MASS TRANSFER STUDIES IN AN AGITATED VESSEL WITH RADIAL-AXIAL IMPELLER COMBINATION

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Abstract

The effect of radial-axial impeller combination in dual configuration was tested for gas liquid mass transfer coefficient (K_La) and compared with that of dual axial impeller (30º Pitched blade) combination. The trials were conducted at gas rates of 2litre/min to 10litre/min and agitation rates of 180rpm to 360rpm.Good mass transfer coefficient was obtained by replacing the lower axial impeller with a radial impeller. Rushton Turbine and Curved blade (half pipe) impeller were used in replacing the lower axial impeller. Amongst the two radial impellers, curved blade resulted in higher K_La than Rushton Turbine at highest gassing rate tested. About 15-35% and 20-48% increase in K_La was observed by replacing lower pitched blade impeller with Rushton and Curved blade impeller each. The results from the present study shows the capability of replacing lower axial impeller with Radial impeller and retrofitting existing lower Rushton Turbine with Curved blade impeller.

Keywords: *Mass transfer coefficient, Rushton, Axial, agitated vessel.*

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1. INTRODUCTION

Many Chemical and Biochemical processes require oxygen and they employ agitators to achieve the goal of mass transfer. Oxygen being sparingly soluble in water requires impellers to induce smaller bubbles and improve the dissolution. This oxygen transfer or dissolution depends on various process parameters. Mass transfer in a gas liquid system depends on properties of the fluid (media, salt solutions), impeller type, the geometry of the system, agitation speed, and the flowrate of air. Few of the literature states that sparger geometry and air flowrate has less effect on mass transfer.

The oxygen transfer rate in a well mixed system is given as

$$dC/dt = OTR = K_La\,(C^* - C_L)$$

Where
C^* is the equilibrium oxygen concentration to be calculated by Henry's law
C_L is the actual oxygen concentration in liquid at any given time
K_L is the liquid phase resistance
a is the gas liquid interfacial area

Radial flow turbines are known to be good gas liquid dispersers. They impart high shear causing the bubbles that reach the impeller blades to break and increase oxygen transfer to the liquid. Standard Flat blade turbine also called Rushton turbine is a top choice in Industries for all the two phase dispersion processes. The classical Rushton turbine has a high power number of 5.5-6. This contributes to the power requirement of the agitated vessel and also the power imparted to the mixing liquid. Besides this Rushton turbine turns out to be a poor gas handler at high aeration rates, they experience significant power drop upon gassing which influences the mass transfer. Disk turbines with curved blades are extensively studied [1,8,9].They are found to be better gas handlers and experience lesser loss in power upon aeration. This blade shape also contributes to lesser cavity formation behind the blades and hence improves the mass transfer capabilities. Axial Impellers are known to impart fewer shears. They also have lower power number and hence require less power. They dissipate less power into liquid and hence lesser utility requirement for heat removal.

Combination of Radial-Axial Impeller is being studied by various researchers. Varied observations with some claiming the combination to be better than dual Rushton and some claiming poor performance in terms of mass transfer can be seen in literature. However the efficiency of the combination depends on the type of axial and radial impeller used. Andrew and Theodore [4] compared K_La obtained from eleven different Impeller combinations. They observed that dual impeller configuration with upper axial impeller gives higher K_La values and that at high aeration rates lower concave/curved blade gave K_La similar to those of the Rushton-axial dual impeller schemes. But they preferred using lower concave blade owing to its improved mass transfer performance. Puthli et al [5] assessed the combination of radial-axial impeller combination in dual and triple impeller configuration and found the best results in terms of K_La were obtained in triple impeller combination with one lower Rushton impeller and two upper pitched blade impeller. Arjunwadkar et al [7] also performed similar experiments and found good gas hold; gas-liquid mass transfer coefficient using the least power could be achieved with combination of lower disc turbine- upper pitched blade downflow impeller.

The present study aims at evaluating the K_La for dual Pitched blade, Rushton Turbine -Pitched blade combination, curved blade-Pitched blade combination at various process parameters.

2. METHODOLOGY

2.1 Vessel Configuration

All the experiments were conducted in a cylindrical vessel with ellipsoidal bottom. The internal diameter (T) of the vessel was 268mm and height 540mm (H). Four removable baffles of T/10 width were placed at right angles to each other. Rushton Turbine, Curved blade (half pipe) Impeller and 30º Pitched blade Impeller (down pumping) of D/T ratio 0.4, 0.43 and 0.5 each were employed in agitation. Ring sparger with diameter of 0.8D with 8holes of 2mm diameter was used. Impellers were used with a clearance of 1.5D from each other (C_1) and clearance of D from bottom (C_2). Dissolved oxygen was measured using a polarographic probe. The experiments were performed at 37±2ºC and without any back pressure. The measurements were done in triplicates to check the reproducibility. A reproducibility of 15-20% was observed. Fig 1 gives the schematic representation and geometrical parameters of the vessel.

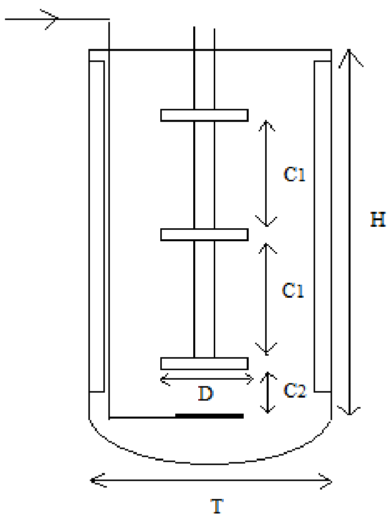

Fig-1: Geometrical Parameters of the vessel

2.2 Determination of K_La

K_La was determined using static gassing out method. Nitrogen was introduced to bring the DO level to less than 1% following which compressed air was introduced to reach a saturated DO level. A plot of ln (C^*-C_L) versus time was drawn for each trial. K_La was obtained from the slope of this plot. The K_La was determined at 2lpm, 5lpm, 10lpm air flowrates and 180rpm, 270rpm, 360rpm agitation rates. The test solutions used were deionised water, 1% Sodium Chloride, 0.6% dextrose. The concentrations of test solutions and the agitation and aeration rates are similar to the one used in fermentation and cell culture processes.

3. RESULTS AND DISCUSSION

3.1 Effect of Impeller Rotation Speed on K_La

Impeller speed is one of the important factors that effects gas liquid mass transfer in an agitated vessel. Fig 2 shows the effect of agitation rate on K_La .The K_La values were found to increase with increasing impeller speed. The increase in K_La values is due to the breakage of rising bubbles by the impeller blade giving rise to more interfacial area for gas transfer. At 10lpm all three Impeller combinations show a linear increase in K_La values with the increasing agitation. Both 1r1p and 1c1p combination yield better mass transfer coefficient values than 2p.1c1p and 1r1p gave similar K_La values at all tested impeller speeds. The lower radial impeller diffuses the gas emerging from the sparger and allows an upward movement of the bubbles. This is a better option than lower down pumping pitched blade impeller.

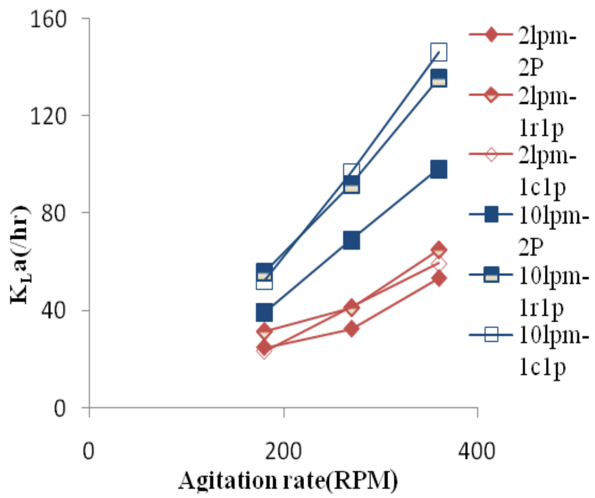

Fig-2: Effect of agitation rate on K_La for different Impeller combinations

3.2 Effect of Gas Flow Rate on K_La

Fig 3 shows the effect of aeration rate on K_La. Increasing the aeration rate increased the K_La values. At a constant agitation rate of 180rpm 1r1p combination showed better mass transfer coefficient than 2P and also at the lowest gas flowrate of 2lpm, 1r1p showed higher performance than 2P and 1c1p combination. However at higher agitation rate of 360rpm both 1c1p and 1r1p yielded significantly higher K_La values than 2P. Two different trends of smaller increase of K_La from 2lpm to 5lpm and greater increase from5lpm to 10lpm at 180rpm was observed. But at 360rpm the two different trend did not exist. Higher gas flowrates accompanied by high speeds help in breaking bubbles thus increasing mass transfer. As the gas flow rate is increased 1c1p combination is better performer than 1r1p. This shows the poor gas handling capabilities of Rushton Turbine. Also Curved blade has lower power requirements at high gas flowrates compared to Rushton turbine [3].

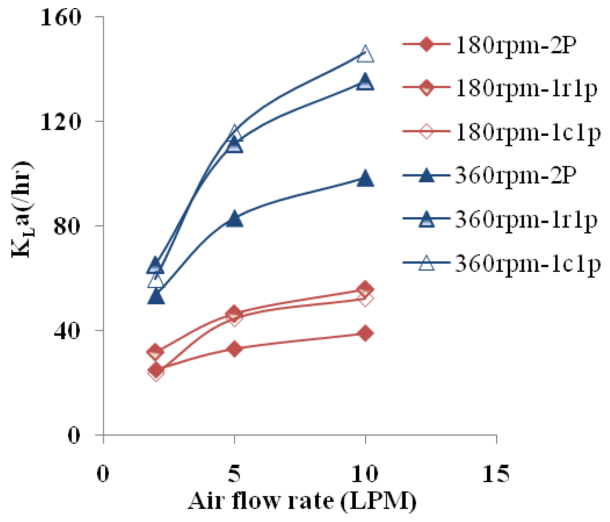

Fig-3: Effect of gassing rate on K_La for different Impeller combination

3.3 Effect of Test Solutions on K_La

Salts and Sugars reduce Bubble coalescence [2].Fig 4 shows the effect of the test fluids on K_La .Deionised water showed lesser K_La values than Sodium Chloride and Dextrose solution at all aeration and agitation rates. However as shown in Figure 4 trials with 1%Sodium chloride resulted in higher K_La values than 0.6% dextrose solution. At 5lpm K_La values leaped at 270rpm and then remained almost neutral at 360rpm.But this leap was not seen at 10lpm-270rpm, where the results were similar to that at 5lpm. Higher flowrates of gas sparging results in coalescence of gas bubbles increasing the interfacial area for mass transfer.The observation made in present study of improved K_La values at 5lpm suggest that gas coalescing is aptly inhibited in the salt solution and thereafter the coalescing nature of high gassing overtakes the inhibition property of salts at 10lpm.

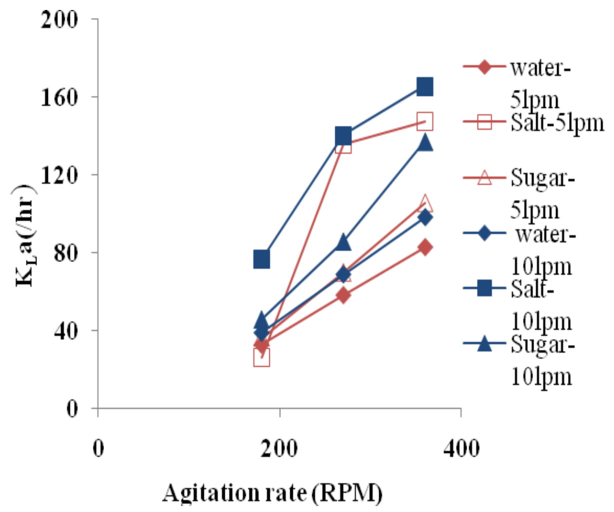

Fig-4: Effect of test solutions on K_La for dual pitched blade Impeller combination

3.4 Effect of Radial-Axial Impeller Combination on K_La

Figure 5 shows the effect of tested impeller combinations on the mass transfer coefficient at 5lpm and 10lpm for the test solution water.

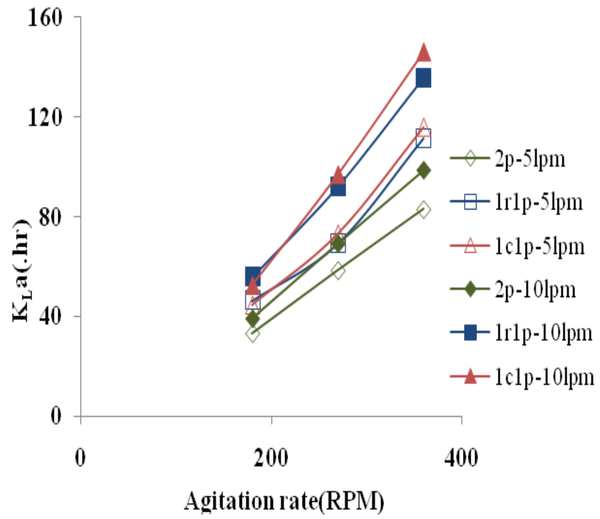

Fig-5: Effect of Impeller combination on K_La.

Studies performed with dual down pumping axial blade impeller showed markedly lesser mass transfer coefficient than radial-axial impeller combinations. Replacing the lower axial impeller with radial impeller - Rushton or curved blade impeller showed improved K_La values. This is because the radial impellers help in the bubble breakage as they emerge from sparger.1r1p and 1c1p impeller combination yielded similar K_La values at 5lpm and lower agitation speeds and only improved slightly at 10lpm and higher agitation rates. However since curved blade impeller requires lesser power than Rushton, using curved blade-pitched blade combination would be a better option.

3. CONCLUSION

Dual Impeller configuration with two Axial (Pitched blade), lower radial (Rushton and Curved) and Upper axial (Pitched blade) were studied and compared for the mass transfer capabilities in terms of mass transfer coefficient. The studies were performed at the conditions similar to Biochemical processes involving cells, choosing the aeration and agitation to match those used in Bioprocess Industry. At lower agitation and aeration rates Rushton-Pitched blade combination gave higher values of K_La. But as the aeration and agitation increased curved blade as lower disperser showed better results. Thus replacing the lower axial impeller with lower power number curved blade impeller can give improved results as it requires lesser power and imparts lesser shear than Rushton Turbine. This proves efficient in terms of maximizing the mass transfer with minimal power. Existing systems with Rushton-Pitched blade combination can be retrofitted with Curved blade.

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BIOGRAPHIES

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