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Effect of Different Configurations of Mechanical Aerators on Oxygen Transfer and Aeration Efficiency with respect to Power Consumption

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Abstract**—**This paper examines the use of mechanical aerator for oxidation-ditch process. The rotor, which controls the aeration, is the main component of the aeration process. Therefore, the objective of this study is to find out the variations in overall oxygen transfer coefficient (K_La) and aeration efficiency (AE) for different configurations of aerator by varying the parameters viz. speed of aerator, depth of immersion, blade tip angles so as to yield higher values of K_La and AE. Six different configurations of aerator were developed and fabricated in the laboratory and were tested for above-mentioned parameters. The curved blade rotor (CBR) emerged as a potential aerator with blade tip angle of 47°.

The mathematical models are developed for predicting the behaviour of CBR w.r.t k_La and power. In laboratory studies, the optimum value of K_La and AE were observed to be 10.33 h^{-1} and 2.269 kg O_2/ kWh.

Keywords**—**Aerator, Aeration efficiency, Dissolve Oxygen, Overall oxygen transfer coefficient, Oxidation ditch.

I. Introduction

AERATION and other gas transfer operation serve a multitude of purpose in both, water and waste-water treatment, occupy a unique place in water quality management and are important factors in the pollution and self purification of natural water. In most instances the objective of the aeration is to increase the dissolved oxygen or the removal of gases and other relative substance from water or both at the same time.

There are three basic categories of aeration methods, viz. surface or mechanical aeration method, diffused aeration method and combined or turbine aeration method. All methods have the same basic purpose, namely to introduce oxygen into the treatment process in the most efficient manner possible. Out of the three, mechanical aerators are widely used because of better efficiency and convenience in operation and maintenance.[1]

Mechanical aerators are commonly divided into two groups based on major design & operating features (aerators with a vertical axis & aerators with horizontal axis). Both groups are further subdivided into surface & submerged aerators. The surface aerators are patterned after the original Kessener brush aerators, a device used to provide both aeration and circulation in oxidation ditches. The brush type aerator has a cylinder with bristles mounted just above the water surface. The bristles were submerged in the water and the cylinder was rotated rapidly by an electric motor drive, spraying wastewater across the tank, promoting circulation, and entraining air in the wastewater. Now days, plastic bars or blades are used instead of bristles.

Submerged horizontal axis aerators are similar in principle to the surface type except that they use disks or paddles attached to rotating shafts to agitate the water.[2] The disks are submerged in the wastewater for approximately one-eighth to three-eighth of the diameter and circulate the water in a continuous, non-pulsating manner. Recesses in the disks introduce entrapped air beneath the surface as the disk turns.

Oxygen transfer into water or waste water is systematized by,

(i) Generally the largest practicable area of interface between liquid volume and air.
(ii) Preventing build up of thick interfacial films or by breaking them down to keep the transfer coefficient high.
(iii) Having as long as possible exposure time and maintaining the highest possible driving force of concentration difference for absorption and desorption.

To provide the required amount of oxygen, an aeration system is always needed. Aeration is usually the single largest cost in a waste water treatment process comprising as much as 50-90% of total energy requirement.[3] The aeration rotor, generally, consists of a series of plates fixed to supporting rods, which in turn are fixed to circular side plates. The plates are mounted on a central shaft, which is connected to a driving unit. Energy is transmitted by the plates to the body of liquid in the ditch by rotating them, when the plates move through top layer of the liquid, the water is carried with the plates and is dispersed in the form of small droplets.

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The action of rotor on the mass of liquid in which it rotates is fourfold.[4]

1. The natural surface of water ripples and surges.
2. Drops of water are thrown into air.
3. Air bubbles are introduced into the mass of water.
4. The agitation of water produces a mixture of air and water around the body of rotor, which may represent a large surface of water in small space.

Because of above-mentioned characteristics of aeration rotor, it is concluded that surface aeration and surface renewal in the water air mixture in the immediate vicinity of brush (aerator) are responsible for the most of the oxygenation that occurs.

A wide variation in performance of aerators in terms of standard aeration efficiency was found, viz. “Taiwanese” aerator (1.17 kg 0_2/kW.h), “Japanese” aerator (1.03 kg 0_2/kW.h) and Auburn university design (2.25 kg 0_2/kWh).[5],[6] For proper aeration, i.e., proper mixing of DO throughout the water volume, [7] suggested the aerator power-to-water volume ratio to be less than 0.1 kW/m^3. While [8] mentioned that the above ratio should lie within 0.01-0.04 kW/m^3.[9] The oxygen transfer rate from gas to liquid phase is dependent on various factors for a given method of aeration such as dynamic variables like speed, mixing intensity and turbulence. Geometrical parameters like size and number of blades, depth of immersion etc. and physicochemical properties of the liquid. Even though the designer or operator can fix or control some of these parameters, successful design requires the knowledge of the effect of all such parameter on re-aeration rate.

The present research work focuses on development of a novel configuration of aerator, so as to yield higher values of overall oxygen coefficient and aeration efficiency by varying some of the dynamic and geometrical parameters so as to consume less power. The different configurations of aerators are developed in the laboratory and are tested for their performance with one of the wastewater treatment process, generally referred as oxidation ditch.

II. Materials and Methods

The experimental setup mainly consists of an oxidation ditch, D.C. motor with variable speed controller, digital wattmeter of range (0-200W). Dissolved Oxygen meter of range 0 -19.99 mg/L, thermometer of range 0 -100 º C and digital tachometer.

III. Aeration Rotors

The oxygen transfer phenomenon mainly depends upon the configuration of aerator; therefore to verify the effect of aerator configuration, different types of aerators are developed.

Cage Rope Wound Rotor (CRWR):

CRWR is a cage type rotor (generally referred as Pasveer rotor) having blades on inner side of the disc. The blades of the size 14cm x 2.5cm are welded such that the cage of two circular discs is formed. The discs are made up of galvanized sheet, 1mm thick &29 cm in diameter. It is also having 6 fins of size 14 cm x 2.5cm welded radially on inner side of both the disc to increase the turbulence. Moreover a nylon rope of 8m in length & 5mm in diameter was wounded on the surface of blade to increase surface area of aerator. A central hole of diameter 1 cm is drilled on the both the disc to accommodate a mild steel shaft of length of 36 cm. The aerator thus fabricated is welded to the shaft & is mounted in the bearing provided at the collar of the ditch

Cage Fin Rotor (CFR):

Cage fin rotor is similar to that of CRWR. In CFR the blades were welded on inner as well as outer side of the disc. The width of the rotor was maintained 14 cm & the diameter 29 cm.

Brush Rotor:

It is also referred to as Kessner brush in the literature. Brush rotor consists of 16 brushes of dimension 14 cm long & 2.5 cm wide made up of galvanized steel sheet 1 mm thick. These brushes are welded on the periphery of hollow pipe of 12 mm diameter. The pipe is subsequently welded to the shaft 10 mm diameter, which passes through the hollow pipe.

Curved Blade Rotor (CBR):

CBR was fabricated using impeller fans made up of fiber & are used in centrifugal pump, which are available in market in variety of sizes. A 23 cm in diameter and 12 small fins of size 5 cm x 3 cm mounted on the fan disc was selected to configure an aerator so that the effective diameter of the disc becomes 26 cm. The different diameter pipes were used so as to get the change in blade tip angles. A pair of fan disc was taken & the strips thus fabricated were screwed on projected fins of the fan discs. The strips were screwed in such a fashion that the projected length of the strip over the disc fins was 1.5 cm. Therefore the effective diameter of rotor thus fabricated amounts to 29 cm with 12 blades (fiber strips) mounted on each aerator rotor. This assembly of aerator was fastened tightly to the shaft & then fixed in the bearings provided on the collars or hubs. Three different configurations were obtained by this method with blade tip angles of 27°, 47° and 60°.

Driving Mechanism:

A D.C shunt motor with variable controlled was used to provide drive to the rotors. The specifications of D.C motor are 0.25 H.P., 1.2 Amp, 1400 rpm. A D.C shunt motor was mounted on the ground and a driving sprocket of same dimension as that of provided on rotor shaft, was mounted on the motor shaft. The number of teethes on driving as well as driven sprocket are 16.

IV. Experimental Methods

To study the effect of various parameters, dissolved oxygen in water due to mechanical aeration is measured under varied condition of aerator configuration, aerator speed, and effect of depth of immersion, blade tip angle and time of aeration.

Effect of Aerator Configuration:

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In order to asses the effect of aerator configuration on overall oxygen transfer coefficient and subsequently on the power consumption, the experiments are carried out for six different configuration of aerators for different speeds and 5.5 cm depth of immersion.

Effect of Aerator Speed:

Initially to asses the effect of aerator speed on overall oxygen transfer coefficient with respect to power consumed, the experiments are carried out at 36, 42, 48, 60 rpm aerator speed and 5.5 cm depth of immersion.

Effect of Depth of Immersion:

In order to asses the effect of depth of immersion on overall oxygen transfer coefficient to recover dissolved oxygen and subsequently on power consumption, the experiments are carried out for 4.8, 5.5, 6.3, and 7.2 cm depth of immersion when the aerator speed was 48 rpm.

Effect of Blade Tip Angle:

CBR aerator is first tested for blade tip angle of 47 º. Under this section the blade tip angles are changed to 27 º and 60 º from 47 º and then the performance under varied blade tip angles is tested for overall oxygen transfer coefficient to recover dissolved oxygen and the power consumption. The speed of aerator is varied from 42 to 60 rpm.

Effect of Time of Aeration:

In the earlier sets, time of aeration is studied for longer period of time but it is found that oxygen transferred remains almost constant after the maximum time of 90 minutes depending on configuration of aerator, therefore the observation are recorded for 120 minutes.

V. Aeration Test Procedure

1. Cleaning of the oxidation ditch and the aeration devices was done thoroughly and the instruments to be used for measurements of various parameters were calibrated before the start of experimentation. The calibration of DO meter was done according to the procedure described by the manufacturer and by using the standard solutions of potassium chloride (KCl), sodium sulphite and distilled water provided by the manufacturer. This procedure was repeated of all sets of experiments.
2. The oxidation ditch was filled with tap water available in the laboratory, till the height of the water in the ditch reached 13 cm. The water volume for every experiment was maintained constant.
3. The deoxygenating-oxygenation procedure used was the non-steady-state reaeration test. [8],[9] The test water was deoxygenated with 10 mg/L of sodium sulphite. Cobalt chloride was not used during test since it is considered hazardous to human health.[10]
4. It took about 10-15 minutes to deoxygenate the water and after maintaining DO between 0.0 – 0.1 mg/L for about 5 minutes both the aerator were put in operation at the same moment and at the same rotational speed and immersion depth.
5. Increase in DO concentration was measured by DO meter at the surface of water and at the half depth from the surface. The observations were recorded for every 15 minutes after switching on the aerators.
6. The observations were taken until the DO concentration increased from 0% saturation to at least 90% saturation. The dissolved oxygen saturation concentration (C_s) used for calculating the K_La was estimated using the highest dissolved oxygen concentration from each test.
7. For every 15 minutes of test interval, DO was measured with the help of DO probe and simultaneously speed of the aerator and temperature was also recorded by using tachometer and thermometer respectively. Simultaneously, the power consumed is observed by wattmeter, which is connected to the variable speed controller and finally the average power was calculated for that particular setup.
8. The collars, on which the aerators were mounted, were fixed at particular height so as to give the required depth of immersion for that particular set of experiment.

The same procedure was repeated for all the aerators under test for their performance evaluation with respect to overall oxygen transfer coefficient by changing the various parameters as mentioned earlier.

VI. Results and Discussion

Out of the various factors which may affect aeration or dissolved oxygen level such as, time of aeration, depth of immersion, speed of aerator, blade tip angle of aerator, are mainly considered. For every set of observation, overall oxygen transfer coefficient K_La, which is a measure of aeration, is computed and its behavior is studied with respect to different variables, keeping other variables constant at that time. Assessment of overall oxygen transfer coefficient of an aeration system is one of the most important factors. Under estimating the oxygen transfer rate results in over designed system, which may be energy intensive and expensive to operate. On the other hand, over estimating the oxygen transfer rate results in inadequate oxygen supply, which in turn, reduces efficiency.

Measurement of overall oxygen transfer coefficient (K_La) :

Various eight types of equations were given by [11], out of these equations; linear fit equation is adopted for mathematical modeling in the present study. Aeration is transfer of air or oxygen in the water. The oxygen transfer in water is governed by Flicks' Law of diffusion and is a liquid film controlled process. [12]

In aeration the rate of oxygen transfer was expressed earlier as

$$dc/dt = K_L.a.(C_s - C_t)$$

Where $K_L.a$ is the rate of oxygen transfer for saturation deficit. Therefore, this is referred as measurement aeration and it forms a good basis of studying the behavior under various variables. This is employed in the studied in the unit of min^{-1} or hr^{-1}.The rate of oxygen transfer equation was converted into

$$C_{(t+h)} = C_t.e^{-K_L.a.h} + C_s(1 - e^{-K_L.a.h})$$

This is comparable to the equation of straight line of the form:

Y= m.X +A

Thus, if a plot is obtained in between $C_{(t+h)}$ and C_t, it would yield a straight line and slope of this line (m) represent the value of $e^{-K_L.a.h}$ from which $K_L.a$ can be calculated. Similarly, the intercept on Y-axis (A) represents the term $C_s(1-e^{-K_L.a.h})$ from which the value of C_s can be known.

Thus it clearly indicates that in order to determine the value of $K_L.a$, it must be carried out at a uniform interval of time. In the present study the curves have been drawn between $C_{(t+h)}$ against C_t and time interval h is taken as 15 minute. The slope of this line is known and the value of overall oxygen transfer coefficient $K_L.a$ is calculated. This method is used for calculation of performance of different aerators. Table 1 represents the $K_L.a$ values computed for various configurations of aerators.

TABLE I

$K_L.a$ VALUES OBTAINED FOR DIFFERENT SPEEDS FOR VARIOUS CONFIGURATIONS OF AERATORS

S.N.	Rotor	Speed	K_La	Power
1	CRWR	36.00	2.51	61.40
2		42.00	2.86	68.00
3		48.00	3.61	82.00
4		60.00	3.78	115.00
5	Brush	36.00	1.61	40.00
6		42.00	2.07	51.00
7		48.00	2.82	55.40
8		60.00	2.94	65.90
9	CFR	36.00	1.36	56.00
10		42.00	2.43	63.00
11		48.00	4.08	80.50
12		60.00	4.33	106.00
13	CBR	36.00	4.15	59.80
14		42.00	6.71	71.00
15		48.00	10.33	73.80
16		60.00	11.50	131.20

Variations in K_La with aerator speed for different aerators:

Plot for variation of K_La with speed for all configurations of aerator is represented in figure (1).

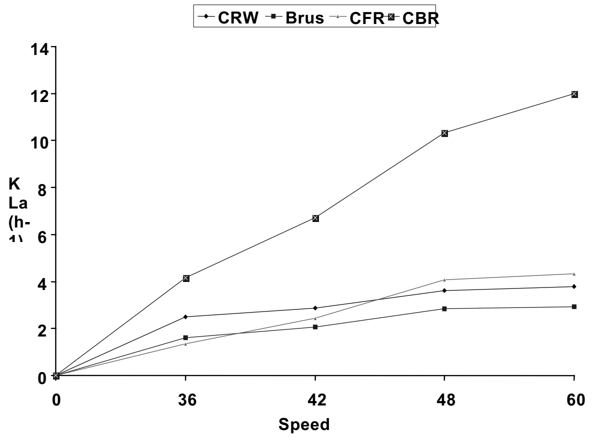

Fig. 1 Variation of over all Oxygen Transfer Coefficient K_La with aerator Speed for different aerators

It is quite evident from figure that the K_La values obtained with CBR aerator at speed ranging from 36 to 60 rpm, are much higher than that of other three aerators. Therefore CBR emerges as a potential aerator out of the other three configurations for any given speed.

Variation of dissolved oxygen with time for different depth of immersion:

In the present study optimization of different values is being done by varying only one parameter at a time and keeping others constant. Hence to evaluate the effect of depth of immersion on D.O concentration for CBR aerator, 48 rpm speed is considered.

Figure (2) shows the variation of increase in D.O concentration against time for CBR aerator. It can be easily identified that the maximum D.O concentration value of 8.2 mg/L can only be achieved by maintaining the 5.5 cm depth of immersion. Further increase or decrease in depth of immersion decreases the D.O concentration.

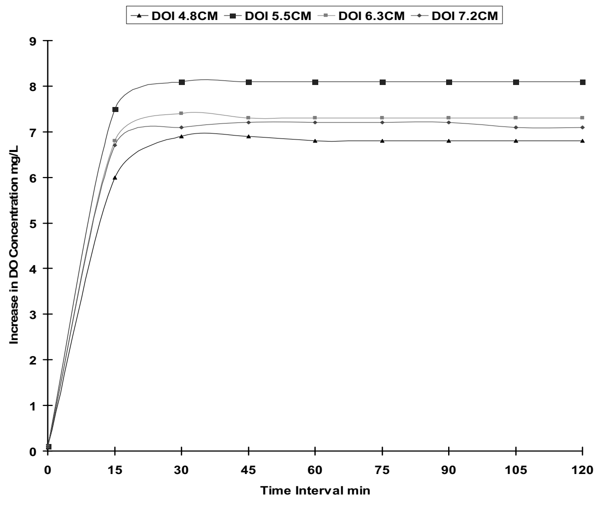

Fig. 2 Variation of Dissolve Oxygen (mg/L) with Time for Different Depth of immersion for CBR Aerator

Influence of depth of immersion on K_La and power (w):

Figure (3) is a plot of depth of immersion with K_La and power, which signifies that with increase in depth of immersion, there is marginal rise in K_La value, but on other hand it suggests that with increase in depth of immersion the power consumption rises sharply, which is obvious because at larger depths the aerator is required to handle large water volume.

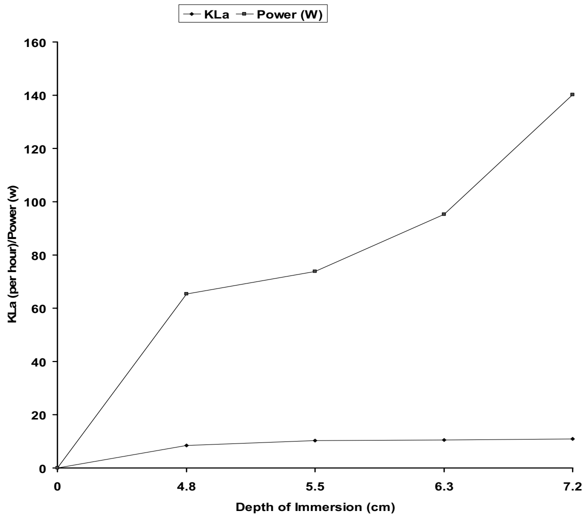

Fig. 3 Influence of Depth of Immersion on Overall Oxygen Transfer Coefficient & Power (W)

Behavior of dissolved oxygen level with time of aeration:

Effect of time of aeration on the dissolved oxygen level with different aerator configurations and at different speeds have been studied from figures (4),(5),(6) and (7). The depth of immersion is kept constant at 5.5 cm for all aerators. In figure (4), the variation of DO with Time for all the aerators at 36 rpm is shown.

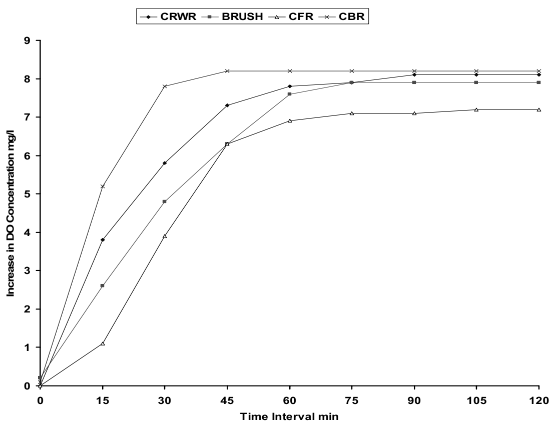

Fig. 4 Variation of Dissolve Oxygen with Time for different Aerators at speed 36 RPM and 5.5 Depth of Immersion

It is observed that the dissolved oxygen level in the aeration tank rises with time, such a rise in D.O. is very high at the beginning but subsequently it attains a value beyond which increase in dissolved oxygen level is very small. It happens because the rate of change of dissolved oxygen concentration is function of saturation deficit. At start, the saturation deficit is high thus causing high rate of change of dissolved oxygen concentration but with increase in aeration time, the saturation deficit decreases, resulting in decrease in the rate of change of dissolved oxygen concentration.

From the figure (7), it can be analyzed that CBR aerator only is capable of reaching maximum saturation value of 8.2 mg/L (90% of saturation value of tap water at standard conditions) and that too just in 45 min. where as the CRWR aerators attains the value of 8.0 mg/L but it takes 90 min to do so. Brush aerator and CFR aerator attains 7.8 and 7.2 mg/L value respectively of DO saturation concentration.

Similar trend is observed with figures (8),(9) and(10) which are plotted for speeds 42, 48 and 60 rpm respectively.

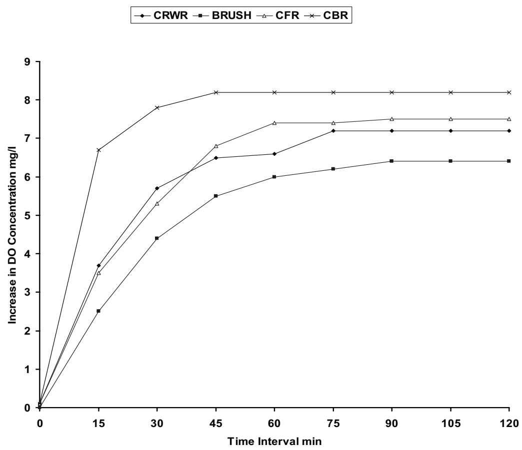

Fig. 5 Variation of Dissolve Oxygen with Time for different Aerators at speed 42 RPM and 5.5 Depth of Immersion

Figure (6) shows that at 48 rpm the dissolved oxygen saturation concentration value of 8.2 mg/L is achieved in 30 min, where as there is no apparent improvement in the saturation values of CRWR and CFR.

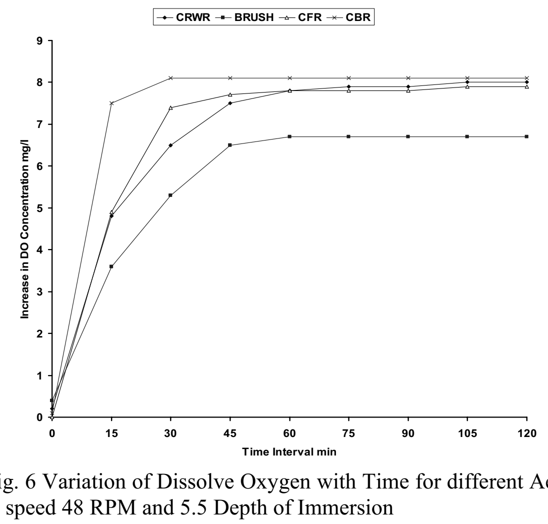

Fig. 6 Variation of Dissolve Oxygen with Time for different Aerators at speed 48 RPM and 5.5 Depth of Immersion

Figure (7), illustrates that the CBR aerator again reaches the value of 8.2 mg/L in 30 min at speed of 60 rpm. CRWR, CFR and Brush aerator attains 80% to 90% of saturation concentration value but time required is higher than 45 min.

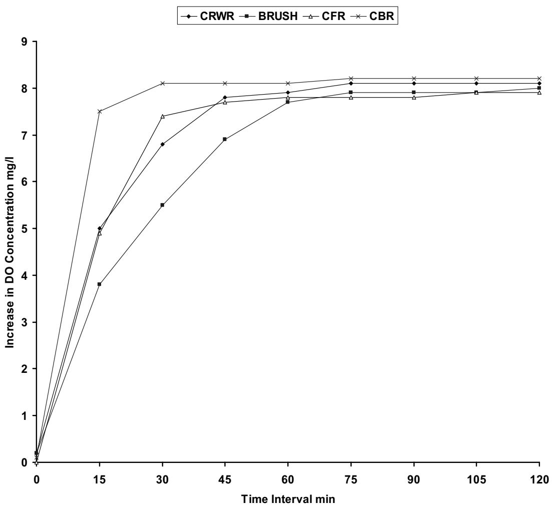

Fig. 7 Variation of Dissolve Oxygen with Time for different Aerators at speed 60 RPM and 5.5 Depth of Immersion

Therefore it can be seen that as the speed increases the time required reaching the maximum dissolved oxygen saturation concentration value decreases. In other words with increase in speed less time is required to attain maximum value of dissolved oxygen saturation concentration.

The CBR aerator, when rotating at 48 and 60 rpm, reaches dissolved oxygen saturation concentration value in 30 minutes; therefore for this parameter also, 48 rpm speed is considered to be optimum.

Variation of aeration efficiency and K_La:

The performance of aerator is better judged by a parameter known as aeration efficiency (AE), which is defined an amount of oxygen transferred per unit power.

Variation of K_La and AE with respect to different types of aerators and speeds:

Figure (8) describes the variation of K_La and AE for all the four types of configurations discussed earlier. It is quite evident from the figure that the maximum value of AE, that is, 2.269 kgO_2/kWh occurs at 48 rpm, 5.5 cm depth of immersion using CBR aerator, when the value of K_La is 10.33 h^{-1}. Till this stage of experimentation the blade tip angle of CBR aerator was maintained at 47°, and all other parameters were optimized.

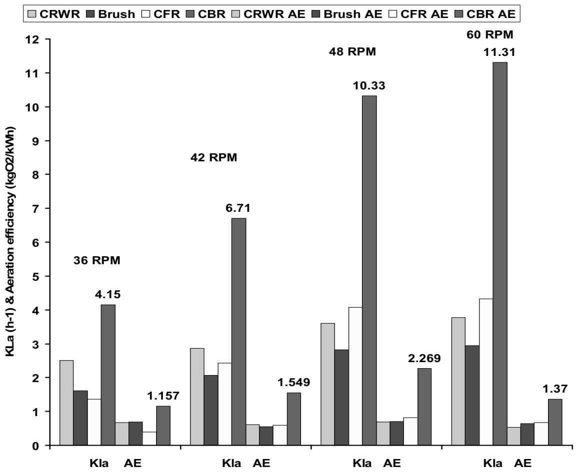

Fig. 8 Variation of $K_La(h^{-1})$ & Aeration Efficiency(kgO_2/kWh) with Rotor Type & Speed of aerator (RPM)

Variation of AE and K_La for different blade tip angles and speed:

Three configurations were developed by changing the blade tip angles (27°, 47° and 60°) and their performance was evaluated for K_La and AE with respect to speed. Each configuration was tested for the aerator speed of 42, 48 and 60 rpm and the plot was obtained. From figure (9) it is observed that at 48 rpm and 47° blade tip angle the optimum value of K_La is observed to be 10.33 h^{-1} for which the CBR aerator recorded the highest value of AE, which is to the tune of 2.269 kgO_2/kWh.

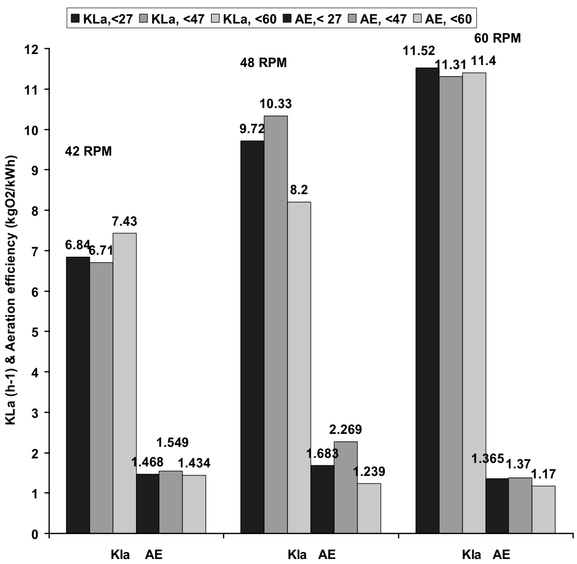

Fig. 9 Variation of $K_La(h^{-1})$ & Aeration Efficiency (kgO_2/kWh) For different blade angles & Speed of aerator(rpm)

This is because of the AE is mainly dependent on power and as stated earlier the power required increases with increase in speed and depth of immersion. From figure it can be seen that even though the values of K_La at 60 rpm and for blade tip angles of 27°, 47° and 60° are more than that of 48 rpm but the power required to attain these K_La values is quite higher. Therefore the AE values for above configuration and 60 rpm speed, decreases drastically to 1.365, 1.37 and 1.17 kgO_2/ kWh respectively as against 1.683, 2.269 and 1.239 kgO_2/kWh when the speed of aerator is maintained at 48 rpm. Performance of CBR aerators with respect to K_La , power and AE for different blade tip angles and speeds is tabulated in Table II.

TABLE-II
PERFORMANCE OF CBR AERATORS W.R.T. K_La , POWER AND A.E. FOR DIFFERENT BLADE ANGLES AND SPEEDS

Sno.	Rotor	Speed	K_La	Power	AE
1	CBR DOI 5.5 27 deg	42.00	6.84	63.05	1.47
2		48.00	9.72	83.60	1.68
3		60.00	11.52	123.40	1.37
4	CBR DOI 5.5 60 deg	42.00	7.43	73.90	1.43
5		48.00	8.20	94.20	1.24
6		60.00	11.40	140.60	1.17
7	CBR DOI 5.547 deg	42.00	6.71	71.00	1.55
8		48.00	10.33	73.80	2.27
9		60.00	11.50	131.20	1.37

Effect of speed on aeration efficiency for CBR aerator:

Figure (10) is the plot between speed and aeration efficiency, which clearly reveals that maximum value of AE is obtained at speed of 48 rpm, 5.5 cm depth of immersion and 47° blade tip angle. Lowest values of AE amongst the three blade angles were recorded for 60°. This is because when the blade angle is at 60°, it handles large amount of water volume as compared to 27° and 47°and because of this the power consumption for this configuration increases, there by decreasing the AE.

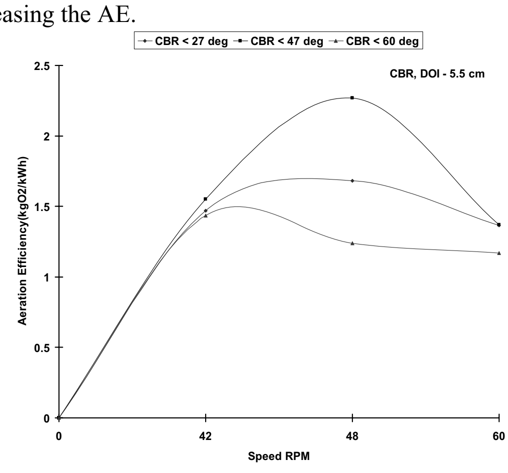

Fig. 10 Effect of Speed on Aeration efficiency for CBR aerator at depth of immersion of 5.5 cm

Table-III reveals that the aeration efficiency of the CBR aerator is quite comparable with the different aerators developed by other researchers.

TABLE III
MAXIMUM AERATION EFFICIENCY FOR TYPICAL AERATORS.[13]

S. N.	Company names/ Reference	Types of Aerator	Aeration Efficiency Kg O_2/kWh
1	Ishikawazima	Horizontal rotor	2.3
2	Kawasaki	Horizontal rotor	2.2
3	Kubota	Horizontal rotor	2.3
4	Kurita	Horizontal rotor	2.4
5	Naskasone.H.	Falling water	2.2
6	Busch et al.(1984)	Paddle wheel	1.3-1.2
7	Ahmad & Boyd (1988)	Paddle wheel	2.9
8	Rummler (1992)	Paddle wheel	1.6
9	Boyd et al.(1988)	Paddle wheel	2.7
10	Colt & Tchobanoglous(1981)	Venturi aerator	1.2-2.4
11	Colt & Tchobanoglous(1981)	Diffused air system	1.2-2.0
12	Stukenberg (1984)	Surface aerator	2.1-1.8
13	Colt & Tchobanoglous(1981)	Low Speed Surface aerator	1.2-2.4
14	Colt & Tchobanoglous(1981)	High speed surface aerator	1.2-2.4
15	Rummler (1992)	Centrifugal surface aerator	1.3
16	Present Study	Horizontal rotor	2.3

Model :

In this paper the attempts are made to correlate the data generated in laboratory and the data calculated by using mathematical model.

In this phenomenon, the author has used two models. From the study of the data generated in laboratory, the attempts are made to identify the dependent and independent variables and by using Buckingham $\boldsymbol{\pi}$ theorem concept, these variables are correlated by best fit mathematical model (BFMM) to study the behavior of CBR.

$$K_L a = 0.000746\left[(N)^{1.76}\left(\frac{h}{D}\right)^{1.03}(\alpha)^{0.03}\right] \tag{1}$$

$$P = 0.0694\left[(N)^{2.06}\left(\frac{h}{D}\right)^{1.14}(\alpha)^{0.19}(K_L a)^{-0.17}\right] \tag{2}$$

Where,
K_La – overall oxygen transfer coefficient min^{-1}.
N – Speed of aerator in rps
h/D – Ratio of depth of immersion to the diameter of aerator.
α - Blade tip angle in degree.
P – Power required in watts (W).

The calculated values using above models yielded good coefficient of determination (R^2) with the experimentally observed values as well as are in good agreement with standard error of estimation. A program in CPP is developed to inter relate the various influencing parameters mentioned above and are solved by multiple linear regression analysis method. Figures (11) and (12) are the plot between experimentally determined values and calculated values from the model formulated for K_La and power respectively.

It has been estimated that the simulation equation (1) and (2) predict the values of K_La and power with an average standard error of estimation of 0.0164 and 7.66 respectively and with R^2 values of 0.979 and 0.989 respectively, when compared with experimentally determined values. Thus equations (1) and (2) are justifiable by taking into consideration all of the experimental errors themselves. Therefore above equations may be used with confidence for predicting the K_La and power (P) and can be considered as design equations for CBR aerator.

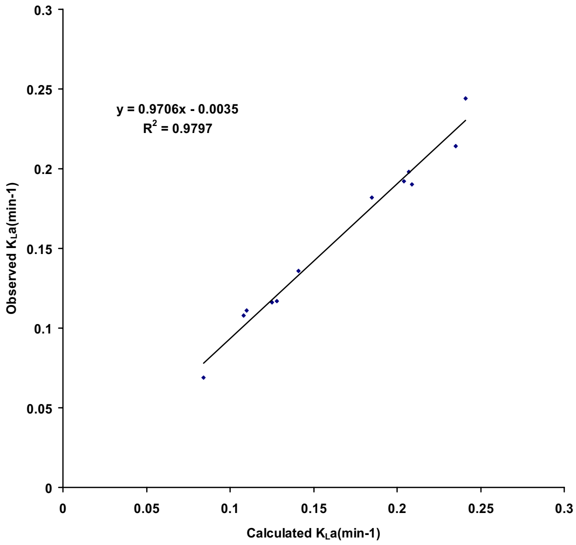

Fig. 11 Relationship between Observed Overall Transfer coefficient (K_La) & Calculated Overall Transfer coefficient (K_La).

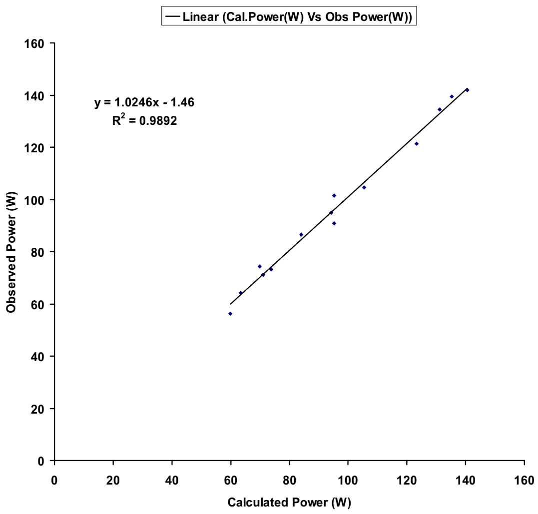

Fig. 12 Relationship between Observed power values (W) & Calculated power values (W)

VII. Conclusion

Considering the influence of various parameters simultaneously, it has been observed that to get the maximum value of overall oxygen transfer coefficient K_La and aeration efficiency, following conclusion are observed to be justified:

(i) From the results, it is clear that the curved blade rotor aerator proved to be a best configuration out of the other configuration tested.

(ii) The value of overall oxygen transfer coefficient K_La and aeration efficiency depends upon the relative depth of immersion of the aerator in the liquid. At 5.5 cm of depth of immersion the value of aeration efficiency (AE) has been obtained maximum.

(iii) The aeration time may be chosen between 30 to 60 min. The lower limits for the case of 5.5 cm depth of immersion, higher speed and for blades tip angle of 47 degree on the rotor. Where as the higher limit is for the case of lower depth of immersion, lower speeds and for blades angles more or less than that of 47 degree.

(iv) The aeration efficiency, which compares the performance of aerators mainly depends on the power consumption of the aerator. In some cases it is found that even though the value of K_La is higher, the aeration efficiency drops drastically. This is mainly because of the increase in power consumption for that particular set up. For example, at 60 rpm, 6.3 depth of immersion, and blade tip angle of 27 degree the value of K_La is found out to be12.87 h^{-1}, but the aeration efficiency drops drastically to 1.385 kgO_2 / kWh. This is mainly because of the power consumption for this configuration, speed and depth of immersion is 135.3 W. As against, at 48 rpm, 5.5 depth of immersion, and blade tip angle of 47 degree the value of K_La is found out to be10.33h^{-1}, but the aeration efficiency increases sharply to 2.269 kgO_2 / kWh, because for this configuration, the power consumption is 73.8 W.

A simplified simulation equations (1) and (2) are developed for CBR, which can be used to calculate the values of K_La and power, for given diameter of aerator(D), depth of immersion (h), blade tip angle (α).

References

[1] Rao, A. R.. "Predication of reaeration rate in square, stirres tanks." J. Environ. Engg. 133(4), 411 – 418. 1999

[2] Metcalf and Eddy Inc. "Waste water Engineering; Treatment disposal and reuse". Tata McGraw Hill. New Delhi, India. American Public Health Association. 2001

[3] Wesner, G.M., Ewing, J. J., Lineck, T.S.,Jr., and 14. Hinrichs, D.J "Energy conservation in municipal wastewater treatment." EPA-130/9-77-011, NTIS No PB81-165391, U.S. EPA Res., Washington, D.C. 1977.

[4] Khadilkar, C.H. "Bulletin on B.O.D. moderator." Central public health research institute, university of Baroda, India.1966.

[5] Boyd, C.E., Watten, B.J. "Aeration systems in Aquacultural." Rev. Aquacultural Sci., 1, 425-472. 1989

[6] Boyd, C.E., "Pond water aeration systems". Aquacultural Eng. 18, 9-40. 1998

[7] Elliott, J.W. "The oxygen requirements of Chinook salmon." Progress. Fish Culturist, 31, 67.1969

[8] APHA, Standard methods for the examination of water and wastewater, 15th Ed., American public Health Association, America Water Works

Association, and Water Pollution Control Federation, Washington D.C. 1980
[9] Moulick, S. Mal, B.C. Bandyopadhyay, S. "Design characteristics of single hub paddle aerator." J. Environ. Engg. 131(8), 1147-1154. 2005.
[10] Cancino, B. "Design of high efficiency surface aerators part2. Rating of surface aerator rotors". Aquacultural Eng. Elsevier., 31, 99-115. 2004.
[11] Fair, G.M., Gayer, J.C., Okun, "Water supply and Waste water disposal, John Wiley & sons, Inc., New York. P. 450.1976
[12] Raj Kumar. "Oxygen transfer by mechanical aeration." M.E thesis, Dept. of Civil Engineering, University of Rurkee, India. 1991.
[13] Nakasone, H., and Ozaki, M. "Oxidation-ditch process using falling water as aerator." J. Environmental Eng., 121(2), 132-139. 1995.

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