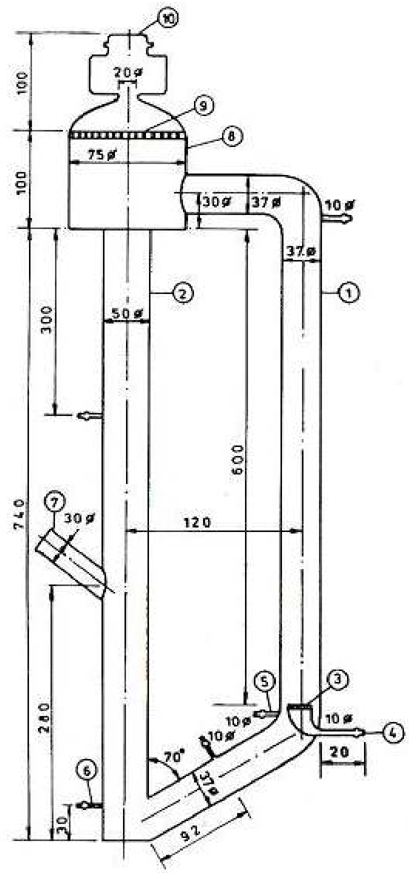

Fig: 1 Conventional External Loop Uniform Tube Air-Lift Contactor (UT-ALC)

1.Riser 2.Down-comer 3.Gas Spurger with 25ϕ sintered glass 4. Gas inlet 5. Sampling port 6. Drain 7. Probe point 8. Gas liquid separator 9. Perforated plate 3ϕ on 10 mm pitch 10. Gas outlet
All dimensions are in mm.

The airlift contactor used in this study are shown in fig.1 (UT-ALC) and fig.2 (CDT-ALC) with dimensions given in table 1. Fractional gas hold-up (ε_G) were determined experimentally for both the reactors (contactors) under identical operating condition . Gas hold-up were calculated by the following relation.

$$\varepsilon_G = (V_d - V) / V \quad \text{-------------------------------------} \quad (2)$$

V_d = dispersed liquid volume in the riser and V = Initial liquid volume in the riser

$$V_d = h_d \,.\, A_r \quad \text{--} \quad (3)$$

h_d is the dispersed liquid height in the riser and A_r is area of riser column.
h_i is the initial liquid height in the riser.
The superficial gas velocity, U_G was obtained by diving the volumetric air flow rate by the cross-sectional area of the riser tube.

$$\varepsilon_G = (V_d - V) / V = (h_d - h_i) / h_i \quad \text{--------------------}(4)$$

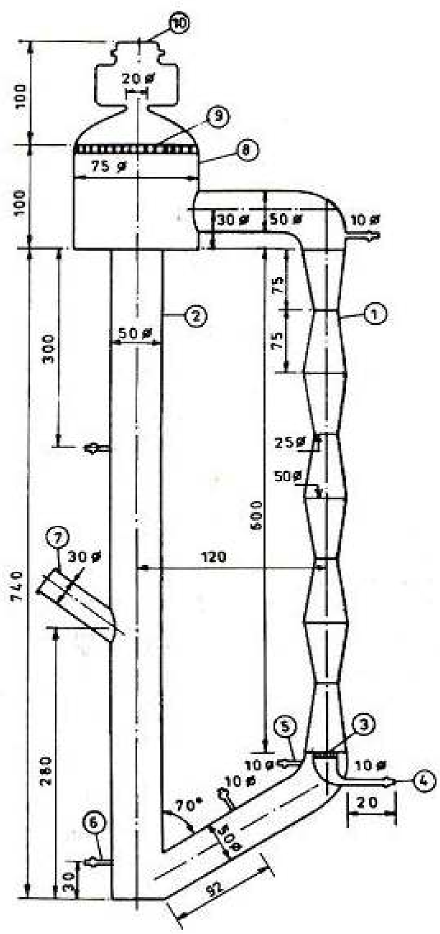

Fig: 2 External Loop Converging-Diverging Tube Air-Lift contactor (CDT-ALC)

1.Riser 2.Down-comer 3.Gas Spurger with 25ϕ sintered glass 4. Gas inlet 5. Sampling port 6. Drain 7. Probe point 8. Gas liquid separator 9. Perforated plate 3ϕ on 10 mm pitch 10. Gas outlet
All dimensions are in mm.

Table 1 Details of Air-lift fermenter (ALF) used.

Material of construction : Borosil glass, All dimensions are in meter

	UT-ALF	CDT-ALF
1. Riser height	0.6000	0.6000
2. Down comer height	0.7400	0.7400
3. Riser diameter		
for CDT-ALF		
Dmax		0.0500
Dmin		0.0250
For UT-ALF		
Dave	0.0375	
4. Down comer diameter	0.0500	0.0500
5. Distance between riser and down-comer	0.1200	0.1200
6. Diameter of top connector	0.0500	0.0500
7. Diameter of bottom connector	0.0500	0.0500
8. Diameter of gas-liquid separator	0.0750	0.0750
9. Height of gas-liquid separator	0.2000	0.2000
10. Diameter of sintered glass Spurger	0.0250	0.0250
11. Volume of the Contactor (m^3)	0.0020	0.0020

4. Result

Range of variables studied :

$$h_i = 0.50 \text{ m to } 0.60 \text{ m}$$
$$U_G = 0.0302 \text{m/sec to } 0.091 \text{ m/sec}$$

h_i is the initial liquid height in the riser.

Results depicted in fig 3 shows that fractional gas hold-up is directly proportional to superficial gas velocity (U_G) but inversely proportional to initial liquid height (h_i). Maximum gas hold-up was 0.152 (ε_G = 0.152) i.e 15.2 % for CDT-ALC at h_i = 0.50 m.. This was 50 % higher compared to UT-ALC under the identical operating conditions. At any operating condition CDT-ALC always shows much higher gas hold-up compared to UT-ALC.

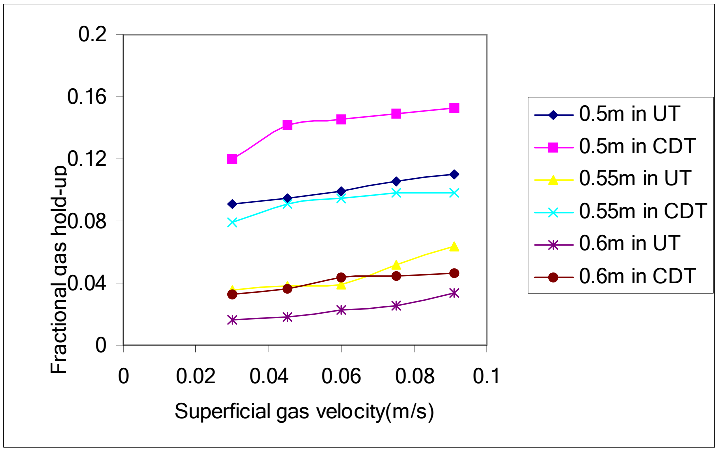

Fig 3 Effect of superficial gas velocity on fractional gas hold-up.

$$\varepsilon_G \propto U_G^{\ n} \quad \text{-----------------------------} \ (1)$$

$$\text{Log } \varepsilon_G = \text{Log } k + n \ \text{Log } U_G \ \text{.................}(5)$$

Fig 4 illustrates the log-log plot of ε_G and U_G. Two constants 'k' and 'n' were determine from the linear relation given below.

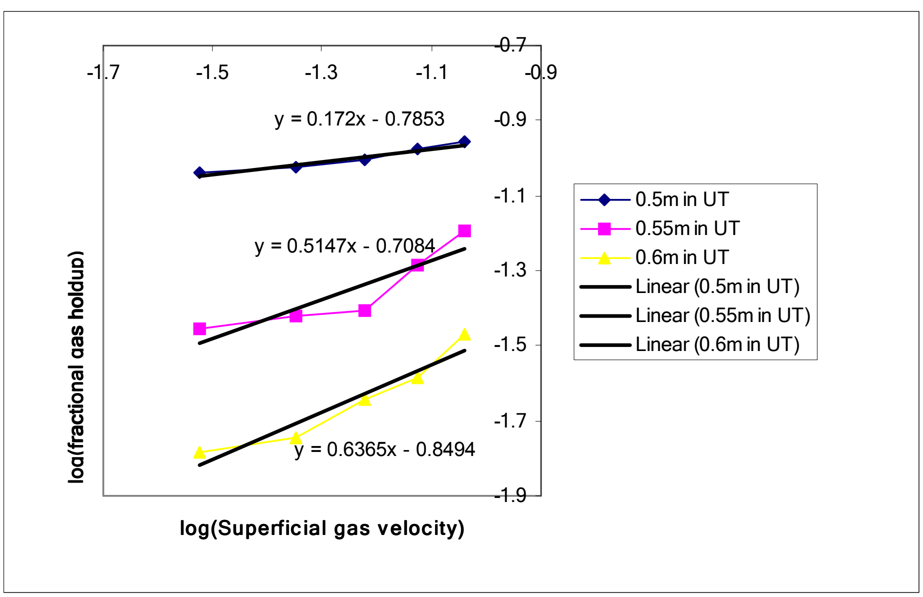

Fig 4 Linear relation between superficial gas velocity and fractional gas hold-up in UT-ALC

The linear relations for UT-ALC are given below.

$Y = 0.17\,X - 0.785$ for $h_i = 0.50$ m
$Y = 0.50X - 0.70$ for $h_i = 0.55$ m
$Y = 0.65\,X - 0.85$ for $h_i = 0.60$ m

So, average 'n' value will be (0.17+0.50+0.65)/3 = 0.45
K = -(0.785+0.7+0.85) = - 0.77

Fractional gas hold-up is proportional to the superficial gas velocity to the power 0.45.

$$\varepsilon_G \propto U_G^{0.45} \quad \text{----------------------------(6)}$$

Final Relation is $Y = 0.45\,X - 0.77$ ---------------------------(7)

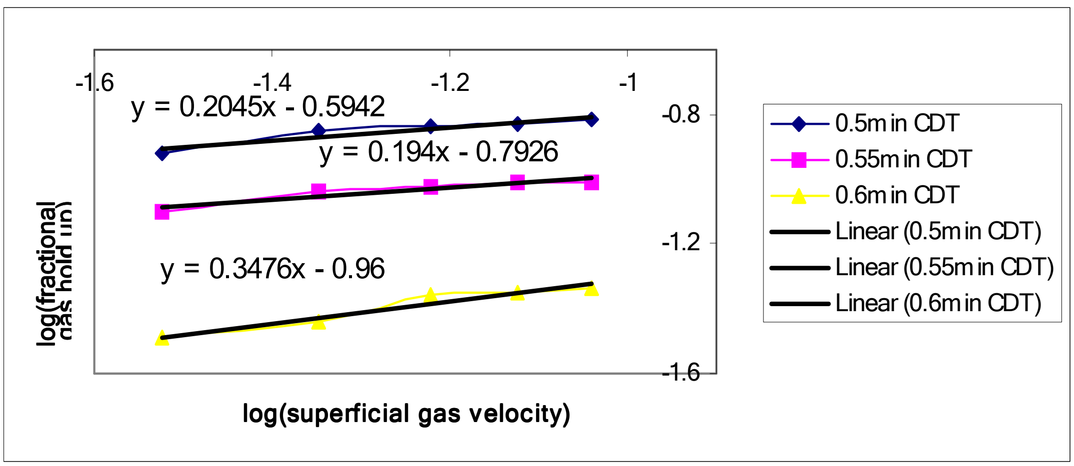

Fig 5 Linear relation between superficial gas velocity and fractional gas hold-up in CDT-ALC

The linear relations for CDT-ALC are given below.

$Y = 0.20\,X - 0.60$ for $h_i = 0.50$ m
$Y = 0.20\,X - 0.80$ for $h_i = 0.55$ m
$Y = 0.35X - 0.96$ for $h_i = 0.60$ m

So, average, n= (0.20+0.20+0.35)/3 = 0.25 and
K = -(0.60+0.80+0.96)/3 = -0.80

So, final relation is $Y = 0.25\,X - 0.80$ ---------------------------(8)

From the two final relation (equation 7,8) we can observe that slope of the equation 7 is 0.45 and slope of equation 8 is 0.25. So straight line for equation 8 is more flat than equation 7. Results depicted in fig 4 and 5 reveled that gas hold-up is less dependent on superficial gas velocity in CDT compared to UT.
So, very high gas hold-up at the lowest superficial gas velocity in CDT is a reality.

5. Discussion

As the geometry is converging and diverging at regular intervals the liquid velocity oscillates which generate pressure fluctuation. As a result bigger bubbles produced by coalescence brakes due to pressure fluctuation in each divergent section[6]. So huge number of tiny bubbles will produce which will be entrapped in side the liquid for long time. This may be the reason why CDT reported much higher (50 %) gas hold up compared to UT-ALC.
At low gas rates bubbly flow regime (U_G less than 0.075 m/s) condition existed, characterized by small fairly uniform sized bubbles. As the gas rate was increased eventually a homogeneous gas-liquid dispersion could not be maintained and some large bubbles were formed that had higher rise velocities than the remaining small bubbles. Operation in this heterogeneous flow regime is not desirable in practice because the gas-liquid mass transfer rate is reduced due to lower gas liquid interfacial area. The gas residence time is also less for higher bubble rise velocities of the large bubbles. The transition from bubble flow to the churn turbulent flow is not so easy to describe.

According to the result depicted in fig 3 CDT-ALC reported much higher (50 %) gas hold-up compared to UT-ALC at very low superficial gas velocity (0.030m/s). As a result it is very easy to maintain bubbly flow regime in CDT-ALC. Much higher gas holdup is always possible at the lowest superficial gas velocity of 0.03 m/s within bubbly flow regime in CDT-ALF. Bubbly flow regime is the ideal operating condition of an airlift contactors.

For the above mentioned reasons CDT-ALC may be used as biological reactor i.e fermenter.
Recently external loop airlift contactors were used as photo-bioreactor for continuous microbial production [7] . Gas hold-up is the key parameter which indirectly control the hydrodynamic environment of the liquid inside the reactor. Hydrodynamic conditions have a significant impact on the bio-film life cycle[8,9,10,11].

6. Conclusion

In this paper author proposed a novel approach to modify airlift Contactor. Performance of both the reactors with respect to gas hold-up were studied. Gas hold-up is a key parameter to determine hydrodynamic characteristics of the airlift contactor. Gas hold-up also contribute to gas liquid mass transfer. Basic investigations reported that CDT-ALC is much better than UT-ALC as far as gas hold-up is concern. So, promising result is expected if commercialized considering all the parameter which may affect the modified system.

10. References

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