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Fabrication and Performance Analysis of Water Vortex Power Plant

Lingaraj.K.Ritti [1]
lingaraj.k.ritti@gmail.com

Pavana Kumara [2]
pavansmvitm@gmail.com

Ranganatha [3]
Ranganatha3@gmail.com

Ambarish M.[4]
ambarish.mpm@gmail.com

[1, 2, 3,4] Assistant Professors, Department of Mechanical Engineering, Shri Madhwa Vadiraja Institute of Technology, Bantakal-574115, Udupi, India

***Abstract*— Gravitation water vortex power plants offer a new way of making use of the hydropower potential of smaller waterways without causing damage to river environment and aquatic life. Basically, when an existing weir is replaced by a gravitation water vortex power plant that has no weir, that section of the river is also renatured and revitalized, restoring continuity for fish and other river creatures. Gravitation water vortex power plants are small and robust river power plants. They require a minimum water level of 0.7 meters and a minimum water flow of about 1,000 liters per second.**

The technology used in gravitation water vortex power plants also called water vortex power plants is completely different from that of conventional small hydropower plants with their ponds and turbines. A water vortex plant consists of a circular tank or basin with a central drain. A symmetrical vortex automatically forms above the drain, as it does when we drain water from a bathtub. The vortex drives a vertically placed rotor turbine. This rotor powers a generator that produces electricity and then transmits it to the power grid. There is no backflow or any increase in water pressure, allowing fish to easily swim upstream and downstream through the power plant.

The main aim is to generate clean power using Gravitational vortex model by developing a stable system which consists of vortex basin, channel and other components. This system is tested by varying different parameters like input head, input flow rate, depth of the vortex, turbine blades, orifice diameter and the readings are noted down. These readings are used to calculate power, torque and output flow rates and these calculations are used to study the different variations in power and to note down the maximum value of power achieved by varying the above parameters

***Index Terms*—** vortex power plant, power, flow rate, turbine vortex depth

I. Introduction

Hydropower is considered clean and environmentally friendly. It does not release CO2 emissions and therefore does not contribute to climate change. But hydropower also involves building dams and weirs which interrupt the natural continuity of rivers and have serious ecological effects on river ecosystems. In some cases, the amount of water diverted from rivers and streams and channeled through turbines is so great that plants and animals cannot survive in watercourses. Weirs are insurmountable obstacles for a river's inhabitants, whether fish, water snails, crabs or water fleas. Many species need to migrate between different parts of a river to reproduce and forage. Second, cross-sectional structures such as weirs and dams slow down river currents and interrupt bed load transport. The clear water which flows over a dam scours missing bed load from the riverbed and banks below the dam, which lowers ground water levels and causes significant damage to riverbanks. Added to that, a considerable share of a river's water upstream from the weirs is frequently diverted to achieve higher drop heights. This leaves entire sections of the river without enough water to sustain aquatic life. The energy potential of many smaller rivers and streams with low drops in height, or heads, cannot be exploited using conventional hydropower technology.

In fluid dynamics a vortex is a region in a fluid medium, in which the flow is mostly rotating on an axis line, the vertical flow that occurs either on a straight-axis or a curved-axis. Vortices form in stirred fluids such as liquid, gas and plasma. Thus the vortices evidenced in smoke rings, the whirlpool of the wake of a boat and of a paddle, the winds surrounding a tropical cyclone (hurricane), a tornado, a dust devil, and vortices in the wake of an aero plane elsewhere, the vortex is a notable feature of the atmosphere of Jupiter.

Vortices are a major component of turbulent flow. In the absence of external forces, viscous friction within the fluid tends to organize the flow into a collection of irrotational vortices, possibly superimposed to larger-scale flows, including larger-scale vortices. In each vortex, the fluid's flow velocity is greatest next to its axis and decreases in inverse proportion to the distance from the axis. The vorticity (the curl of the flow velocity) is very high in a core region surrounding the axis and nearly nil in the greater vortex; and the pressure drops with proximity to the axis of the vortex.

Once formed, vortices can move, stretch, twist, and interact in complex ways. A moving vortex carries with it some angular and linear momentum, energy and mass. In a stationary vortex, the streamlines and path lines are closed. In a moving or evolving vortex the streamlines and path lines are stretched by the overall flow into loopy but open curves.

In a stationary vortex, the typical streamline (a line that is everywhere tangent to the flow velocity vector) is a closed loop surrounding the axis; and each vortex line (a line that is everywhere tangent to the vorticity vector) is roughly parallel to the axis. A surface that is everywhere tangent to both flow velocity and vorticity is called a vortex tube. In general, vortex tubes are nested around the axis of rotation. The axis itself is one of the vortex lines, a limiting case of a vortex tube with zero diameters.

II. FABRICATION AND CONSTRUCTION OF WATER VORTEX POWER PLANT

A connecting rod is a machine member which is subjected to alternating direct compressive and tensile forces. The model of water vortex power plant consists of vortex basin, channel, sump, pump, turbine and generator. The WVPP experimental model is set up as shown in figure below

The water stored in the sump is pumped to vortex basin through channel tangentially. Water vortex is created in the basin rotates the turbine placed at the centre of the vortex. The turbine in turn rotates the generator that is a 100 RPM 12V DC geared motor.

The frame supports vortex basin, turbine, sump, channel and pump. It is made up of 50×50×5mm mild steel L-angle plate having a length of 1.5m, width of 1.1m and a height of 1.1m. The legs of the frame are of 100mm height.

The vortex basin is the component where water vortex is created. The basin used in the experiment is a cylindrical basin with the inlet channel connected to it tangentially. The inlet channel is located at the upper part of the basin, uncovered at the top bottom part of the basin has a hole at the centre. Vortex is formed at the centre of the hole at the bottom of the basin. Vortex basin is made up of stainless steel (403) 16 gauge having a diameter of 0.45m and a height of 0.7m. The diameter of the hole at the bottom centre of the basin is 2.5 inches

The sump is used to store and recirculate water to vortex basin through the channel with the help of the pump. Open loft tank made of PVC (Poly Vinyl Chloride) is used as sump Channel is a conduit with free surface. It helps the water to flow tangentially to vortex basin that is being pumped from the sump A turbine is a rotary mechanical device that extracts energy from a fluid flow and converts it into useful work. A turbine is a turbo machine with at least one moving part called a rotor assembly, which is a shaft or drum with blades attached. Moving fluid acts on the blades so that they move and impart rotational energy to the rotor

A generator is a device which converts mechanical energy of rotation of turbine to electrical energy A pump is a device that moves fluids or sometimes slurries by mechanical action. Pumps can be classified into three major groups according to the method they use to move the fluid: direct lift, displacement and gravity pumps.

III. EXPERIMENTAL PROCEDURE

The sump is filled with water and Input discharge is measured for full, ¾th, ½ ball valve position by switching ON the pump. The outlet discharge of vortex basin is also measured and noted for different ball valve positions and orifice diameter. 8 blade turbine is coupled to a generator and current, voltage is measured using multimeter and hence power is calculated also the depth of vortex is varied and the variations are noted. The speed of the turbine is noted using tachometer for different ball valve positions and vortex depth and torque is calculated

IV. PERFORMANCE ANALYSIS OF WATER VORTEX POWER PLANT

Performance analysis of water vortex power plant is done by varying the parameters like the orifice diameter, depth of the vortex, flow rate, head and the following readings and results are noted. From these readings the required power and torque calculated.

A. Calculation of input flow rate

The table I. shows the results of the input flow rate for full opening of the valve and orifice. The flow rate is calculated by using the following equation. Similarly, tables II to IV measures the output flow rate for different orifice diameter.

$$Q = \frac{V}{t}$$

Where, Q=Discharge or flow rate V=Volume of water, in cubic meter T=Time, in seconds

TABLE I.
INPUT FLOW RATE READINGS

Valve position	Volume of water (Litres)	Time (sec)	Flow rate (m3/sec)
Full open	14	5	$2.8x10^{-3}$
¾ open	14	6	$2.3x10^{-3}$
½ open	14	8	$1.8x10^{-3}$

B. Calculation of outlet flow rate

TABLE II.
FLOW RATE READINGS FOR 2.5" OUTLET DIAMETER

Valve position	Volume of water (Litres)	Time (Sec)	Flow rate (m^3/sec)
Full open	14	17	$8.235x10^{-4}$
¾ open	14	19	$7.368x10^{-4}$
½ open	14	24	$5.830x10^{-4}$

TABLE III.
FLOW RATE READINGS FOR 1.5" OUTLET DIAMETER

Valve position	Volume of water (Litres)	Time (Sec)	Flow rate (m^3/sec)
Full open	14	18	$7.778x10^{-4}$
¾ open	14	19	$7.368x10^{-4}$
½ open	14	27	$5.185x10^{-4}$

TABLE IV.
FLOW RATE READINGS FOR 1" OUTLET DIAMETER

Valve position	Volume of water (Litres)	Time (Sec)	Flow rate (m^3/sec)
Full open	14	24	$5.833x10^{-4}$
¾ open	14	24	$5.833x10^{-4}$
½ open	14	22	$6.3636x10^{-4}$

C. Calculation of theoretical input head

The input head is calculated by using the following equation for different input power and flow rate and results of the same are given in the table V.

$$h = \frac{P}{Qg\rho}$$

Where,
h=Head of water, in meter
P=Input power, in watts
g=Acceleration due to gravity, m^2/sec
ρ=Density of water, kg/m^3
Q=Flow rate, m^3/sec

TABLE V.
INPUT HEAD READINGS

Valve position	Power (watts)	Flow rate (m^3/sec)	Head (m)
Full open	372.85	$2.8x10^{-3}$	13.6
¾ open	372.85	$2.3x10^{-3}$	16.29
½ open	372.85	$1.8x10^{-3}$	21.69

D. Calculation of optimum vortex strength

The optimum vortex strength for different orifice diameters can be calculated in the following manner and calculations are given as follows;

$$Optimum\ vortex\ strength = \frac{orifice\ diameter}{Tank\ diameter} * 100$$

$$k = \frac{d}{D} * 100$$

Where,
k= Optimum vortex strength
d= orifice diameter, in meter
D=tank diameter, in meter

Vortex tank test model with 0.25m tank diameter and 0.3m tank height

1) For 3cm orifice diameter

$$k = \frac{0.03}{0.25} * 100 = 12.00\%$$

2) For 3.5cm orifice diameter

$$k = \frac{0.035}{0.25} * 100 = 14.00\%$$

3) For 3cm orifice diameter

$$k = \frac{0.04}{0.25} * 100 = 16.00\%$$

Cylindrical Vortex basin with 0.45m diameter and 0.7m basin height

1) For 2.5" orifice diameter

$$k = \frac{0.0635}{0.45} * 100 = 14.11\%$$

2) For 2" orifice diameter

$$k = \frac{0.0508}{0.45} * 100 = 11.29\%$$

3) For 1.5" orifice diameter

$$k = \frac{0.0381}{0.45} * 100 = 8.56\%$$

4) For 1" orifice diameter

$$k = \frac{0.0254}{0.45} * 100 = 5.64\%$$

5) For 0.5" orifice diameter

$$k = \frac{0.0127}{0.45} * 100 = 2.82\%$$

IV. RESULTS AND DISCUSSIONS

A. Output power calculation for 8 blade turbine

For 2.5" outlet diameter and valve full open posotion

The table VI shows the values for power and flow rate for 2.5" outlet diameter and valve position full open, for different depth of vortex. Figure 2 shows the variation of power output for different depth of vortex.

TABLE VI.
POWER AND FLOW RATE READINGS FOR 2.5" OUTLET DIAMETER AND VALVE POSITION FULL OPEN

Depth of vortex (cm)	Volume (litres)	Time (sec)	Flow rate (m^3/sec)	Voltage (V)	Current (mA)	Power (watts)
20	14	5.44	$2.57x10^{-2}$	9.3	182	1.69
25	14	5.28	$2.65x10^{-2}$	8.4	170	1.43
30	14	5.56	$2.51x10^{-2}$	7.7	153	1.18
35	14	5.22	$2.68x10^{-2}$	8	90	0.72
40	14	6.00	$2.33x10^{-2}$	7	85	0.59

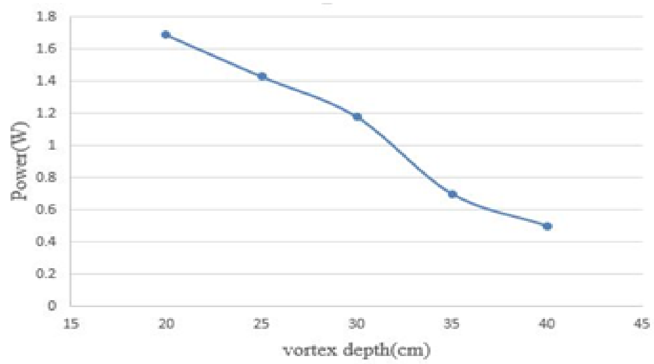

Figure 2: Vortex depth V/S Power for2.5" outlet diameter (full open)

B. For 2.5" outlet diameter and valve position ¾th open

The table VII shows the values for power and flow rate for 2.5" outlet diameter and valve position ¾th open, for different depth of vortex. Figure 3 shows the variation of power output for different depth of vortex

TABLE VII.
POWER AND FLOW RATE READINGS FOR 2.5" OUTLET DIAMETER AND VALVE POSITION ¾TH OPEN

Depth of vortex (cm)	Volume (litres)	Time (sec)	Flow rate (m^3/sec)	Voltage (V)	Current (mA)	Power (watts)
20	14	6.22	$2.25x10^{-2}$	8.73	192	1.67
25	14	6.25	$2.24x10^{-2}$	7.7	185	1.42
30	14	6.41	$2.18x10^{-2}$	6.8	132	0.89
35	14	6.22	$2.25x10^{-2}$	5.42	88	0.47
40	14	6.12	$2.29x10^{-2}$	4.32	36	0.16

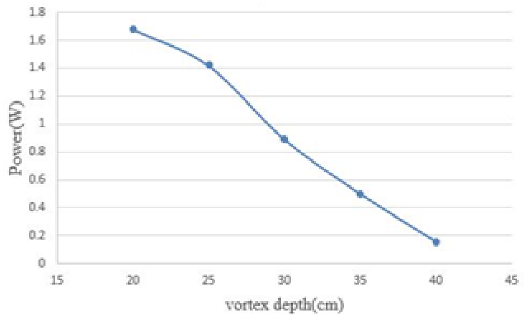

Figure 3: Vortex depth V/S Power for 2.5" outlet diameter (¾th open)

C. For 2.5" outlet diameter and valve position ½ open

The table IX shows the values for power and flow rate for 2.5" outlet diameter and valve position ½th open, for different depth of vortex. Figure 4 shows the variation of power out put for different depth of vortex

TABLE IX.
POWER AND FLOW RATE READINGS FOR 2.5" OUTLET DIAMETER AND VALVE POSITION ½ OPEN

Depth of vortex (cm)	Volume (litres)	Time (sec)	Flow rate (m^3/sec)	Voltage (V)	Current (mA)	Power (watts)
20	14	9.96	$1.41x10^{-3}$	6.68	10	0.07
25	14	9.85	$1.42x10^{-3}$	-	-	-
30	14	9.74	$1.43x10^{-3}$	-	-	-
35	14	9.54	$1.46x10^{-3}$	-	-	-
40	14	9.37	$1.49x10^{-3}$	-	-	-

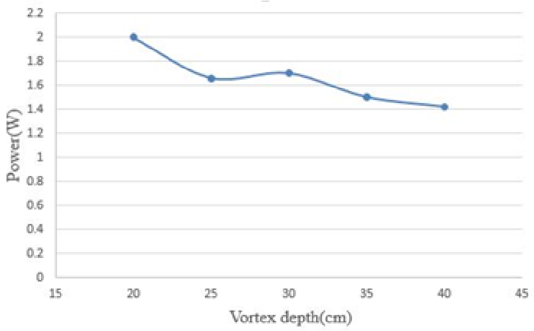

Figure 4: Vortex depth V/S Power for 1.5" outlet diameter (full open)

D. For 1.5" outlet diameter and valve position full open

The table VIII shows the values for power and flow rate for 1.5" outlet diameter and valve position full open, for different depth of vortex. Figure 5 shows the variation of power output for different depth of vortex.

TABLE VIII.
POWER AND FLOW RATE READINGS FOR 1.5" OUTLET DIAMETER AND VALVE POSITION FULL OPEN

Depth of vortex (cm)	Volume (litres)	Time (sec)	Flow rate (m^3/sec)	Voltage (V)	Current (mA)	Power (watts)
20	14	6.13	$2.28x10^{-2}$	8.68	199	2.00
25	14	5.72	$2.45x10^{-2}$	8.30	200	1.66
30	14	5.34	$2.62x10^{-2}$	8.50	200	1.70
35	14	5.94	$2.36x10^{-2}$	8.05	196	1.67
40	14	3.97	$2.35x10^{-2}$	7.68	185	1.42

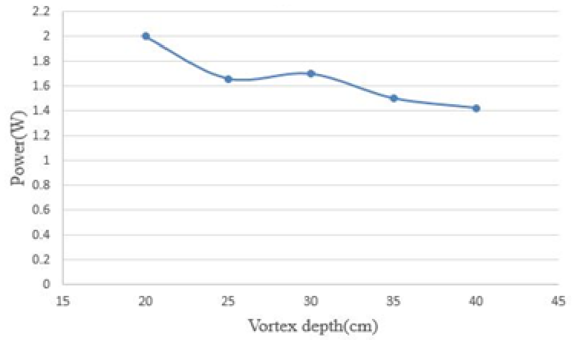

Figure 5: Vortex depth V/S Flow rate for1.5" outlet diameter (full open)

E. For 1.5" outlet diameter and valve position ¾th open

The table X shows the values for power and flow rate for 1.5" outlet diameter and valve position ¾th open, for different depth of vortex. Figure 6 shows the variation of power out put for different depth of vortex.

TABLE X.
POWER AND FLOW RATE READINGS FOR 1.5" OUTLET DIAMETER AND VALVE POSITION ¾TH OPEN

Depth of vortex (cm)	Volume (litres)	Time (sec)	Flow rate (m^3/sec)	Voltage (V)	Current (mA)	Power (watts)
20	14	6.32	$2.21x10^{-2}$	8.17	200	1.63
25	14	6.00	$2.33x10^{-2}$	7.95	182	1.45
30	14	5.35	$2.61x10^{-2}$	8.13	180	1.46
35	14	4.94	$2.83x10^{-2}$	7.92	176	1.39
40	14	5.69	$2.46x10^{-2}$	7.82	169	1.32

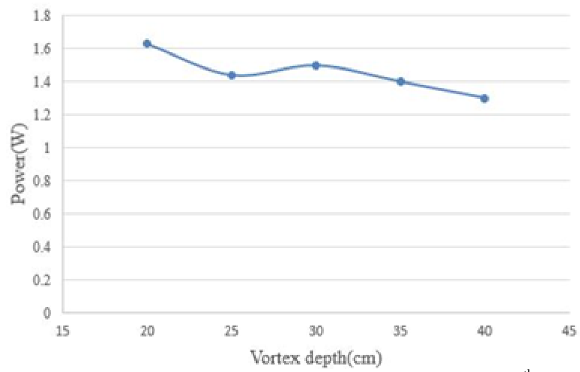

Figure 6: Vortex depth V/S Power for1.5" outlet diameter ($3/4^{th}$ open)

F. For 1.5" outlet diameter and valve position ½ open

The table XI shows the values for power and flow rate for 1.5" outlet diameter and valve position ½th open, for different depth of vortex.

TABLE XI.
POWER AND FLOW RATE READINGS FOR 1.5" OUTLET DIAMETER AND VALVE POSITION ½ OPEN

Depth of vortex (cm)	Volume (litres)	Time (sec)	Flow rate (m^3/sec)	Voltage (V)	Current (mA)	Power (watts)
20	14	9.37	$1.49x10^{-2}$	7.83	28.7	0.22
25	14	-	-		-	-
30	14	-	-	-	-	-
35	14	-	-	-	-	-
40	14	-	-	-	-	-

IV. CONCLUSIONS

Water vortex power plant model is set up by fabricating different components like the vortex basin open channel, main frame etc. and clean power is achieved by the current model. All the parameters like input head, input flow rate, vortex depth, orifice diameter are varied for the two sets of turbine blades one having 8 blades and another having 4 blades and different observations are recorded. The current model with 8 blade turbine yields a maximum power of 2 watts for the vortex depth of 20cm, input flowrate of $2.8*10^{-2}$ m^3/sec and vortex strength 0f 8.56%. The tests conducted indicates that the best position for the placement of turbine is the bottommost position. Also the input flow rate should be maximum to obtain maximum power. Larger output discharge variation are noted with and without the turbine blades. Vortex strength of 8.56% yields good result.

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