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Simulation of Oxygen Transfer Rates in Circular Aeration Tanks

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Experiments were conducted to study the performance of circular and square tank surface aerators on the oxygen transfer coefficient and to a limited extent on power requirements. All the tanks are geometrically similar except for their shapes. They consist of a rotor of diameter, D, fixed with six flat blades rotating with a speed, N, in pure waters of viscosity, υ, at room temperature. A simulation equation to predict the oxygen transfer coefficient, $k = K_La_{20}(\upsilon/g^2)^{1/3}$ for any given dynamic parameter governing the theoretical power per unit volume, $X = N^3D^2/(g^{4/3}\upsilon^{1/3})$ was developed for circular tank aerators. The data on square tank aerators support another such simulation equation developed earlier for square tanks. A comparison of results, while re-aerating the same volume of water in both the shapes of tanks, leads to the interesting conclusion that for a given rotor speed the oxygen transfer rate is substantially more in square tanks than in circular tanks; whereas for a given effective input power to the rotor the oxygen transfer rate is more in circular tanks than in square tanks. This suggests that square tanks are preferred to circular tanks to raise the oxygen concentrations at a faster rate, whereas the circular tanks are advantageous as far as power requirements are concerned.

Key words: **circular surface aerator, square surface aerator, oxygen transfer, scale effects, theoretical power per unit volume parameter, water treatment, aeration, aerator**

Introduction

Aeration is one of the important operations of gas transfer in water and wastewater treatment. The objective of aeration is either the removal of dissolved gases and other volatile substances from water, oxygenation of water, or both. The present study deals with the gas transfer operation of oxygen in water in order to raise the dissolved oxygen (DO) level to sustain the aerobic bacterial activity. The biochemical oxygen demand (BOD) of the effluent will thereby be reduced leading to an improvement of water quality. The devices used for such processes are called aerators. There are many types of aeration devices, such as gravity aerators, spray aerators, diffusers, mechanical aerators, etc. Mechanical surface aerators were chosen for the present study as they provide convenience in operation and maintenance as well as higher efficiency.

A typical surface aerator with six flat blades (used in this study) is shown in Fig. 1. The main component of these surface aerators is an impeller or rotor, to which the six flat blades are fitted. The rotor is rotated to create turbulence in the water body so that aeration takes place through the interface of atmospheric oxygen and the water surface. The rate of oxygen transfer depends on a number of factors including intensity of turbulence, which in turn depends on the speed of rotation, size, shape and number of blades; diameter and immersion depth of the rotor; and size and shape of aeration tank. The physical, chemical and biological characteristics of water are also factors.

It is of interest to study the individual as well as the relative performance of geometrically similar square and circular tank aerators of different sizes on oxygen transfer rates and the corresponding power requirements. The authors aimed to develop an equation to simulate oxygen transfer rates in circular tanks for design purposes. Power measurements were also made to a limited extent to compare and contrast the two shapes of tanks on oxygen transfer rates.

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Theory and Background Information

The Oxygen Transfer Coefficient

The relevant theory and background information is available in many standard publications (Horvath 1984; Marais 1975; Banks et al. 1983; Rao 1999, etc.). Salient features of the oxygen transfer coefficient are explained here. According to the well-known two-film theory (Manual 1988; Droste 1997), mass transfer occurs through the gas and liquid interface until a dynamic equilibrium is established. An equation governing such a mass transfer in terms of dissolved oxygen (DO) concentrations is generally expressed in terms of an oxygen transfer coefficient, K_La_T, at a temperature of T (°C) of the liquid, as:

$$K_La_T = [\ln(C_s - C_0) - \ln(C_s - C_t)]/t \qquad (1)$$

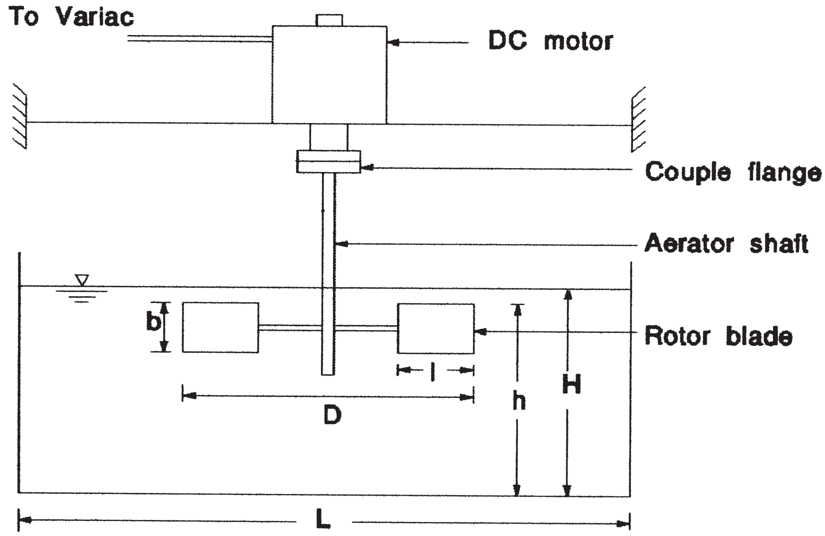

Fig. 1. Schematic diagram of aerator.

where C_s is the saturation concentration of DO in the liquid, C_0 and C_t are DO concentrations at times t = 0 and t = t, respectively, ln represents natural logarithm of the given variables. The concentrations C_s, C_0 and C_t are usually expressed in parts per million (ppm). The value of K_La_T can be obtained as the slope of the linear plot between $\ln(C_s - C_t)$ and the corresponding time, t. The value of K_La_T thus obtained can be corrected for a temperature other than the standard temperature of 20°C as K_La_{20}, using the Vant-Hoff Arrhenins equation (Manual 1988) as:

$$K_La_T = K_La_{20}\,\theta^{(T-20)} \quad (2)$$

where θ is the temperature coefficient 1.024 for pure water.

Dimensional Analysis

Dimensional analysis of various geometric, dynamic and physical variables play a significant role in the simulation of oxygen transfer in different sizes of tanks and under varying dynamic conditions. Many investigators such as Rushton (1951), Schmidtke and Horvath (1977), Banks et al. (1983) and Rao (1999) have successfully made use of the theory of dimensional analysis in their studies on the aeration process. According to Rao (1999), the functional relationship relating various non-dimensional variables, which can influence the oxygen transfer coefficient, for a given shape of an aeration tank (as shown in Fig.1), with a rotor of diameter, D, fitted with six blades as shown in Fig.1, is given by:

$$k = f(\sqrt{A}/D, H/D, l/D, b/D, h/D, X) \quad (3)$$

where k is the non-dimensional oxygen transfer coefficient, expressed as:

$$k = K_La_{20}(\upsilon/g^2)^{1/3} \quad (4)$$

and X is a non-dimensional dynamic parameter governing the theoretical power per unit volume expressed as:

$$X = N^3D^2/(g^{4/3}\upsilon^{1/3}) = F^{4/3}R^{1/3} \quad (5)$$

where F and R are Froude and Reynolds numbers, respectively, defined as $F = N^2D/g$ and $R = ND^2/\upsilon$; N is the rotational speed of the rotor of diameter, D, fitted with six flat blades of dimensions b and l; h is the distance between the top of the blades and the horizontal floor of the tank; and A is the cross-sectional area of the tank in which water depth is H. The kinematic viscosity of water is υ, and g is the acceleration due to gravity. The first five non-dimensional variables in equation 3 represent the "geometric similarity" of the system and the last one represents the "dynamic similarity."

Geometric Similarity

An optimal solution to the geometrical similarity was suggested by Udaya Simha et al. (1991) for square tanks by varying √A/D, H/D, l/D, b/D and h/D to a great extent in their experiments. The following are the values for maximum K_La_{20}, for any rotational speed, N, of the rotor:

$$\sqrt{A}/D = 2.88,\ H/D = 1.0,\ l/D = 0.3,\ b/D = 0.24 \text{ and } h/H = 0.94 \quad (6)$$

In order to compare and contrast the relative performance of both shapes of circular and square tank aerators, the geometric similarity as mentioned in equation 6 is followed in both of the shapes of tanks in the present experiments.

Dynamic Similarity

When the geometric similarity conditions, as per equation 6, are maintained, the functional relationship represented by equation 3 will be reduced to a function of only dynamic similarity as:

$$k = f(X) \tag{7}$$

An explicit form of equation 7 for square tanks, was developed by Rao (1999) by conducting experiments in six geometrically similar (as per equation 6) square tanks of linear dimensions varying from 305 to 1000 mm. A simulation equation thus obtained is given as follows.

$$k_s = \{17.32 \exp[-0.3/X^{1.05}] + 3.68 - 0.925\exp[-750(X - 0.057)^2]\}10^{-6}\sqrt{X} \tag{8}$$

The above simulation equation is verified with the present experiments on square tanks. Thus, the concept based on "theoretical power per unit volume expressed in terms of X and the oxygen transfer coefficient, k, are uniquely related" has been re-established. Hence the traditional criteria of simulation based on Reynolds and Froude numbers cannot be followed to simulate oxygen transfer rates. It is, however, possible to simulate the same only with X, which in turn depends on both Froude and Reynolds numbers as expressed in equation 5.

Experiments

Experimental Setup

A schematic diagram of the experimental setup is shown in Fig. 1 and an overview of the different types of experiments conducted is given in Table 1. In all, three circular tanks of diameters 463, 812 and 1128 mm and three corresponding square tanks (of same cross-sectional area) of respective linear dimensions, L = 410, 720 and 1000 mm, were tested under laboratory conditions. The significance of these dimensions is such that in each of the corresponding tanks of square and circular tanks the other linear dimensions, such as rotor diameter, D, blade sizes b and l, water depth, H, and the distance between the top of the blade to the horizontal bottom of the tank, h, are kept the same as per the geometric similarity given in equation 6, and they are listed in Table 1. The geometric scaling of the tanks thus followed was suggested to be optimal (Udaya Simha et al. 1991) in producing maximum K_La_{20} in square tanks and hence the experiments were conducted by following the similar dimensions in every tank of both the shapes to have a comparative study of circular and square tanks.

Types of Experiments

Two types of experiments, Type A and Type B, were conducted. In Type A experiments, measurements were carried out on oxygen transfer coefficient, k, for any value of X in all six tanks (Table 1) to solve the explicit form of equation 7, or in other words, to develop a simulation equation of circular tanks. Type A experiments with square tanks were conducted to verify equation 8, which is a simulation equation of square tanks developed earlier by Rao (1999). The Type B experiments were carried out exclusively to measure effective power input, P, to the rotor for given values of X in a pair of medium-sized tanks. One of the tanks was square and the other one was circular, both having the same cross-sectional areas of 0.5184 m^2. This was done to evaluate the relative power requirements of square and circular tanks.

Determination of K_La_{20}

Tap water at room temperature, free from contamination, was used in all experiments. Initially, water was filled in the aeration tank and deoxygenated completely by adding required amounts of sodium sulfite and cobalt chloride while thoroughly mixing the chemicals in the water. The deoxygenated water then was re-aerated by rotating the rotor with constant speeds of rotation, N.

TABLE 1. Range of experimental variables[a]

		C/S area	*Length, L or diameter, d*	*Rotor diameter*		*Water depth*	*Immersion height*	*Blade dimensions*		*Rotor speed*		*No. of experiments*	
Sl. No.	*Tank shape*	*A (m²)*	*L (mm)*	*d (mm)*	*D (mm)*	*H (mm)*	*h (mm)*	*l (mm)*	*b (mm)*	*Min. (rpm)*	*Max. (rpm)*	*Type A*	*Type B*
1	Circular	1.0	—	1128	347	347	326	104	83	14	148	32	—
2	Square	1.0	1000	—	347	347	326	104	83	30	110	09	—
3	Circular	0.5184	—	812	250	250	235	75	60	14	247	39	19
4	Square	0.5184	720	—	250	250	235	75	60	58	161	10	21
5	Circular	0.1681	—	463	142	142	134	43	34	143	246	10	—
6	Square	0.1681	410	—	142	142	134	43	34	151	262	10	—

[a]Note: Geometric similarity followed is as per equation 6. Temperature variation of water is T = 20–29°C; number of flat blades fixed to rotor are 6. Type A experiments are conducted in all tanks to find k for a given X, then used to develop a simulation equation between X and k. Type B experiments are conducted exclusively to determine power requirements for a given X while the rotor is rotating in the same volume of water in both circular and square tank aerators.

The speed of rotation was set to a desired value by using a variac connected to the D.C. motor.

To verify and ensure uniform mixing throughout the depth of water in the tank, the DO concentrations were measured at various depths and at regular intervals. The values of such DO concentrations remained steady at any given time in the water body, which confirmed uniform mixing everywhere in the water body, and there were no spatial (along the depth) concentration gradients for DO as shown in Table 2.

The DO concentrations were measured by a commercially available Lutron Dissolved Oxygen meter, which displays the concentration of DO and temperature of water. The DO meter was calibrated with the modified Winkler's method (Indian Standards 1964; Standard Methods 1985). The following method (Rao 1999) was adapted to estimate the saturated value of oxygen concentration, C_s, from the experimental data. To the known values of DO measurements in terms of C_t at regular intervals of time, t, (including the known value of C_0 at t = 0) a line was fitted, by linear regression analysis of equation 1, between the logarithm of $(C_s - C_t)$ and t, by assuming different but appropriate values of C_s such that the regression that gives the minimum standard error of estimate was taken and thus the values of K_La_T and C_s were obtained simultaneously. The values of K_La_{20} were computed using equation 2 with $\theta = 1.024$ as per the standards for pure water (Manual 1988). The values of K_La_{20} were thus determined for different rotational rotor speeds, N, in all geometrically similar tanks. The ranges of data of different variables and parameters covered in the present experiments are listed in Table 1.

Power Measurements

Effective power requirements were estimated with an electrical method by measuring input voltages and currents and armature resistance by the following equation (Cook and Carr 1947).

$$P = I_2V_2 - I_1V_1 - R_a(I_2^2 - I_1^2) \quad (9)$$

TABLE 2. Values of K_La_{20} at different depthsa

Depth from the water surface (mm)	*Values of K_La_{20} (per minute) for rotor speeds, N (rpm)*			
	45 rpm	*80 rpm*	*110 rpm*	*118 rpm*
10	0.016	0.049	0.179	0.191
20	0.017	0.048	0.180	0.193
50	0.017	0.049	0.180	0.193
100	0.016	0.047	0.180	0.192
200	0.015	0.047	0.179	0.192

[a]Circular tank, d = 812 mm, D = 250 mm, H = 250 mm.

where P is the effective power input to the rotor shaft in watts; I_1 and V_1 are current (amperes) and voltage (volts) under no-load conditions, i.e., when the rotor is rotating freely in air at a constant speed, N; and I_2 and V_2 are the respective values under loading conditions, i.e., when the rotor is rotating in water at the same speed, N, and R_a is the armature resistance in ohms. It may be noted that equation 9 represents the effective power input to the rotor as the difference between powers under loading condition, i.e., $I_2V_2 - R_aI_2^2$ and under no-load condition, i.e., $I_1V_1 - R_aI_1^2$. Thus, by doing so, it is expected to eliminate inherent frictional and other internal losses in the given electrical direct current motor system, thereby leading to a better estimate of effective power input to the rotor.

Data Analysis and Discussion

Simulation of Oxygen Transfer

Type A experiments have two objectives. The first is to develop a simulation equation relating oxygen transfer coefficient, k, and a parameter governing the theoretical power per unit volume, X, for circular tanks, thus solving the explicit form of equation 7. The second objective is to verify the simulation equation 8 of square tanks. Accordingly, a plot between $X = F^{4/3}R^{1/3}$ and $k = K_La_{20}(\upsilon/g^2)^{1/3}$ which contains all the experimental data is shown in Fig. 2. It is observed that the entire set of data points of all sizes of circular and square tanks fall closely on their respective curves, suggesting a very good correlation between k and X, as long as the geometric similarity of the tanks is maintained. Thus, it is clearly established that the oxygen transfer coefficient, k_c, in circular tanks is uniquely related to the parameter governing theoretical power per unit volume, X, irrespective of the size of a tank. In Fig. 2, the following equation fits reasonably well for the entire range of data points of circular tanks.

$$k_c = \{10.45 \exp[-4.5/X] + 2.45 - 0.7\exp[-5(X - 0.35)^2]\}10^{-6}\sqrt{X} \quad (10)$$

Thus, equation 10 may be considered as a simulation equation for circular surface aerators, which determines the oxygen transfer coefficient, k_c, for a given dynamic parameter, X, governing theoretical power per unit volume.

It can be seen from Fig. 2 that all the present experimental data on square tanks falls quite satisfactorily on the curve drawn from simulation equation 8, thus this equation is verified. Therefore, the concept of theoretical power per unit volume is confirmed quantitatively to simulate oxygen transfer rates in both circular and square tank aerators, however with two different simulation equations, 10 and 8, respectively.

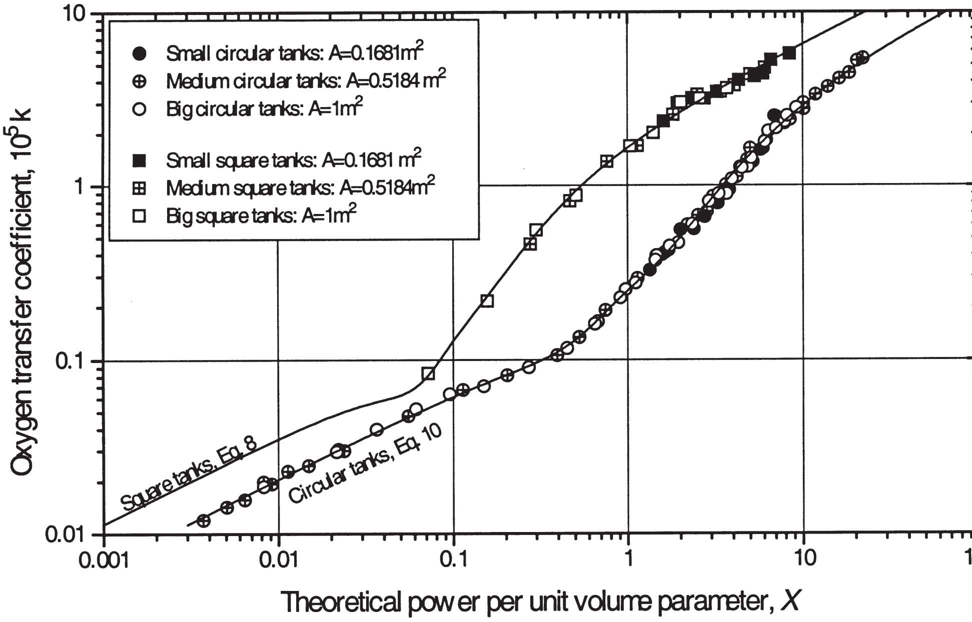

Fig. 2. Simulation of oxygen transfer in circular tanks along with square tanks.

Comparison of Simulation Equations 8 and 10

The relative performance of circular and square tank aerators on oxygen transfer parameter, k, for a given X is shown in Fig. 3, which is based on equations 8 and 10. An important feature of Fig. 3 is such that for any given X, the oxygen transfer coefficient, k_s, of square tanks is always more than oxygen transfer coefficient, k_c, of circular tanks. Thus the ratio k_s/k_c is always greater than one. It may be attributed to the fact that for a given rotational speed of rotor there could be relatively more surface turbulence in square tanks due to sharp corners whereas it is less in circular tanks. As turbulence intensity increases one can expect more oxygen transfer, hence k_s is always more than k_c.

The other characteristic features of the curve shown in Fig. 3 are as follows. The ratio k_s/k_c gradually decreases as the value of X increases up to a value of $X \cong 0.053$, at which it attains a minimum value of $k_s/k_c \cong 1.4$. It is of interest to mention that the slope of the simulation curve of square tanks on log-log scales (Rao 1999), as shown in Fig. 2, is such that it is the min-

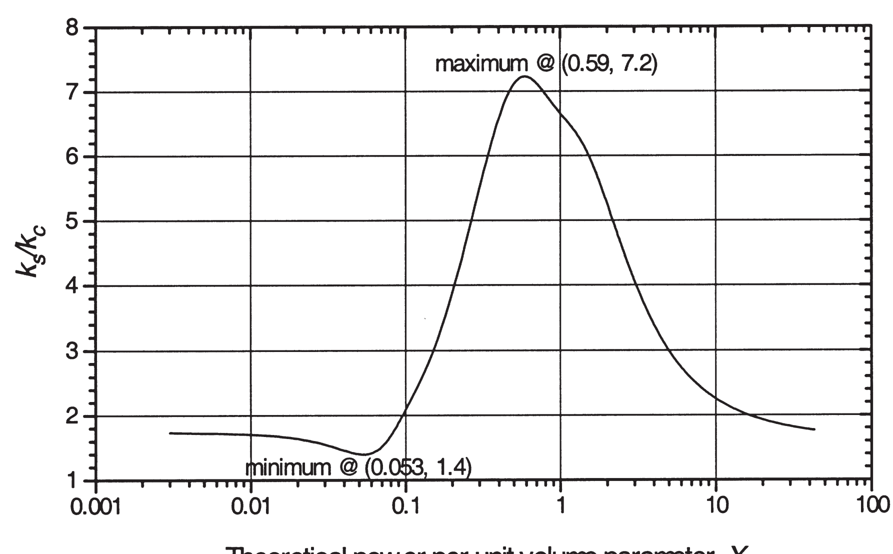

Fig. 3. Relative performance of circular and square tank aerators on oxygen transfer parameter, k, for any given X.

imum at around the value of X = 0.054. Furthermore, as X increases, the value of k_s/k_c increases and reaches the maximum value of about 7.2 at X ≅ 0.59. The value of k_s/k_c decreases again after attaining this maximum value with the increase in value of X. Thus, it may be said that the value of the rate of oxygen transfer for square tanks can be 7.2 times higher than the value of oxygen transfer for circular tanks under similar conditions. It is of practical significance to note that square tanks are preferred to achieve desired levels of oxygen concentrations at a much faster rate than circular tanks. However it is of interest to estimate the power requirements before making a decision on which shape of tank is really preferred and such a point is discussed in the next section.

Effective Power Input

In Type B experiments, effective input power, P, is estimated (as explained earlier in this paper) for a given X in one square tank and the other one is circular such that both the tanks are of the same cross-sectional area, A = 0.5184 m^2 and contain the same volume of water. Both tanks are geometrically similar except for their shape. Thus, such a type of experiment would facilitate a direct comparison of actual power requirements, at least qualitatively, in both shapes of tanks. Accordingly, Fig. 4 shows the plot between effective input power per unit volume of water, P/V, and the corresponding oxygen transfer coefficient, k. From Fig. 4, one can come to an important conclusion that for a given value of power, the oxygen transfer rate is higher in a circular tank than in a square tank while aerating the same volume of water. While comparing Fig. 2 and 4 it is clear that for a given X the value of k is higher in a square tank than in a circular tank (Fig. 2). Such an observation is reversed in the case of power requirements that for a given power the value of k is more in a circular tank than in a square tank (Fig. 4) while aerating the same volume of water in both shapes of tanks.

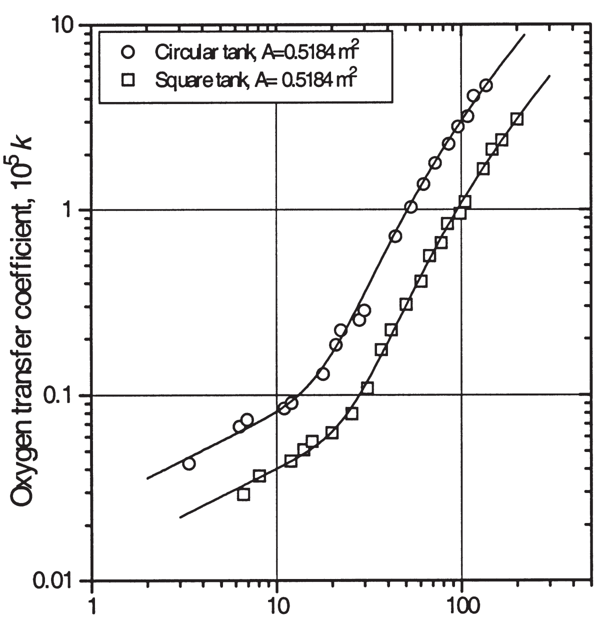

Fig. 4. Power requirements to aerate same volume of water in circular and square tank aerators.

The ratio k_c/k_s is plotted with P/V in Fig. 5 to demonstrate the relative performance of both shapes of tanks. The characteristic features of the curve shown there are as follows. The ratio k_c/k_s is always greater than or equal to a value close to 2 and attains a maximum value of about 3.3 at about P/V = 40 Watts/m^3. Thus, one can conclude that circular tanks require less power than square tanks to achieve the same value of oxygen transfer coefficient, k, while aerating the same volume of water. More experiments on power measurements in different sized geometrically similar tanks are needed to develop a simulation equation relating the oxygen transfer coefficient and the corresponding input or actual power requirements.

Based on simulation equations 8 and 10 as well as Fig. 2 and 3, it is established that for a given X, the oxygen transfer rate is higher in square tanks than in circular tanks. Figures 4 and 5 show that for a given input power the oxygen transfer rate is higher in a circular tank than in square tank. It is worthwhile to study, at least qualitatively, energy requirements to determine which shape of tank is more energy efficient while aerating a given volume of water in both tank shapes.

Application of Results

Example. Compare and contrast the performance of square and circular tank aerators to re-aerate 1.296 m^3 of water at X = 0.1. The rotor is rotated at a constant speed until DO concentration, C_t, attains 80% of the saturation value. Assume the initial DO concentration, C_0 = 0 and water temperature, T = 25°C. Also, find the power and energy requirements.

Solution

Step 1. As per geometric similarity given in equation 6, $\sqrt{A}/D$ = 2.88 and H/D = 1. Volume V = AD = AH = 129,600 cm^3. Hence, A equals the required size of the tank, having a cross-sectional area A = 5184 cm^2. Therefore, the required size of a square tank of linear dimension, L = 72 cm and a circular tank of diameter d = 81.24 cm. The other linear dimensions of the aerator that are to be maintained are given in Table 1 for both square and circular tanks of cross-sectional area of 0.5184 m^2. The rotational speed, N ≅ 42 rpm in both the tanks, which can be worked out from equation 5 for X = 0.1 and by taking, $\upsilon = 0.887 \times 10^{-6}$ at 25°C and g = 9.80665 m^2/s.

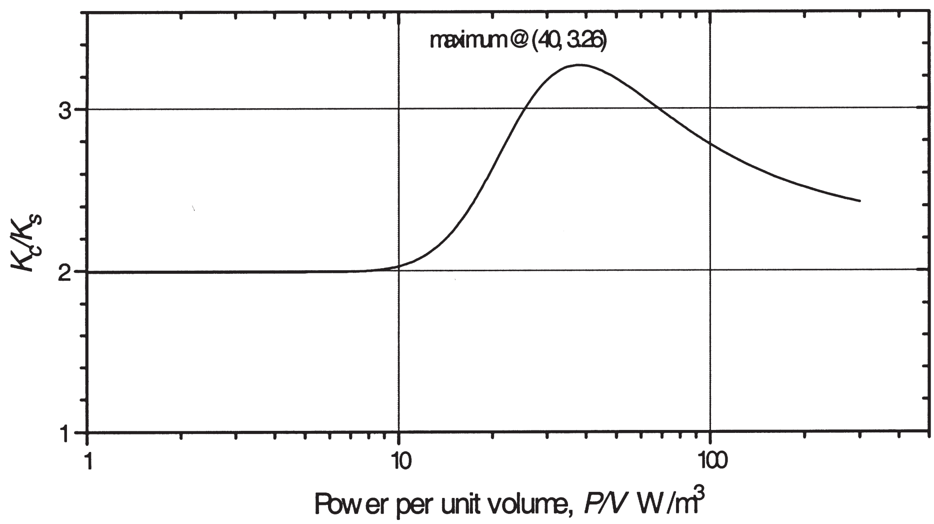

Fig. 5. Relative performance of circular and square tank aerators on oxygen transfer coefficient, k, for any given input power per unit volume.

Step 2. As per simulation equations 8 and 10 the values of oxygen transfer coefficient, k at X = 0.1, for square and circular aerators are obtained as: $k_s = 0.1279 \times 10^{-5}$ and $k_c = 0.0612 \times 10^{-5}$, respectively. Thus for a given speed, k_s is more than k_c.

Step 3. From equation 4, K_La_{20} for square and circular tanks is 61×10^{-5} and 29.2×10^{-5} per second, respectively (by taking $\upsilon = 0.887 \times 10^{-6}$ at 25°C and g = 9.80665 m^2/s, respectively). From equation 2, the respective values of K_La_T at 25°C are 68.7×10^{-5} and 32.9×10^{-5} per second.

Step 4. Time, t, required to reach 80% saturation value ($C_t/C_s = 0.8$) from an initial concentration of zero ($C_0 = 0$) can be worked out from equation 1 and is $t_s = 2343$ and $t_c = 4898$ seconds, respectively, for square and circular tanks. These values indicate that for a given X (or rotor speed, N, for a given size of tank) oxygen transfer rate is faster in square tanks than in circular tanks.

Step 5. By knowing k_s and k_c, the corresponding values of power per unit volume can be obtained from Fig. 4 as $(P/V)_s = 32.3$ and $(P/V)_c = 5.8$ watts per m^3 for square and circular tanks, respectively. The effective energy consumed per unit volume of water, E = (t/3600)(P/V) watt-hours. Thus the energy consumption in square and circular tanks is $E_s = 2343 \times 32.3/3600 = 21.02$ watt-hours/m^3 and $E_c = 4898 \times 5.8/3600 = 8.21$ watt-hours/m^3, respectively, and the ratio $E_s/E_c = 2.66$. Thus energy savings by using circular tanks compared to square tanks to aerate the same volume of water of 0.1296 m^3 is (21.88 - 8.21)/21.88 = 62.5%, which is a substantial savings.

Step 6. A parameter, ξ, may be introduced to judge which shape of tank is better for aeration purposes, as: $\xi = E/k$. The smaller the value of ξ, the better the tank shape. Therefore, the values of such a parameter for square and circular tanks are $\xi_s = 21.02/(0.1279 \times 10^{-5}) = 164 \times 10^{-5}$ watt-hours/m^3 and $\xi_c = 7.89/(0.0612 \times 10^{-5}) = 129 \times 10^{-5}$ watt-hours/m^3, respectively. Thus, circular tanks are better than square tanks because ξ_c is less than ξ_s by about 27% (because $\xi_s/\xi_c = 1.27$).

Conclusions

1. A simulation criterion for oxygen transfer based on the concept of theoretical power per unit volume is found to be valid in circular tank surface aerators also. Accordingly, a simulation equation correlating uniquely the oxygen transfer coefficient, k, and a dynamic parameter, X, governing the theoretical power per unit volume is developed for geometrically similar circular tanks. A similar simulation equation relating k and X developed earlier for square tanks under the same geometric similarity in a previous study, is verified by conducting additional experiments in square tanks as well.
2. From such simulation equations it is found that for a given X the value of k is always more in square tanks than in circular tanks. Thus, while under the re-aeration process, it is established that DO concentrations can be increased at a much faster rate in square tanks than in circular tanks while re-aerating the same volume of water in both shapes of tanks which are geometrically similar (except the shape) and under the same rotor speeds.
3. Power measurements, which are made only to a limited extent, present the interesting conclusions that

for a given effective input power to the aerator oxygen transfer coefficient, k, is substantially higher in circular tanks than in square tanks. In other words, the power requirement to achieve the same k in a given volume of water, is higher in square tanks than in circular tanks.

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Notations

A	Cross-sectional area of an aeration tank (L^2).
B	Width of the blade (L).
C_0	Initial concentration of dissolved oxygen at time t = 0 (ppm).
C_s	Saturation value of dissolved oxygen at test conditions (ppm).
C_t	Concentration of dissolved oxygen at any time, t (ppm).
d	Diameter of the circular tank (L).
D	Diameter of the rotor (L).
E	Effective energy per unit volume used by the aerator, watt-hours/m^3 (ML^2/T^2).
E_c, E_s	Effective energy in circular and square tank aerators (ML^2/T^2).
$F = N^2D/g$	Froude number.
$g = 9.80665$ m/s^2	Acceleration due to gravity (L/T^2).
h	Distance between top of the blades and horizontal floor of the tank (L).
H	Depth of water in an aeration tank (L).
I_1, I_2	Currents in amperes under no-load and loading conditions, respectively.
$k = K_La_{20}(\upsilon/g^2)^{1/3}$	Non-dimensional oxygen transfer coefficient.
k_c	Non-dimensional oxygen transfer coefficient for circular tanks.
k_s	Non-dimensional oxygen transfer coefficient for square tanks.
K_La_{20}	Overall oxygen transfer coefficient at 20°C.
K_La_T	Overall oxygen transfer coefficient at room temperature water, T (°C).
l	Length of the blade (L).
L	Size of square tank (L).
N	Rotational speed of the rotor with blades (1/T).
P	Effective power input to the rotor (ML^2/T^3).
$R = ND^2/\upsilon$	Reynolds number.
R_a	Armature resistance in ohms.
T	Time of rotation/aeration (T).
t_c, t_s	Time of rotation/aeration in circular and square tanks, respectively (T).
T	Temperature of water in degrees centigrade.
V	Volume of water in the aeration tank (L^3).
V_1, V_2	Voltage in volts under no-load and loading conditions.
$X = N^3D^2/(g^{4/3}\upsilon^{1/3}) = F^{4/3}R^{1/3}$	Theoretical power per unit volume parameter.
$\theta = 1.024$	Constant for pure water used in equation 2.
υ	Kinematic viscosity of water (M^2/T).
$\xi = E/k$	A parameter used to judge which shape of tank is better.
$\xi_c = E_c/k_c$	For circular tanks (ML^2/T^2).
$\xi_s = E_s/k_s$	For square tanks (ML^2/T^2).