INFLUENCE OF THROAT HOLE PARAMETERS ON THE PERFORMANCE OF VENTURI AERATOR

Anamika Yadav[1*], Sudipto Sarkar[3], Avinash Kumar[2]

Department of Agricultural Engineering, Triguna Sen School of Technology, Assam University, Silchar, Assam, (India)

ABSTRACT

Oxygen plays a crucial role on the growth and production of aquatic organisms. Dissolved oxygen (DO) deficiency can directly affect feed consumption and metabolism in fish, as well as environmental conditions prevailing in the aquatic body. Artificial aeration using aerators have been found to be effective in increasing the DO concentration in water by entraining air bubbles and are also helpful in removing unwanted dissolved gases such as carbon dioxide, volatile organic chemical, etc. The present paper describes the effect of different throat air hole positions on the performance of aerator in aeration of water using venturi device. Especially the effect of varying the number, position, and status of the air hole is investigated. A venturi creates pressure differential that forms a vacuum (air suction) on air hole as per the Bernoulli's principle. The maximum DO concentration accomplished by using different rpm at 10 mm throat length. At higher discharge (higher rpm) the average rate of diffusion was more than that of at lower discharge (lower rpm). The standard oxygen transfer rate and power consumption increases with increasing discharge rate. It can be seen from overall observations that the venturi aeration might contribute significantly to air entrainment and aeration efficiency.

Keywords: Aeration, Venturi, Dissolve Oxygen, Aeration Efficiency, Oxygen Transfer.

I. INTRODUCTION

The various physico-chemical processes occurring in the aquatic environment are dependent on the amount of dissolved oxygen (DO) present in water. The depletion in the DO can be compensated by the artificial addition of DO by the use of aerators [1]. Aerators are the most common practical solution to improve the water quality for human use as well as to maintain the health of an aquatic body in terms of DO concentration [2]. Aerator increases the contact area between air and water, thus enhancing the oxygen transfer and simultaneously provides for water circulation which prevents the stratification in the water body [3]. These studies were carried out and authenticated by various researchers such as [4]. Baylar and Wilhelms et al. [5], Chanson [6], Ervine [7], Baylar and Emiroglu [8] and Emiroglu and Baylar [9], Venturi aeration is a popular method to increase the DO level in water treatment. The venturi consists of three parts converging section, throat section and finally a diverging section. Venturi creates a pressure differential in form of negative pressure at the air holes of venturi tube based on the Bernoulli's principle [10]. These tubes are highly efficient, requiring less than 20% differential to initiate suction. The operation of a venturi initiates when the fluid such as water enters through the venturi inlet, it is constricted in the converging section till the fluid reaches the throat section. By the time the fluid reaches the throat portion of the venturi, reduction in the flow cross-section increases the velocity thereby reducing the pressure thus resulting in a pressure differential. This pressure drop enables air to be sucked through the air hole and is dynamically entrained into the flowing stream of fluid.

Venturi has been widely used in air quality studies and other field for accurate gas flow rate control [11]. Ozkan et al. [12] concluded that the air and liquid injection rates vary with the pressure differential across the venturi. Ozkan et al. [13] studied the experimental investigation to the effects of inlet and throat diameters of venturi tube, pipe length downstream of venturi tube, flow velocity at inlet portion of venturi tube on the air entrainment rate and the aeration efficiency. Boyd and Ahmad [14] compiled standard oxygen transfer rate (SOTR) and standard aeration efficiency (SAE) values for a variety of aerators used in pond aquaculture. Ghomi et al. [15] observed that by decreasing the nozzle diameter from 20 to 14 mm, SAE value is significantly increased.
This paper studies the performance of a fabricated venturi aerator for different throat hole positions by evaluation of SOTR and SAE.

II. MATERIALS AND METHODS

In order to carry out the study, fabrication of a venturi device was done having three different sections converging, throat and diverging. The converging and diverging sections of the aerator were of same length i.e. 100 mm and were connected with a throat portion of 10 mm. The venturi was fabricated using aluminium of 5 mm thickness and holes of 1 mm were drilled in the throat section. The study was carried out for individual holes when rest of the holes were kept closed. The distance of a particular hole under consideration from the starting of the throat section was termed as the effective length of the hole. Details of the venturi tube are shown in Table 1 and Fig. 1.

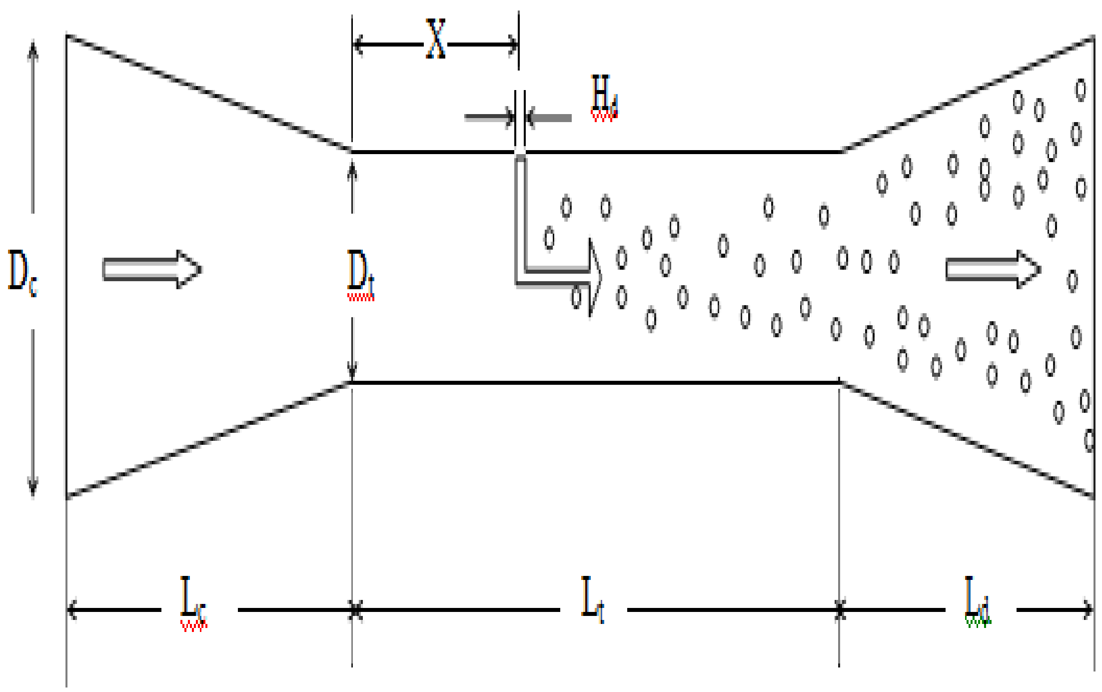

figure1: Geometric Parameters of the fabricated venture table : Details of the Venturi detail

S. No.	Notations	Details		Dimensions (mm)
1.	D_c	Diameter of converging section		30
2.	D_t	Diameter of throat section		10
3.	L_c	Converging length		100
4.	L_t	Throat length		10
5.	L_d	Diverging length		100
6.	H_d	Hole diameter		1
7.	X	Effective length	Hole 1	3
			Hole 2	7
			Hole 1´	2
			Hole 2´	5

The study was conducted using the experimental setup in the Laboratory of Department of Agricultural Engineering, Assam University, Silchar, Assam. The setup consisted of an DC electric motor coupled with a centrifugal pump, storage tank, collecting tank and pipe fittings for closed loop water circulation as shown in Fig. 3.

The setup also consists of a storage tank of dimension 90 cm×55 cm×45 cm (220 l) and a collecting tank with 60 cm×35 cm×45 cm (94 l) connected through pipes. A Centrifugal pump coupled with direct current (DC) motor re-circulates the water from the storage tank through the venturi and back to the storage tank. DC motor's rotations were controlled by DC voltage regulator so as to regulate the discharge. Each experiment was carried by filling the storage tank with tap water and adding 10 mg/l of Na_2SO_3 and 0.1 mg/l of $CoCl_2$ to bring DO concentration to 0 mg/l. When DO reached to 0 mg/l, the experiment is started and water is passed through the venturi. The DO and temperature measurements of storage tank were taken using a calibrated portable YSI Pro ODO DO meter. DO was monitored up to when it reached at 80% saturation level at room temperature. Water was continuously supplied at the top and flows through the venturi. When the water flows down through the aerator only one hole is kept open and rest of the holes are blocked by a water resistant tape.

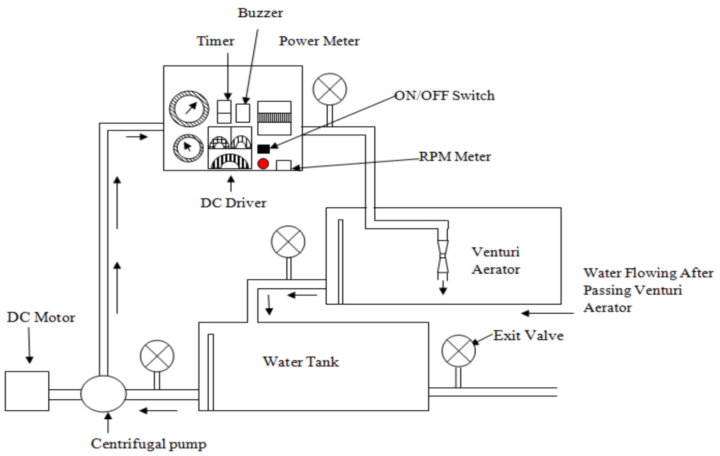

Figure 2: Experimental Setup

The performance evaluation was carried out by altering the at different discharge rates by varying the rotational speed of the motor. The value of mass transfer coefficient (K_La) can be obtained by using a semi logarithmic plot of $ln(C_s-C_t)/(C_s-C_0)$ with respect to time [15].

$$ln\frac{C_s - C_t}{C_s - C_o} = K_L\, a \qquad \ldots 3.1$$

where, C_s is the value of saturation concentration of oxygen in water at ambient condition. C_o and C_t is oxygen concentration in water at the initial and time t.

The aeration performance of venturi oxygen transfer efficiency as defined the following equation:

$$K_L a_{20} = K_L a_T \times \theta^{(20-T)} \qquad \ldots 3.2$$

where, $K_L a_{20}$ = Standard oxygen transfer coefficient at temperature 20°C (h^{-1}), $K_L a_T$ = oxygen transfer coefficient at temperature (°C), and θ = 1.024.

Ability of aerator to transfer the oxygen from atmosphere expressed in terms of SOTR and SAE calculated as follows:

$$SOTR = K_L a_{20} \times (C_s - C_o) \times V \times 10^{-3} \qquad \ldots 3.3$$

where, C_s = the DO saturation concentration at 20° C,

V = Aeration water volume (m^3)

$SOTR$ = Standard oxygen transfer rate (kg O_2/h)

$$SAE = \frac{SOTR}{P} \qquad \ldots 3.4$$

$$= \frac{K_L a_{20} \times (C_s - C_0) \times V \times 10^{-3}}{P}$$

where, SAE = Standard aeration efficiency (kg O_2/KWh) and P = Power input (KW)

III. RESULTS AND DISCUSSION

The experiments for performance evaluation were carried out by varying throat effective lengths and discharge as mentioned earlier. In order to study the effect of throat hole on DO diffusion the effective length of throat hole was varied. The rise in DO concentrations were measured at an interval of 10 seconds. It was seen from the study that the DO diffusion rate increases with time. The experimental details along with their results are presented in Fig. 3 to Fig. 6. The maximum DO concentration was found 7.38 mg/l at 0.660 lps in a time of 1520 seconds.

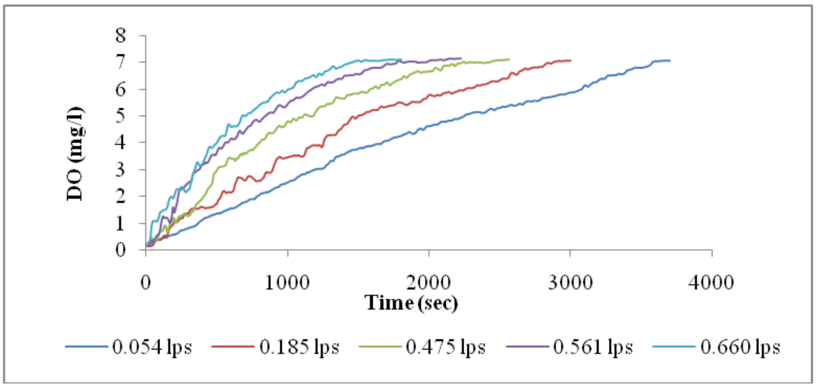

Figure 3: Variation of DO at different discharge for hole 1 of 3 mm effective length

The results obtained indicated that DO concentration increases with increasing time at various discharge rates. It was also observed that DO diffusion depends on the effective length of throat hole i.e. increases with maximum discharge. It was achieved from all observations that the maximum diffusion rate of oxygen is achieved for in higher flow rate because of higher flow turbulence. The maximum DO concentration obtained at discharge rate of 0.054 lps, 0.185 lps, 0.478 lps, 0.561 lps and 0.66 lps for 1 mm throat hole were 7.07 mg/l, 7.12 mg/l, 7.15 mg/l, 7.22 mg/l and 7.38 mg/l, respectively.

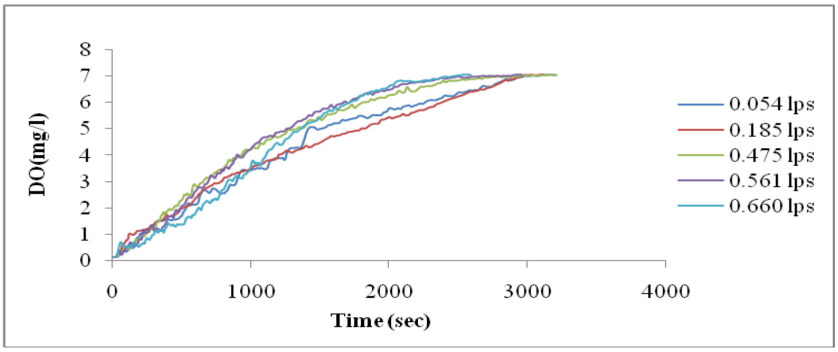

Figure 4: Variation of DO at different discharge for hole 2 of 7 mm effective length

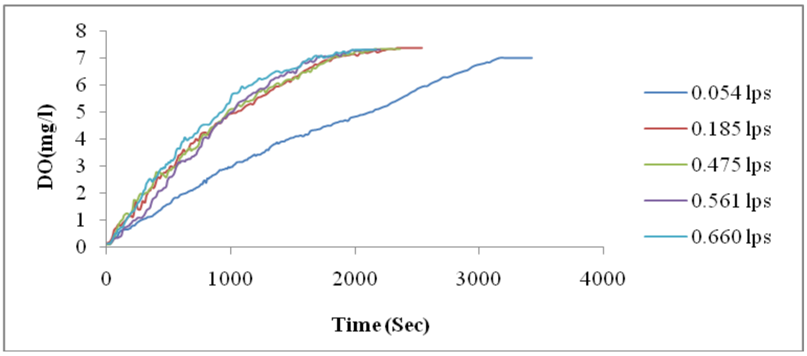

Figure 5: Variation of DO at different discharge for hole 1´ of 2 mm effective length

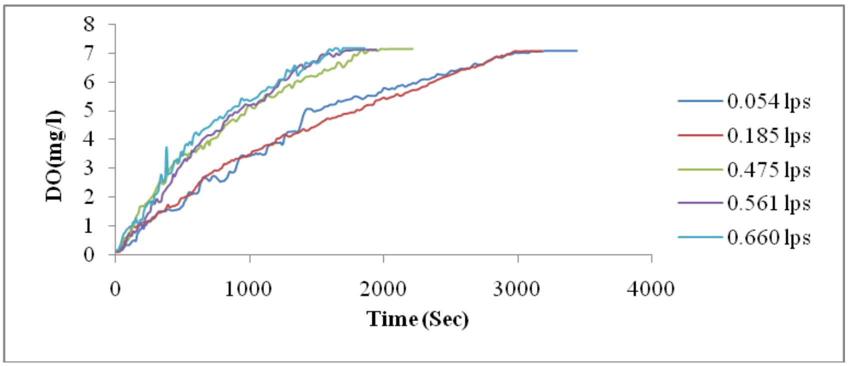

Figure 6: Variation of DO at different discharge for hole 2´ of 5 mm effective length

Figure 7 and 8 shows the variation of SOTR and SAE for orientation of throat hole at different discharge rate. The value of SOTR and SAE linearly increases with increasing discharge rates. At higher discharge rate the power consumption also increases. The maximum value of SOTR and SAE was found at 0.660 lps discharge 12.38 x 10^{-3} kg O_2/h and 55.53 x 10^{-3} kg O_2/kWh, respectively at orientation of hole 2. It was found out maximum at rise in discharge causes due to increase in molecular turbulence the rate of exchange of gas between liquid film and gas increases.

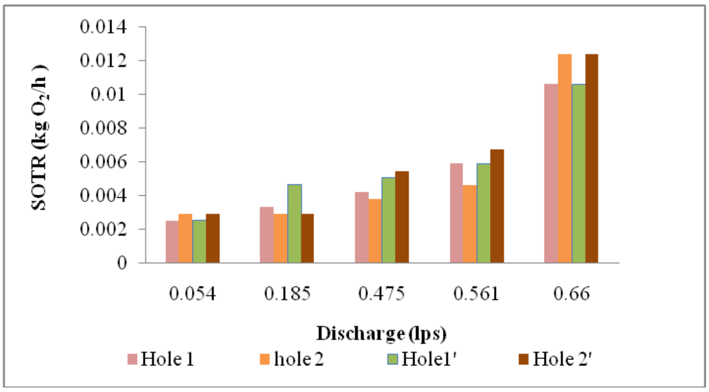

Figure 7: Effect of SOTR with respect to the different discharge rates

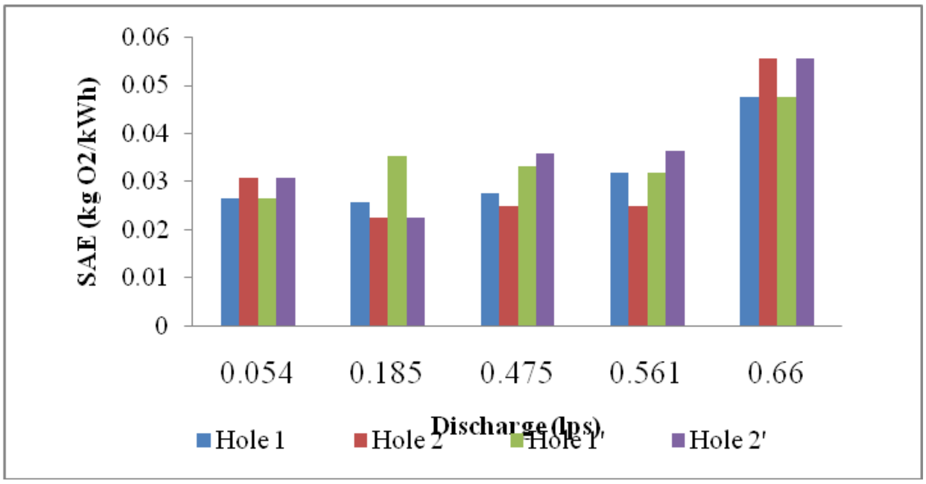

Figure 8: Effect of SAE with respect to the different discharge rates

VI. CONCLUSION

From this study we can draw the conclusion that venturi aeration is one of the ideal forms to increase air entrainment and oxygen content in to the water. Moreover, the results revealed that the DO diffusion is largely dependent on the effective throat length and discharge and varies respect to time. The value of DO diffusion was observed to be higher at maximum discharge. It was found that at higher rate of discharge the SOTR and SAE values increases when the power consumption increases accordingly. Based on the findings of this study, effective length of throat hole position was found to be the most important factor influencing the air entrainment rate and the oxygen transfer efficiency. As a result, the venturi tube can be used as a highly efficient aerator in water aeration system.

REFERENCES

[1] S. Sarkar, A. Kumar, D. Kumar, L. N. Sethi, M. M Hazarika, and G. Das, Optimal Size of Fish Pond for Socio-Economical Development of Cachar (Assam). International Journal of Agriculture, Environment and Biotechnology. 8 (2), 2015, 121-127.

[2] American Public Health Association (APHA), American Water Works Association, and Pollution Control Federal, 16th edition. APHA, Washington, DC. 1980, 541.

[3] C.E. Boyd, and D.J. Martinson, Evaluation of propeller-aspirator-pump aerators in Aquaculture. 36 (3), 1984, 283–292.

[4] J.S. Gulliver, J.R. Thene, and A.J. Rindels, Indexing Gas Transfer in Self-aerated Flows. J. Envir. Engrg., ASCE, 116(3), 1990, 503-523.

[5] S.C. Wilhelms, J. S. Gulliver, and K. Parkhill, Re-aeration at Low-head Hydraulic Structures. Technical Report HL-91, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MI. 1992, 56-63.

[6] H. Chanson, Predicting oxygen content downstream of weirs, spillways and waterways. Proc. Inst. Civ. Engrs. Water, Marit. and Energy, London, 112, 1995, 20-30.

[7] D.A. Ervine, Air Entrainment in Hydraulic Structures: A Review. Proc. Inst. Civ. Eng. Water, Marit. Energy, 130, 1998, 142–153.

[8] A. Baylar, and M. Emiroglu, Air Entrainment and Oxygen Transfer in a Venturi, Proc. of the Institution of Civil Engineers-water and Maritime Engineering, 156(3), 2003, 249-255.

[9] M. Emiroglu, and A. Baylar, Study of the Influence of Air Holes along Length of Convergent- Divergent Passage of a Venturi tube on Aeration. J. Hydr. Res., 41(5), 2003, 513-520.

[10] C.E. Boyd, Pond Water Aeration Systems. Aquacultural Engineering. 18 (1), 1998, 9–40.

[11] X. Wang, and Y. Zhang, Development of a Critical Airflow Venturi for Air Sampling. Journal Agricultural Engineering and Resource. 73, 1999, 257-264.

[12] F. Ozkan, M. Ozturk, and A. Baylar, Experimental Investigations of Air and Liquid Injection by Venturi tubes. Water and Environment Journal. 20, 2006, 114–122.

[13] F. Ozkan, A. Baylar, and M. Tugal, The Performance of Two Phase Flow Systems in Pond Aeration. International Journal of Science and Technology. 1, 2006a, 65-74.

[14] C.E Boyd, and Ahmad. Evaluation of Aerators for Channel Catfish Farming. Alabama Agricultural Experiment Station, Auburn University, AL. Bulletin, 1987, 5–84.

[15] M.R. Ghomi, M. Sohrabnejad, and M.R. Ovissipour, An Experimental Study of Nozzle Diameters, Aeration Depths and Angles on Standard Aeration Efficiency in a Venturi Aerator. Water Practice and Technology. 4(3), 2009, 1-8.

[16] W.K. Lewis, and W.G. Whitman, Principles of Gas Absorption. Ind. and Engg. Chem. 16(12), 1924, 1215-1220.