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MASS TRANSFER STUDIES AND OPTIMIZATION OF GEOMETRICAL VARIABLES FOR A DOWN FLOW JET LOOP REACTOR

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ABSTRACT

Studies were carried out in a down flow jet loop bioreactor for air-water and air-additive system. The effects of variables such as operating variable and geometrical variables on the behaviour of a down flow jet loop bioreactor have been studied. In addition, the overall volumetric mass transfer coefficient and the influence of draft tube to column diameter ratio, nozzle diameter, projection depth of the aeration tube from the nozzle and immersion height has been determined.

Key words: Volumetric mass transfer coefficient (K_La), Down flow reactor, Jet loop reactor, Two fluid nozzle.

INTRODUCTION

Loop reactors are characterized by well-defined flow pattern; better dispersing effects and higher mass transfer performance compared to conventional reactors. The majority of investigations reported on jet loop reactor was considered with a central draft tube and two fluid nozzle installed at the bottom of the reactor[1]. This type of construction was characterized by a jet or an annular nozzle, in which the liquid jet enters the reactor space through a nozzle, which is center of a gas jet. The liquid jet performs the functions of distributing and dispersing the gas as fine bubbles in the liquid and also in circulating the gas liquid mixture by momentum transfer. This type of arrangement was also found disadvantageous when the reactor was used as a slurry reactor and in processes involving sparingly soluble gas, due to the blockage of nozzle and a lower residence time of the gaseous phase.

These operational difficulties led to the development of a new jet propelled loop reactor where gas introduced from the top of the reactor. The gas phase residence time can be increased considerably in down flow reactor when the gas is introduced from the top of the liquid flowing co-currently downwards, so that bubbles were found to move in a direction opposite to their buoyancy.

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Application of jet loop reactor

(i) Hydrogenation of caster oil and fatty acids.

(ii) Reduction of adiponitrile to hexamethylene diamine.

(iii) Amination of aldehyde to amine.

(iv) Low-pressure synthesis of methanol.

(v) Biological treatment of wastewaters.

(vi) Reduction of carbonyl group and acid chlorides.

(vii) Biodesulphurisation of petroleum

EXPERIMENTAL

All the experiments are conducted at the ambient temperature.

Volumetric mass transfer coefficient (K_La), in the reactor is obtained by the well-known transient technique. A batch of liquid of volume slightly more than that of reactor and pipelines was taken in the storage tank and the liquid circulation was started at desired liquid flow rates. The gas flow rate was stopped by closing the aeration tube with suitable enclosure, and the liquid was deaerated to approximately zero oxygen concentration in a few minutes by rapid addition of 160 gm/m^3 of Sodium sulfite ($Na_2SO_3.7H_2O$) together with 2 gm/m^3 of Cobaltous chloride ($CoCl_2.6H_2O$) as a catalyst. Air flow to the reactor was started by opening the enclosure of the aeration tube and time change in the dissolved oxygen concentration was monitored by a dissolved oxygen electrode. The assumption of constant gas phase composition with respect to axial position in the reactor, well mixed transfer time ($1/K_La$) for the entire range of liquid velocity covered was made. The influence of oxygen dynamics of electrode on K_La is neglected as the time constant of the probe τ_E is less than 10 sec and condition $\tau_E << (1/K_La)$ is fulfilled.

The K_La for each run is obtained from the slope of the straight line in the plot -

$$\ln (C^*-C_o/C^*-C_L) \ \text{vs,} \quad t$$

The steady state value of DO meter at desired operating conditions of liquid flow rates was taken as the saturation or equilibrium concentration (C^*) of oxygen in the liquid for that particular experimental run[2].

Assumption

(i) Constant gas phase composition

(ii) Well-mixed liquid

(iii) Negligible effect of dynamics of the dissolved oxygen electrode.

RESULTS AND DISCUSSION

Air-water system

Effect of draft tube to column diameter ratio DE/D on K_La

It was observed that the K_La increased up to a D_E/D ratio of 0.44 and decreased with further increase in D_E/D ratio. An increase in D_E/D ratio increases the superficial liquid velocity in the annulus due to the decrease in cross sectional area, which results in the increased recirculation of the gas bubbles into draft tube which in turn resulted in increased K_La. The higher liquid velocities in the annulus, decreased the residence time of the gas bubbles in the reactor which in turn resulted in decreased K_La. The present trend agrees well with that reported in the literature.

Effect of nozzle diameter (dT) on volumetric mass transfer coefficient (K_La)

It was observed that the K_La showed an increasing trend up to a nozzle diameter of 10 mm and then decreased as diameter is increased further. As the nozzle diameter decreases, dispersion effect will be more pronounced. Hence 10 mm nozzle was taken as the best within the range of operation and the rest of the experiments were carried out with this nozzle. The present trend agrees well with that reported in the literature.

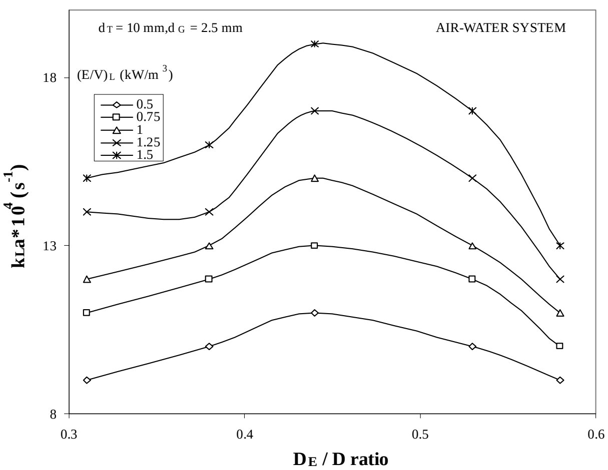

Fig. 1

Effect of projection depth of aeration tube

The effect was studied with the 2.5 mm aeration tube placed in 10 mm nozzle. The projection depth was varied in steps of five from 4-24 mm. It was found that the projection depth, which gave maximum mass transfer coefficient, was different for different nozzles. It was also found that the projection depth was a function of aeration tube diameter. The best projection depth obtained for different nozzles were comparable with the model proposed (given below),

$$e = (1/m)\,[d_T - (d_G/(1 - A_1/A_2)^{0.5})]$$

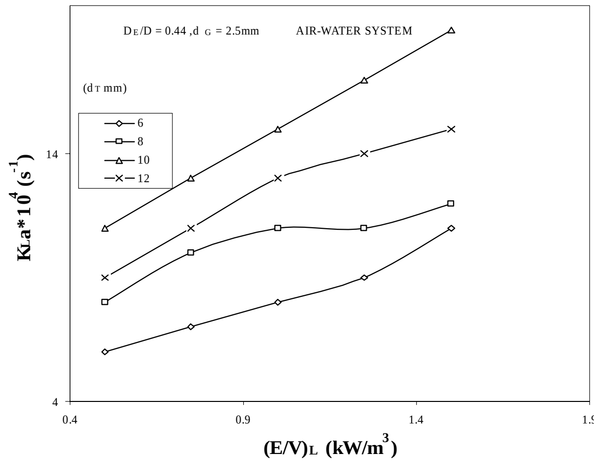

Fig. 2

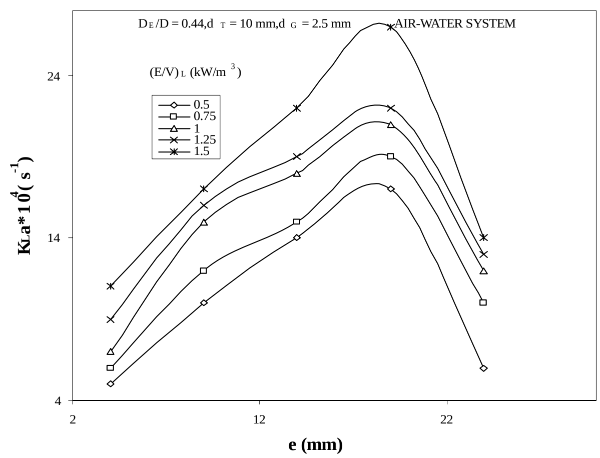

Fig. 3

Comparison of projection depths

The comparison of the projection depths obtained from the model and the experiment values of the projection depths is shown in Table. From the Table, it was observed that the experimentally obtained best value of the projection depth deviated from the value obtained from the model.

Nozzle diameter (mm)	Best projection depth Experimental e (mm)	Best projection depth from Model e (mm)
10	19	21.5

Effect of immersion height of the two fluid nozzle

The effect was studied with three different immersion height of two fluid nozzle (i,e., 100, 150 and 200 mm). It was observed that volumetric mass transfer coefficient increased with decrease in immersion height of two fluid nozzle.

The smaller values of the immersion height of the nozzle longer the residence time of the gas bubbles due to increase in the circulation path length. An increase in residence time of the gas bubbles increases the volumetric mass transfer coefficient. On other hand the possibility of gas bubble escaping from the reactor is larger at larger values of immersion height of the nozzle. The present trend agrees well with that reported in the literature.

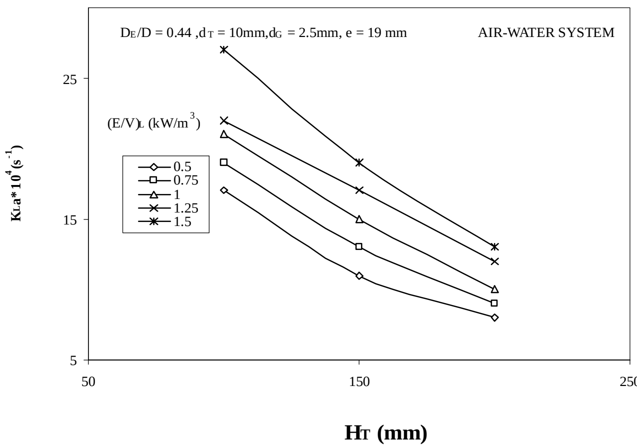

Fig. 4

Air – additive (Propanol) system

Effect of propanol on volumetric mass transfer coefficient

The effect of addition of propanol on volumetric mass transfer coefficient is shown in Fig. Propanol is the well known coalescence inhibitor and due to that more bubbles were formed and hence the interfacial area increases, thus the volumetric mass transfer coefficient increased.

Correlation

The volumetric mass transfer coefficient in Air-Water system was predicted based on the energy dissipation rate per unit volume and draft tube to column diameter ratio. An empirical correlation is proposed of the form -

$$K_La = a\ (E/V)_L^{\ b}\ (D_E/D)^c \qquad \ldots(1)$$

The predicted values of volumetric mass transfer coefficient were plotted against the experimental values of volumetric mass transfer coefficient as shown in Fig. 4.7. It is seen that the proposed correlation predicts the present data well within ± 15% and RMS error is 4.5%.

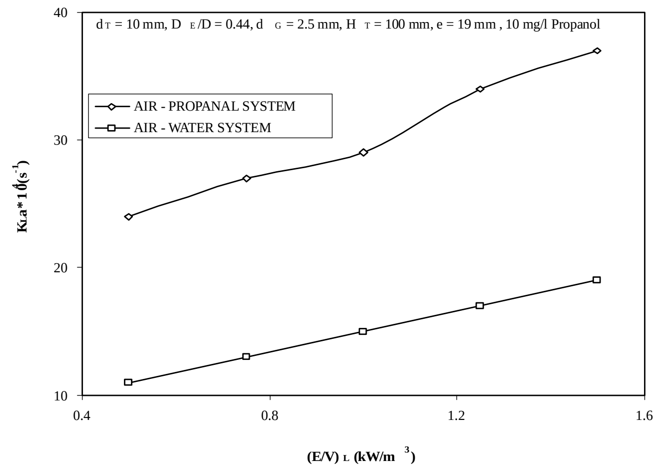

Fig. 5

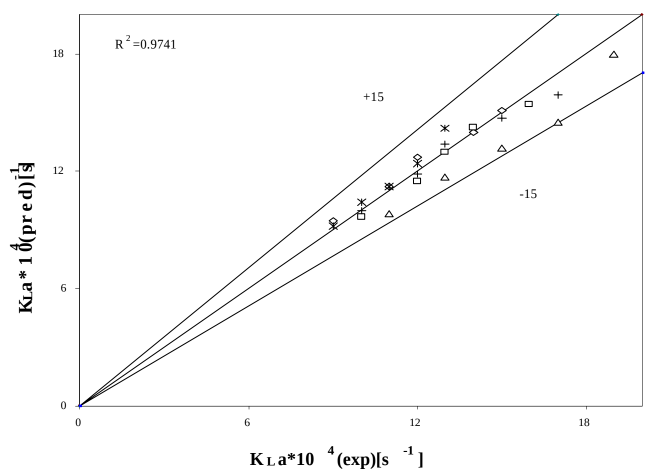

Fig. 6

The values of the constants are -

a = 0.0014, b = 0 .1072, c = 0.4232 and R^2 = 0.9741.

CONCLUSIONS

The mass transfer studies on down flow jet loop reactor under ejector mode operation were carried out with air-water system, air-CMC system and air-additive (propanol) system The influence of the operational parameter (liquid flow rate) and geometrical parameter (draft tube to column diameter ratio, nozzle diameter) on K_La was studied.

The mass transfer coefficient increased with the liquid flow rate for these systems. The geometrical variables were found to have significant influence on K_La. The values of the geometrical variables that gave higher mass transfer coefficient within the range of investigation are -

$D_E/D = 0.44$; $d_T = 10$ mm; $d_G = 2.5$ mm, and e = 19 mm

The increase in concentration of CMC increased the liquid viscosity which in turn decreased the K_La. Air-propanol system offered higher K_La values than air-water system. An empirical correlation proposed for the prediction of K_La predicted the experimental data well within ± 15%.

REFERENCES

1. H. Blenke, Loop Reactors, Advances in Biochemical Engineering, T. K. Ghose, A. Fiechter and Black Brough (Eds.), Springer-Verlag, Berlin, Vol. 13 (1979) pp. 121-214.
2. R. A. Bello, C. W. Robinson and M. Murray Young, Mass Transfer and Liquid Mixing in External Circulation Loop Contactors, Advances in Biotechnology, Vol. 1, Scientific and Engineering Principles, Pergamon Press, Toronto (1981) pp. 547-552.
3. A. K. Bin, Minimum air Entrainment Velocity of Vertical Plunging Liquid Jets, Chem. Engg. Sci., **43**, 379-389 (1988).
4. H. Blenke, Biochemical Loop Reactors in Biotechnology, Fundamentals of Biochemical Engineering, H. J. Rehm, G. Reid and H. Brauer (Eds.), Weinheim, VCH, (1985) pp. 465-517.
5. P. H. M. R. Cramers, A. A. C. M. Beenackers and L. L. Van Dierendonck, Hydrodynamics and Mass Transfer Characteristics of a Loop-Venturi Reactor with a Down Flow Liquid Jet Ejector, Chem. Engg. Sci., **47**, 3557-3564 (1992).
6. P. H. M. R. Cramers, L. Smit, G. M. Leuteritz, L. L. Van Dierendonck and A. A. C. M. Beenackers, Hydrodynamics and Local Mass Transfer Characteristics of Gas-Liquid Ejectors, Chem. Engg. Jl, **53**, 67-73 (1993).
7. C. A. M. C. Dirix and Vander Wiele, Mass Transfer in Jet Loop Reactors, Chem. Engg. Sci., **45**, 2333-2340 (1990).
8. N. N. Dutta and V. Raghavan, Mass Transfer and Hydrodynamic Characteristics of Loop Reactors with Down Flow Liquid Jet Ejector, Chem. Engg. Jl., **36**, 111-121 (1987).