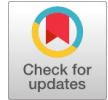


Design Characteristics of Venturi Aeration System

Anamika Yadav, Avinash Kumar, Sudipto Sarkar



Abstract: The crucial phenomenon of air and water mixing together is called aeration. The venturi aeration is mainly responsible to transfer air directly through the atmosphere into the flowing water attribute to its simplicity and reliability. A water tank of 1000 litres capacity having dimensions $100 \times 100 \times 100 \text{ cm}^3$ was used to conduct the experiments for aeration for the purpose of studying the characteristics of venturi aeration system design. Venturi having three significant sections i.e. inlet, constricted and outlet section, used as a differential pressure producer basis on Bernoulli's theorem where the middle section of the venturi often called as constricted section is responsible for the energy conversion, which transfers oxygen by aspirating air into the constricted section and producing interfacial area between the air and water. On the basis of dimensional analysis, non-dimensional numbers associated with geometric, dynamic and process parameters were analysed. The non-dimensional geometric parameters like throat length (t_1), hole distance from beginning of throat (h_a), throat hole diameter (t_h) were optimized and additionally conducted at constant flow rate ($v_w=0.396 \text{ m/s}$). To assess the performance of designed venturi, the selection of different t_1 as 20, 40, 60, 80 and 100 mm, with varying number of holes inserted, depends on the t_1 and keeping t_h constant at 2 mm. The SAE values were initiated more with increasing t_1 . The maximum SAE values were obtained with maximum number of holes open as $6.200 \times 10^{-3} \text{ kg O}_2/\text{kWh}$ for 100 mm t_1 . A constant flow rate was maintained to construct the equations for the prediction of venturi aeration system's characteristics via simulations. For the purpose of simulations different geometric conditions of the venturi design system were considered. The simulation equations developed for t_1 based on the Re and Fr are subjected to $12.655 \times 10^{-5} > Re > 2.531 \times 10^{-5}$ and $1.251 < Fr < 6.256$, respectively. It was also concluded that from the non-dimensional study, the simulation equation developed for NDSA based on the t_1 be valid and subjected to $3.890 \times 10^3 < NDSA < 0.215 \times 10^3$.

Key words: Dissolve oxygen, Froude number, Reynolds number, Standard aeration efficiency, Venturi.

I. INTRODUCTION

With increasing demand of aquatic species united by less fish production from inherent water bodies has required promoting the highest fish production and healthy environment globally. Development of water bodies through extensive and semi-intensive culture techniques can

increases the higher yield potential. The fish or other aquatic animal production in intensive and semi-intensive aquaculture operations rely on various water quality parameters in which dissolved oxygen (DO) plays a vital role. The ponds used for production, may witness a drop in DO by 5-10 mg/l at night, also the concentration of DO may further drop to less than 2 mg/l at sunrise in un-aerated ponds [1]. Stress and mortality rate are high in the cultured species due to low DO concentrations. All the aquatic animals required DO to produce energy for their body maintenance, movement and biosynthetic process [2]. To improve the energy efficiency for the transfer oxygen mass many researchers have developed varied types of artificial aerators [3]. These techniques provides proper sufficient bulk liquid mixing of DO into the entire volume of water during excessive feeding, high fertilization and high stocking density thus increase the DO concentration in aquatic water bodies [4]. Venturi system one of them is admired aeration process which highly efficient and required less than 20% pressure difference to pledge suction for sufficient supplementations of DO makes a sustainable environment friendly system of mass production. When compared to diffusers, venturi system shows better efficiency in energy consumption but at the cost of poor performance in respect to standard oxygen transfer efficiency (SOTR) [5]. Venturi systems have value between 0.5 and 3.0 kgO_2/kWh as the typical value for standard aeration efficiency (SAE) [6], [7]. The purpose of designing the venturi type aeration system is to increase the DO level of water prior to its addition into the water reservoir. In a typical venturi, the air gains entry into the water at the point of maximum constriction, where the streaming water gains a higher velocity, which in other hand witnesses a drop in static pressure. This is according to Bernoulli's theorem [8]. At the constricted portion of venturi, air enters from the atmosphere into the water as a result of reducing static pressure by the procedure called gas stripping or absorption. Mixing occurs in to the water flow because of the turbulent nature of flowing water. Therefore, mechanical agitation or mixing in bulk liquid is not required [9]. A diligently developed system for aeration is very crucial to maintain a satisfactory and constant supply of DO to fulfil the demand of the aquatic species. A venturi comprises with the three sections i.e. a converging section, a throat section and a diverging section. A venturi allows air entrainment through air holes into the flowing water cause of pressure difference occurs at throat section, therefore increment of DO concentration inside the water [10]. This mechanism of air entrainment and oxygen transfer through venturi aeration influenced by various geometric parameter that earlier researchers have adopted such as throat length, throat hole diameter, water velocity, converging and diverging angle [6], [11], [12], [13], [14].

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Many more experimental studies also have been carried out on oxygen transfer efficiencies of different projections of venturi system with different operational conditions by [15]-[23]. However few of them considered the effect of geometry on the execution of venturi aeration system. Venturi aeration has been also applied for the treatment of wastewater [24], [25]. Authors in [26] concluded that the performance of parallel venturi system for oxygen transfer into water outsmarts the series venturi system for two and three aerator modules the co-efficient of oxygen transfer was found to be 9.67 and 5.93 h⁻¹ respectively. It was also observed that the maximum aeration efficiency for the parallel venturi aeration of two modules as 0.14 kgO₂/kWh. Authors in [27] proposed that with increasing contraction ratio, the suction and mass flow rate increases. Whereas both the suction and mass flow rate reduces as the diffusion angle increases and gave out at an optimal angle (30°) favourable for more mass flux observed by [8], [11], [12], [18], [28] conducted a series of experiments come across at the potential of mass transfer using a venturi which connected to a downstream side and can best retched to the base of the water body. In addition air holes on the throat of the venturi also aided in improving the aeration efficiency and the saturation of air and water increases with increasing the DO concentration at the side of inlet and downstream length of venturi respectively. Accordingly the saturation concentration also increases through minimum flow rate at inlet side and at the constricted throat section of venturi to some extent [29]. By increasing the flow rate of venturi managed more ferocious air bubble and they collapse in the diverging section and finally producing excessive air bubbles of smaller diameter [30]. The present study evaluates the performance of venturi aeration system in terms of its optimum geometric and dynamic parameters and assessment of its applicability in the aquaculture pond.

II. THEORETICAL CONSIDERATION

A. Causes of Oxygen Transfer by Venturi Principle

The oxygen transfer is critically optimized for DO with the successive utilization of venturi. Two-film theory [31] has been most prominent theory used to evaluate the oxygen transfer rate. According to two-film theory, the oxygen transfer coefficient at T°C, $K_L a_T$ may be expressed as follows:

$$K_L a_T = \frac{\ln(C_s - C_0) - \ln(C_s - C_t)}{t} \quad (1)$$

where, \ln represents natural logarithm and C_s , C_0 and C_t are dissolved oxygen concentrations in parts per million (ppm). C_s is the saturation oxygen concentration, C_0 is the initial

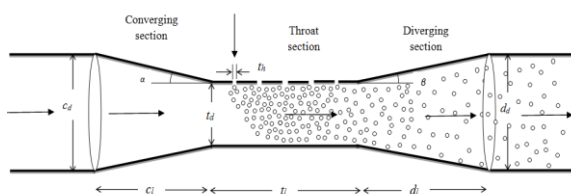


Figure 1: Schematic view of designed venturiJet ejectors with or without venturi end throat are extensively studied and contrasted in [42]. In [43] jet ejectors without diffusers are evaluated it was evident from the study that jet ejectors are less effective when a diffuser or a throat is absent, while

oxygen concentration and C_t is the oxygen concentration at time t . Similarly other theories offered by [32]-[34] as alternative models to the two-film theory. According to the Henry's Law "The equilibrium concentration of oxygen in water is proportional to the partial pressure of oxygen in the atmosphere". Depending on the magnitude of the sources and sinks of oxygen the water bodies may be either supersaturated or under saturated with oxygen. On high level of super saturation condition the dissolved gas in form of micro bubbles that eventually coalesce, rise, and burst at the water surface. Because of the saturated air is in contact with the unsaturated water [30].

For the sake of uniformity $K_L a$ is normalized at 20°C standard temperature during the comparison of different systems. Eq. (2) describes the aeration performance of venturi oxygen transfer efficiency under influence of temperature [35].

$$K_L a_{20} = K_L a_T \times \theta^{(20-T)} \quad (2)$$

Ability of an aerator to transfer the oxygen from atmosphere expressed in terms of $SOTR$ and SAE . $SOTR$ of an aeration system is defined as the mass of oxygen transfer into a body of water per unit time at standard conditions of 20 °C water temperature, 0 mg/L initial DO concentration, one atmospheric pressure, and clear tap water [36]. $SOTR$ can be calculated as follows:

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

SAE is one of the better comparative parameter, which is defined as $SOTR$ per unit of power [37].

$$SAE = \frac{SOTR}{P} = \frac{K_L a_{20} \times (C_s - C_0) \times V \times 10^{-3}}{P} \quad (4)$$

where, C_s is the DO saturation concentration at 20°C, V is the water volume (m³), $SOTR$ is the standard oxygen transfer rate (kgO₂/h), SAE is the standard aeration efficiency (kgO₂/kWh) and P is the power input (kW).

B. Geometry of the Venturi

The numerous application of venturi aeration on air entrainment have been carried out so far by various researchers [8], [9], [14], [18], [38], [39], [40]. The venturi contains three general sections primarily an inlet (converging section), followed by middle (throat section) and ends with a gradual expansion (diverging section) shown in Figure 1. Venturi has most frequently worked on mixing air and water passing through the constricted section that improves the water quality by maintaining efficient DO level in the water bodies. In this regard, it is well-known that the constricted section of the venturi plays a significant role to create vacuum that draws air into the water [41]. The venturi's discharge can be described using Bernoulli's equation and Continuity equation, which are similar to the closed conduit venturi flow evaluation. Since a negative pressure occurred at the inserted holes on the throat section between converging and diverging section of the venturi. a jet ejector with a throat or diffuser is much more efficient. An air hole bored into the pipe at a point where this vacuum occurs will cause air to be drawn into the main flow measured by Clemens Herschel in 1886.

C. Dimensional Analysis

Dimensional analysis used for a long time to design the aerators in the field of aquaculture and wastewater treatment. The air entrainment per unit volume of water and their distribution is the rate of oxygen transfer, which affects the variance of both the geometric and dynamic parameters

Table I: Variable considered for dimensional analysis

Class of Variables	Name of variables	Variable	Units	Dimension
Geometric parameter	Throat length	t_l	M	L
	Throat diameter	t_d	M	L
	Throat hole diameter	t_h	M	L
	Hole distance from beginning of throat	h_d	M	L
	Angle of inclination at inlet	A	°	—
	Angle of inclination at outlet	B	°	—

Author's in [44] concluded that the absorption rate coefficient $K_L a_{20} \times V$ and expressed as

$$K_L a_{20} \times V = SOTR/\Delta C \tag{6}$$

is the most important parameter for air absorption process. Thus, the variable that can influence the efficiency of the system hence, the functional relationship between $SOTR/\Delta C$ and the key variables expressed as follows:

$$SOTR/\Delta C = f_1(t_l, t_d, t_h, h_d, \alpha, \beta, V, \rho_a, \rho_w, g, v_w, \sigma_w, v_w) \tag{7}$$

According to the Buckingham II theorem, dimensional analysis may be expressed as follows in the dimensionless form:

$$Y = f_2(t_d/t_l, t_h/t_l, h_d/t_l, \alpha, \beta, V/t_l^3, \rho_a/\rho_w, gt_l/v_w^2, \sigma_w/tlv_w^2\rho_w, v_w/tlv_w) \tag{8}$$

where, Y = absorption number = $(SOTR/\Delta C)/t_l^2 v_w \rho_w$,

gt_l/v_w^2 = Froude number (Fr),

$\sigma_w/tlv_w^2\rho_w$ = Weber number (W),

v_w/tlv_w = Reynolds number (Re)

From the above Eq. (8) the geometric similarity is represented by the first seven non-dimensional parameters and the dynamic similarities represented by the last parameter. Venturi aerator operated with a pure water-air system so the ρ_a/ρ_w kept as constant and hence can be dropped from Eq. (8). Furthermore, volume of the tank (V) and converging (α) and diverging angle (β) is not varied during experimentation. Therefore, V/t_l^3 , α and β remains

water tank and valves arranged in a closed loop system shown in Figure 2.

of an aerator. The performance of venturi aeration system depends on various parameters especially geometrical parameter, flow parameter and physical parameter. For dimensional analysis all the variable are characterised into three groups of 14 relevant variables as listed in Table I.

	Volume of tank	V	m^3	L^3
Flow parameter	Gravimetric acceleration	G	m/s^2	LT^{-2}
	Flow velocity	v_w	m/s	LT^{-1}
Physical parameter	Mass density of air	ρ_a	Kg/m^3	ML^{-3}
	Mass density of water	ρ_w	Kg/m^3	ML^{-3}
	Apparent density	$\Delta\rho$	Kg/m^3	ML^{-3}
	Kinematic viscosity of water	ν_w	m^2/s	L^2T^{-1}
	Surface tension of water	σ_w	N/m	MT^{-2}

constant throughout the experimentation and can be omitted from the Eq. (8). Thus Eq. (8) can be rewritten as:

$$Y = f_3(t_d/t_l, t_h/t_l, h_d/t_l, Fr, W, Re) \tag{9}$$

For the purpose of this study W may be dropped from Eq. (9) as it is of little or no significance. The power consumption dictates the overall aeration efficiency of the aeration system, which on the other hand is a function of pressure loss. The power consumption P of a given venturi aerator is, in general, dependent upon the same parameters as the term $SOTR/\Delta C$. Therefore the relationship can be expressed in non-dimensional form as [45].

$$N_p = f_4(N_{Re}, N_{Fr}) \tag{10}$$

where, N_p = power number = $P/\rho_w \times (g/v_w)^3 \times t_d^5$

$$N_p = f_5(t_d/t_l, t_h/t_l, h_d/t_l, Fr, Re) \tag{11}$$

Expressing in terms of SAE by dividing the absorption number Y with N_p , the expression is modified as

$$NDSAE = Y/N_p = (SOTR/P) \times (\Delta C \times t_l^2 \times v_w \times \rho_w)^{-1} \times \rho_w \times (g/v_w) \times t_d^5 \tag{12}$$

$$NDSAE = f_6(t_d/t_l, t_h/t_l, h_d/t_l, Fr, Re) \tag{13}$$

III. EXPERIMENTAL SETUP

The aeration experiments were conducted with 1000 litre capacity water tank having dimensions of $100 \times 100 \times 100$ cm³. The setup consist of the venturi which are supported on the trolley stand, pumping unit, distribution pipeline,



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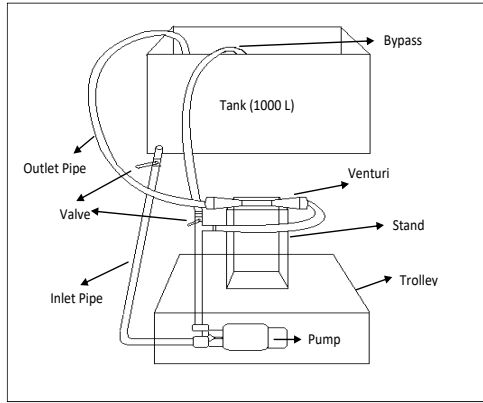


Figure 2: Experimental setup

The clean tap water is used to circulate through venturi aeration system by using 2HP centrifugal pump at maximum discharge rate of 1.25 lit/sec. The non-steady re-aeration test is performed to deoxygenated water for each experiment [36]. The clean tap water was deoxygenated by using 10 mg of sodium sulphite and 0.1 mg of cobalt chloride per litre volume of water as a catalyst in all experiments for lowering of each mg/L of DO [46], [47]. The HYDRAS3 LT Sonde MS5 DO meter is used to measure the DO concentration by inserting luminescent dissolved oxygen (LDO) sensor probe at the bottom of the water tank. DO readings are taken at regular intervals until and unless DO concentration reaches to 80% saturation. The temperature and atmospheric pressure were also recorded along with the DO readings at the same time during DO measurements. K_{La20} , $SOTR$ and SAE were calculated by using Eq. 1, Eq. 2 and Eq. 3 respectively. Based on the obtained data, the non-dimensional numbers viz. $NDSAE$, Fr and Re were computed.

The fabricated venturi with three substantial sections was made of aluminium of 5 mm thickness which can be dismantled from each other. The details of the dimensions of geometric parameters of fabricated venturi are presented in Table II. The converging and diverging section of venturi is kept similar in dimensions as length of 140 mm. Throat length of venturi were varied from 20 mm to 100 mm at an equal interval of 20. The 2 mm diameter holes inserted on throat and assumed to have an equal distance of 5 mm. A detail of the various throat sections of different lengths is presented in Figure 3.

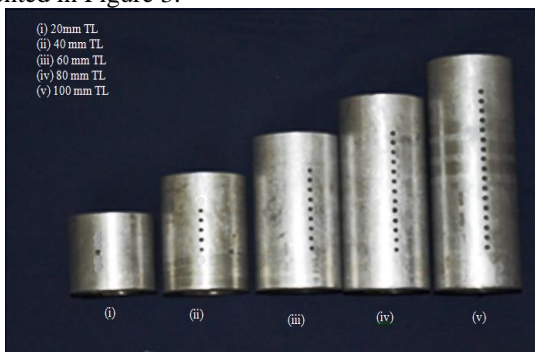


Figure 3: Fabricated sections of different throat lengths (t_i)

Table II: Dimensions of geometric parameters of venturi

S. No.	Notations	Details	Dimensions (mm)
1.	c_d	Diameter of converging section	60
2.	t_d	Diameter of throat section	20
3.	d_d	Diameter of diverging section	60
4.	c_l	Converging length	140
5.	d_l	Diverging length	140
6.	t_l	Throat length	20, 40, 60, 80, 100
7.	t_h	Throat hole diameter	2
8.	A	Angle of inclination at inlet	10°
9.	B	Angle of inclination at outlet	10°

The schedules of experimental sets to optimize the geometric parameter of the venturi aeration system are mentioned in Table III. Optimum non-dimensional geometric parameters (t_d/t_l , t_h/t_l , and h_d/t_l) are determined by performing the above sets of experiments. In all experiments, flow rate v_w (0.396 m/s) is kept as constant to maintain a particular dynamic condition. Initial experiments were carried out with single hole and subsequently numbers of holes were increased up to the maximum number of holes made upon the particular value of t_l of the venturi. Number of experiments varies with the value of t_l . A total number of 1, 5, 9, 13 and 17 experiments were carried out for value 20, 40, 60, 80 and 100 mm of t_l respectively. Therefore forty five numbers of experiments were carried out in different sets of experiments which are mentioned in Table III.

Table III: Schedule of experiments optimize the geometric parameters of venturi aerator

Set of experiments	t_l	Number of holes
Set-I	20	1
Set-II	40	5
Set- III	60	9
Set- IV	80	13
Set- V	100	17

IV.RESULTS AND DISCUSSION

A. Performance of the venturi aerator

Total forty five numbers of experiments were carried out in order to evaluate the optimum value of $SOTR$ for different sets of t_l of venturi. Details of the experimental results particular to Set I, II, III, IV and V are presented in Table IV. The experimental result data corresponding to the optimum values of K_{La20} , $SOTR$, SAE as per the experimental sets as mentioned in the Table III are presented in Table IV.

Table IV: Experimental results for optimization of t_i of ventur

Sets of Experimental Run	t_i	Number of holes	K_{La20} (h ⁻¹)	SOTR (kg O ₂ /h)	SAE × 10 ⁻³ (kg O ₂ /kWh)	Re × 10 ⁻⁵	Fr	NDSAE × 10 ³
Set-I	20	Hole 1	0.3	0.0026	1.733	12.655	1.251	3.890
		Hole 1	0.361	0.0031	2.067			1.160
		Hole 2	0.44	0.0038	2.533			1.421
Set-II	40	Hole 3	0.466	0.004	2.667	6.328	2.502	1.496
		Hole 4	0.533	0.0046	3.067			1.721
		Hole 5	0.643	0.0055	3.667			2.057
		Hole 1	0.239	0.002	1.333			0.333
		Hole 2	0.282	0.0024	1.600			0.399
Set- III	60	Hole 3	0.301	0.0026	1.733	4.218	3.753	0.432
		Hole 4	0.471	0.004	2.667			0.665
		Hole 5	0.563	0.0048	3.200			0.798
		Hole 6	0.607	0.0052	3.467			0.865
		Hole 7	0.687	0.0059	3.933			0.981
		Hole 8	0.984	0.0085	5.667			1.413
		Hole 9	1.045	0.009	6.000			1.496
		Hole 1	0.28	0.0023	1.533			0.215
		Hole 2	0.303	0.0025	1.667			0.234
		Hole 3	0.317	0.0028	1.867			0.262
		Hole 4	0.421	0.0037	2.467			0.346
		Hole 5	0.447	0.0039	2.600			0.365
		Set- IV	80	Hole 6	0.456			0.004
Hole 7	0.474			0.0041	2.733	0.383		
Hole 8	0.525			0.0046	3.067	0.430		
Hole 9	0.531			0.0046	3.067	0.430		
Hole 10	0.56			0.0049	3.267	0.458		
Hole 11	0.589			0.0051	3.400	0.477		
Hole 12	0.561			0.0049	3.267	0.458		
Hole 13	0.627			0.0055	3.667	0.514		
Hole 1	0.502			0.0043	2.867	0.257		
Hole 2	0.543			0.0047	3.133	0.281		
Hole 3	0.677			0.0059	3.933	0.353		
Hole 4	0.699			0.0061	4.067	0.365		
Hole 5	0.763			0.0066	4.400	0.395		
Set- V	100	Hole 6	0.796	0.0069	4.600	2.531	6.256	0.413
		Hole 7	0.811	0.0071	4.733			0.425
		Hole 8	0.851	0.0074	4.933			0.443
		Hole 9	0.864	0.0075	5.000			0.449
		Hole 10	0.901	0.0078	5.200			0.467
		Hole 11	0.917	0.008	5.333			0.479
		Hole 12	0.88	0.0076	5.067			0.455
		Hole 13	0.966	0.0084	5.600			0.503
		Hole 14	0.98	0.0085	5.667			0.509
		Hole 15	1.013	0.0088	5.867			0.527
		Hole 16	1.027	0.0089	5.933			0.533
		Hole 17	1.072	0.0093	6.200			0.557

From the Table IV it can be seen that the SAE of the venturi aeration increases with the number of holes shown for each set of experiment as shown in Figure 4. From Set I with t_i 20 mm, the SAE value was obtained as 1.733×10^{-3} kg O₂/kWh. Second sets of experiments with t_i 40 mm extended the SAE values from 2.067 to 3.667×10^{-3} kg O₂/kWh and can be observed in Table IV. The SAE values vary from 1.333 to 6.000×10^{-3} kg O₂/kWh for Set III with a t_i value of 60 mm. The SAE values differ from 2.867×10^{-3} to 6.200×10^{-3} kg O₂/kWh for 100 mm t_i value.

From the overall experimental runs, the maximum SAE was obtained as 6.200×10^{-3} kg O₂/kWh with highest number of holes and maximum t_i value of 100 mm. This may be due to the fact that higher atmospheric oxygen dispersion occurred through the maximum number of holes which is responsible to increase the efficiency of the venturi aeration system.

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Consequently, the air bubbles arrived through the constricted section of venturi and they split up into more number of bubbles towards the outlet end of the venturi. The power equation has fitted well with the SAE value with number of holes of the maximum t_l .

$$SAE = 2.800(NH)^{0.268} \quad (R^2 = 0.979) \quad (14)$$

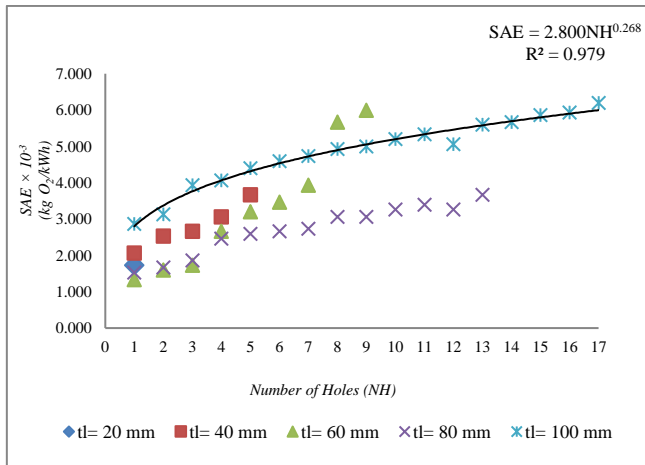


Figure 4: Variation of SAE with number of hole of different t_l

B. Effect of Re on t_l

The plot between Re and t_l of venturi is presented in Figure 5. It is observed from the figure above that the relation between Re and t_l of venturi can be fitted by a power function of the following form with R^2 equals to the value of 1.

$$Re = 253.1(t_l)^{-1} \quad (R^2 = 1) \quad (15)$$

It can be observed from the Figure 5 that the value of Re decreases with increasing t_l . The maximum Re value is attained at 12.655×10^{-5} of t_l 20 mm value. This may be due to the highest turbulences having seen with maximum t_l , therefore, Re effect gets minimum. Thus, the diverging section is more responsible to create strong communication between air entrainment and turbulent flow. The maximum value of Re was obtained at 20 mm t_l value which is given in Table IV. The results demonstrated the advantages of using venturi as an aeration method about promoting of maximum aeration efficiency.

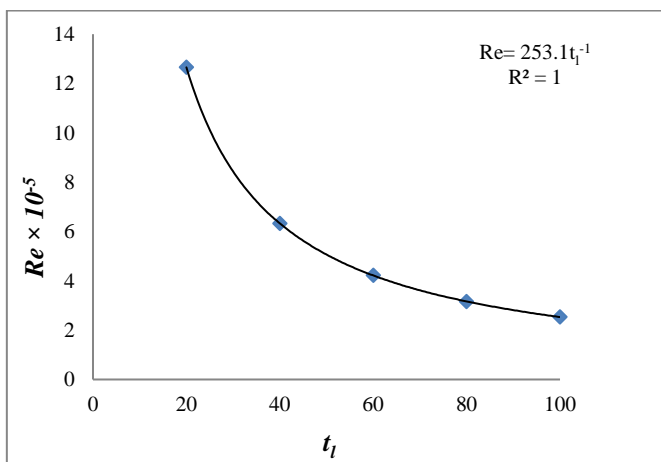


Figure 5: Variation of Re with different size t_l

C. Effect of Fr on t_l

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A similar process was followed to find out the relationship between Fr and t_l as shown in Figure 6. In case of venturi aeration, t_l was found to have a significant relationship with Fr . It can be noticed from the Figure 6 that the Fr attains a linear trend with the t_l . The values of Fr increases linearly from 20 mm t_l to 100 mm t_l . The highest value of Fr was obtained at maximum t_l of 100 mm due to the increase of number of holes this is due to turbulences attained on the throat section of venturi and with the increase in the number of holes on the throat. This is may be due to the fact that supercritical flow condition occurred at constricted section of venturi. This supercritical flow was controlled at the converging side of venturi further disturbances are transmitted in constricted section and diverging section side. From the Figure 6 it is seen that the relation between Fr and t_l of venturi satisfies by the linear function of the following form with R^2 value 1.

$$Fr = 0.0626(t_l) \quad (R^2 = 1) \quad (16)$$

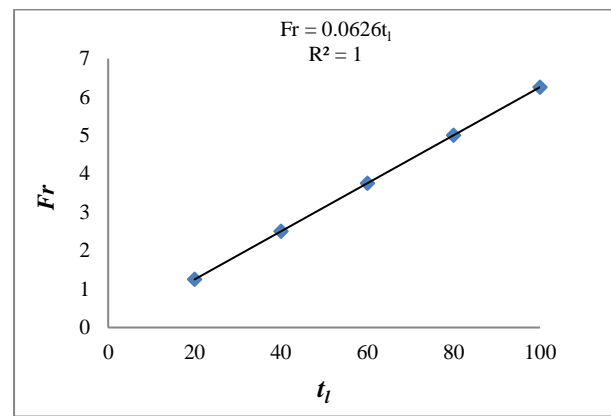


Figure 6: Variation of Fr with different size t_l

D. Variation of $NDSAE$ with t_l

Another plot between $NDSAE$ and t_l of venturi aeration is presented in Figure 7. The high values of $NDSAE$ were obtained by the increasing number of holes for each sets of experimentation. The maximum $NDSAE$ value was found to be 3.890×10^3 for t_l value of 20 mm. It can be noted from the Figure 7 that the experimental sets of data points produces a single curve throughout the sizes of t_l indicating an underlying relationship between $NDSAE$ and t_l . The polynomial type of Eq. 17 satisfies the entire range of data points.

$$NDSAE = -2E-05t_l^3 + 0.0044t_l^2 - 0.3466t_l + 9.2033 \quad (R^2 = 0.9994) \quad (17)$$

In case of $NDSAE$, the data points reaches at a higher value of $NDSAE$ for 20 mm t_l value, whereas for other t_l , the data points comes closer to each other for every number of hole thus there is no such difference between them for increasing t_l . This may be due to the fact that the flow pattern in case of venturi aeration is strictly governed by pressure differences resulting in increasing flow rate at the constricted section of venturi and the result becomes in form of air bubbles.



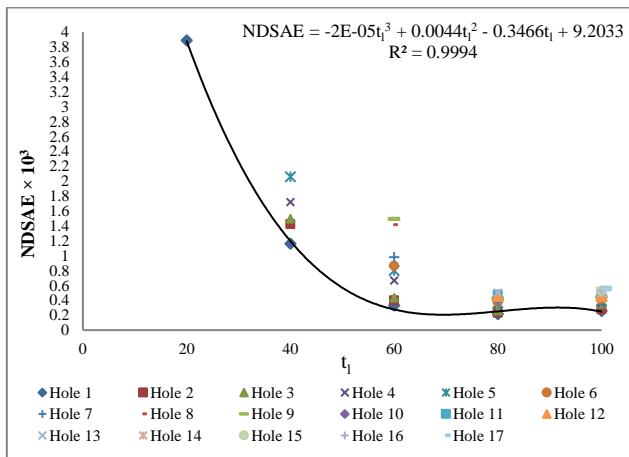


Figure 7: Variation of NDSAE with different size t_1

V.CONCLUSION

The aeration performance of venturi aerator depends on the geometric parameters. Performance of venturi aeration system was evaluated at constant flow rate to determine the effect of geometric parameter. It can be concluded that the SAE values increases rapidly with an increase value of t_1 . The maximum SAE values were obtained with maximum number of holes. Maximum SAE value was found to be 1.733×10^{-3} , 3.667×10^{-3} , 6.000×10^{-3} , 3.667×10^{-3} and 6.200×10^{-3} kg O_2 /kWh for different values of t_1 such as 20 mm, 40 mm, 60 mm, 80 mm and 100 mm, respectively. In case of venturi aeration system, t_1 was found to fit well with both Fr and Re . The simulation equations developed for t_1 based on the Re and Fr are subjected to $12.655 \times 10^{-5} > Re > 2.531 \times 10^{-5}$ and $1.251 < Fr < 6.256$, respectively. It was also concluded that from the non-dimensional study, the simulation equation developed for NDSAE based on t_1 and it is valid subjected to $3.890 \times 10^3 < NDSAE < 0.215 \times 10^3$. In broad sense the venturi aeration can be considered as a precise mechanism through which air is arrived into the constricted section and then towards the outlet section without any exertion. The diverging section is also more responsible to create solid interaction between air entrainment and turbulent flow.

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