Volume: 7 Issue: IV Month of publication: April 2019

DOI: https://doi.org/10.22214/ijraset.2019.4059

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 7 Issue IV, Apr 2019- Available at www.ijraset.com

Design and Fabrication of Gravitational Vortex Water Turbine

V. Vivekananda Swami[1], J. S. D. Pavan Teja[2], K. Pavan Kumar[3], U. Naveen[4] **Dr.M.D.Ahasan[5],**
[5]*Associate Professor,* [1, 2, 3, 4]*Sri Venkateswara Institute of Science and Information Technology, Venkataramanagudem*

I. INTRODUCTION

The gravitation water vortex power plant is a type of micro hydro vortex turbine system which is capable of converting energy in a moving fluid to rotational energy using a low hydraulic head of 0.7-3 metres (2 ft 4 in -9 ft 10 in).The technology is based on a round basin with a central drain, Above the drain the water forms a stable line vortex which drives a water turbine.

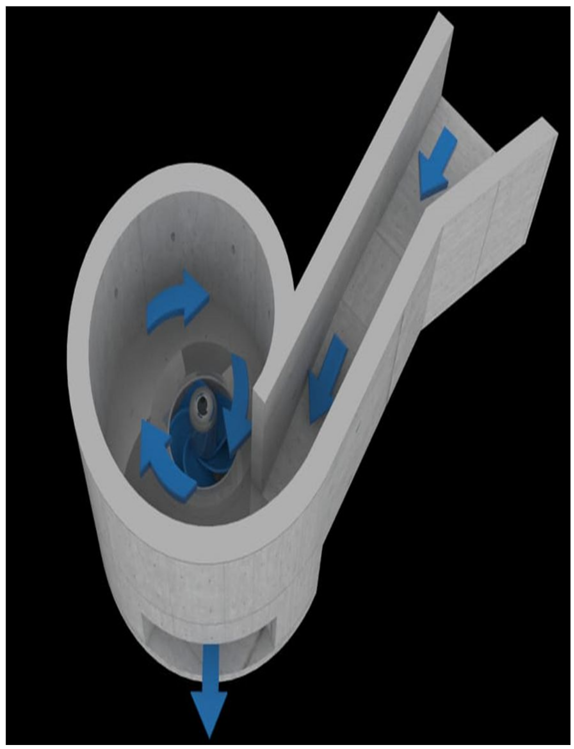

Figure : Gravitational vortex water turbine.

The gravitational water vortex turbine is an ultra-low head turbine which can operate in a low head range of 0.7 to 2m which is often seen as too low for conventional hydroelectric turbines. In addition, there is positive environmental effect on the river as water passing through the turbine is aerated.

The gravitational vortex is seen as a milestone in hydrodynamic development because was necessary in the past it to use energy to aerate water, but this technique uses a water, but this technique uses a water aeration process to produce electrical energy.

The turbine does not work on pressure differential but on the dynamic force of the vortex.

Systems range in size from <500 W to 100KW, and a series of units can be installed in a serial or parallel configuration along the river to increase power production .The limiting factors to the size of the unit are not clear but may be the formation of a vortex and the inlet and outlet size restrictions. The vortex may not form on larger basins and with larger outlets.

The use of multiple controllable smaller units is probably a better option than a single large unit. The lower size limit is seen to be a minimum head of 0.7 m and flow rate of 1kl/s although several units work with lower flow rates.

Although vortex characteristics are well understood, the mechanism behind the formation of a gravitational vortex is not. The fully developed air core vortex is often attributed to the carioles effect but this is seen to be too weak at the scale of water vortices to have any affect .In the case of the GWVPP, the initial rotation is caused by the shape of the basin and is amplified by gravitational force.

A. Several Studies have Yielded the following Useful Characteristics

1) Optimum vortex strength occurs within the range of orifice diameter to tank diameter ratios ($^{d}/_{D}$) of 14 to 18% for low and high head sites respectively.
2) The vortex height varies linearly with discharge .that is, as the discharge rate increases, the height of the vortex increases too. This impacts turbine placement as, at low discharge rates, the turbine will not be fully immersed in the water and this could limit the operational range of the system.

B. Linear Correlations for H_v and Q can be Scaled Accurately to Prototype Size

1) Maximum hydraulic efficiency should arise when the impeller velocity is half that of the fluid velocity.
2) A maximum hydraulic output of 1 kW can be obtained with a flow rate of only $0.1m^3$ and a
3) head of only 0.6 m . The simple design of the turbine makes it easy to downscale to small sizes.
4) The power output is influenced by the height of the vortex and the water flow rate Q.
5) The speed of the water and , therefore , the speed of the turbine , is affected by the kinetic energy of the water flowing into the turbine and the potential energy of the hydraulic head .
6) Depending on how the intake channel is placed, the water flow rate can be influenced by the speed of water flowing in the river. If the intake is placed at right angles to the flow, the effect will be less than if the intake were placed in the line of flow. Higher flow rates will increase output power above that of a static body of water.
7) The efficiency of the turbine is defined as the mechanical or electrical power output compared to the theoretical hydraulic power available. Studies indicate efficiencies in the region of 30 to 40% while commercial claims go as high as 80%. An efficiency of 50% will give 500 W output for a flow rate of $1m^3/s$ and a head of 0.6 m.

II. PERFORMANCE OF A GRAVITATION VORTEX WATER TURBINE:

Many large-scale conventional hydraulic power generations mainly use medium- or high-heads and water turbines [1, 2] for conduits, such as the Francis water turbine.

Recently, however, as public consciousness about renewable energies has risen, the demand for small-scale hydraulic power generation with a water turbine [3, 4] for open channels has been increasing, with the use of so-far unused common rivers or waterways that have low heads and low flow rates.

Therefore, we focused on a water turbine used in the Gravitation Water Vortex Power Plant (GWVPP) [5], which generates electricity with a low head and a low flow rate .This gravitation vortex type water turbine mainly comprises a runner and a tank.

On introducing a flow of water into the tank, the turbine generates electricity from the gravitation vortex that occurs while draining the water from the bottom of the tank. In addition, it is thought that this water turbine has an aeration function to raise the dissolved oxygen concentration of the downstream water by rolling up the air above the free surface around the runner.

Despite the fact that this water turbine has a relatively simple structure, the flow field is extremely complicated because of its free surface. However, although some studies on other types of runners related to this kind of water turbine have been presented [6, 7], their flow fields have not been investigated in detail.

To improve the performance of the water turbine, it is important to study the flow field in detail in order to determine its relevance to the performance characteristic. Although a numerical analysis is effective for this, because this water turbine operates by using a gravitation vortex, it is necessary to conduct a numerical analysis with consideration to the free surface. Because a numerical analysis with consideration to the free surface requires a large computational load, there are few examples of where it has been applied to a water turbine. Recently, however, it has started to be applied to a spiral water turbine [8], an undershot cross-flow water turbine [9, 10], and a propeller water turbine [11, 12].

In light of this background, this study aims to clarify the performance of a gravitation vortex type water turbine and elucidate its flow field.

We performed numerical analysis by considering the free surface, conducted a performance test and a visualization experiment, and verified the validity of our analysis. Furthermore, we examined the flow field around the runner at the center of the blade width in detail using a numerical analysis.

III. EXPERIMENTAL APPARATUS AND METHODS

Gravitation Vortex Type Water Turbine:

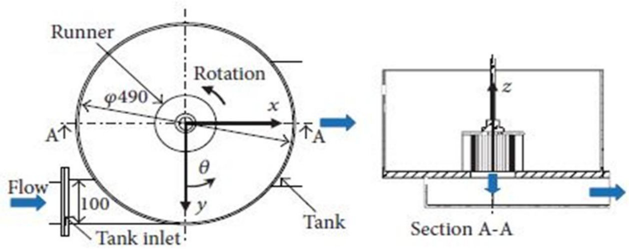

Figure: Test water turbine

An overview of the gravitation vortex type water turbine is shown in Figure. This water turbine mainly comprises a runner and a tank and generates electricity from the gravitation vortex that occurs in the tank when the water is drained. An overview of the runner, and its specifications are given in Table. This runner has a centrifugal form, which is different from the form of the paddle-type runner that has been used in previous studies [6, 7].The blade inlet diameter (outer diameter) is D_1 = 140 mm, blade outlet diameter (inner diameter) is D_2 = 90 mm, blade inlet width is b_1 = 91 mm, blade outlet width is b_2 = 91 mm, and number of blades is z = 20. Section B-B in Figure 2 is a section at the center of the blade width.

The inner diameter of the cylindrical tank is 490 mm, and the diameter of the hole at the bottom of tank is 100 mm.

In addition, the coordinate system is defined as shown in Figure. The circumferential angle θ I is defined as $\theta = 0$∘ on the positive y axis, and its positive direction is

Counter clockwise.

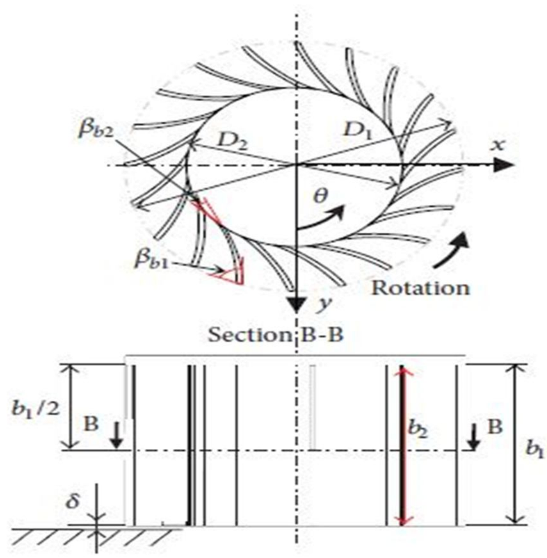

Figure: Runner

Specifications of runner.

Outer diameter: D_1	1 0.14m
Inner diameter: D_2	0.09m
Inlet width: b_1	0.091m
Outlet width: b_2	0.091m
Inlet angle: β_{b1}	71.9°
Outlet angle: β_{b2}	19.1°
Tip clearance: δ	0.5mm
Number of blades: Z	20

An overview of the experimental apparatus is shown in Figure. The flow rate Q of water supplied by the pump was measured with an electromagnetic flow meter (Toshiba Corporation;
LF620). The experiment was conducted under the condition of constant flow rate Q = 0.00285m3/s.
The load to the runner was controlled by a motor and an inverter, and the rotational speed was arbitrarily set. The rotational speed n and torque T were measured with a magnetic rotation detector (Ono Sokki Co., Ltd.; MP-981) and a torque detector (On SokkiCo., Ltd.; SS-005), respectively. The turbine output P was obtained by

$$P = \frac{2\Pi nt}{60} \quad - (1)$$

Here the torque T was corrected by measuring the idling torque without the runner. The effective head H is defined by the following as shown below,

$$H = h^1 + h_3 + \frac{v^2{}_3}{2g} - h_4 - \frac{v^2{}_4}{2g} \quad - (2)$$

Here the upstream water depth h3 was measured at the tank inlet in the vicinity of the wall surface on the +y-axis with a ruler. The downstream water depth h4 was measured by a point gauge (Kenek Corporation; PH-102) at five points from the vicinity of the wall surface on the +y-axis to the center at the position of 6D_1 downstream from the downstream atmospheric opening from which the average water depth was obtained. The upstream velocity v3 and downstream velocity v_4 were calculated by

$$V_3 = \frac{Q}{B_3 h_3} \quad - (3)$$

$$V_4 = \frac{Q}{B_4 h_4} \quad - (4)$$

Here B_3 and B_4 are the waterway widths of the tank inlet and downstream, respectively. In addition, the turbine efficiency η was calculated by

$$\eta = \frac{P}{\rho g Q H} \quad \_ (5)$$

A digital camera (Casio Computer Co., Ltd.; EXILIM EXF1) was used to visualize the flow field at a frame rate of 30 frames per second (fps).

A. Theoretical Calculation

Effective head (H):

$$H = h^1 + h_3 + \frac{{v_3}^2}{2g} - h_4 - \frac{{v_4}^2}{2g}$$

$$v_3 = \frac{Q}{b_3 h_3} = \frac{0.00285}{0.1*0.3} = 0.095\, m/sec$$

$$v_4 = \frac{Q}{b_4 h_4} = \frac{0.00285}{0.4*0.15} = 0.0475 \text{ m/sec}$$

$$H = h^1 + h_3 + \frac{{v_3}^2}{2g} - h_4 - \frac{{v_4}^2}{2g}$$

$$= 0.20 + 0.3 + \frac{(0.095^2)}{2*9.81} - 0.15 - \frac{0.0475^2}{2*9.81}$$

$$= 0.20 + 0.3 + 4.599 * 10^{-4} - 0.15 - 1.149 * 10^{-4}$$

= 0.3503 m

The maximum hydraulic power output of the turbine is given by

$$P = r * g * Q * h_v$$

Where

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 7 Issue IV, Apr 2019- Available at www.ijraset.com

H_v = height of vortex (m)
Q = flow rate (m^3/sec)
r = water density (kg/m^3)
g = Gravitational constant

By considering vortex height:

$$P = r * g * Q * h_v$$

= 1000*9.81*0.0134*0.3
= 39.43 watts

By considering effective head (H):

$$P = r * g * Q * h_v$$

= 1000*9.81*0.0134*0.3503
= 46.048 watts/hr

IV. MODELING AND SIMULATION

For modelling and simulation we used SOLIDWORKS 2013*64 Edition SP03 software. We assumed the design parameters from the research article Performance and Flow Field of a Gravitation Vortex Type Water Turbine.

A. Modeling

As per the design parameters we modelled all the parts in the solid works software as shown in the following figures:-

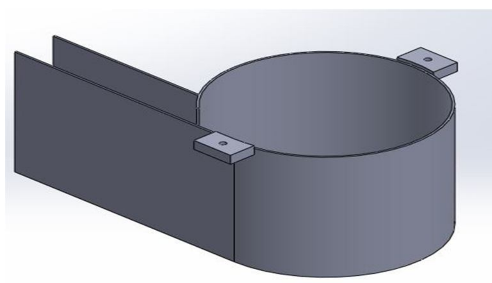

Figure: Water basin

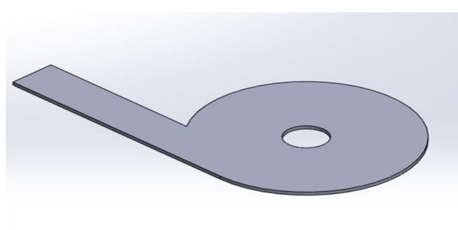

Figure: Water basin base plate

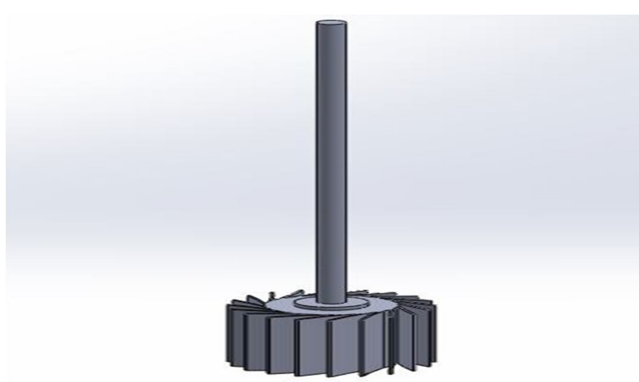

Figure: Turbine blade and shaft assembly

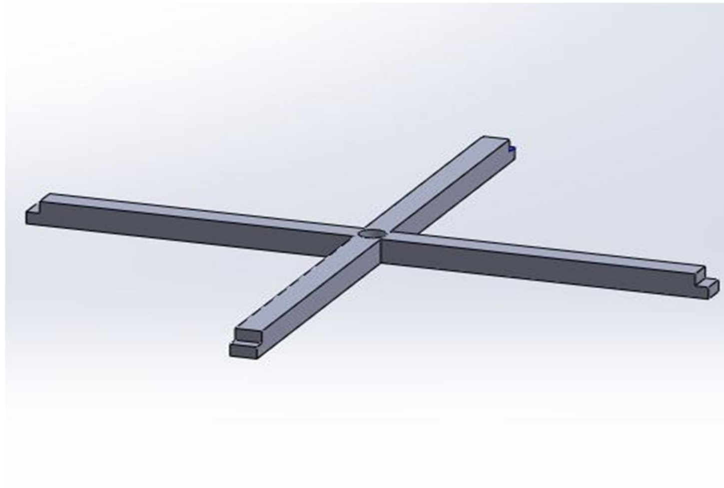

Figure: Top frame for supporting blade and dynamo

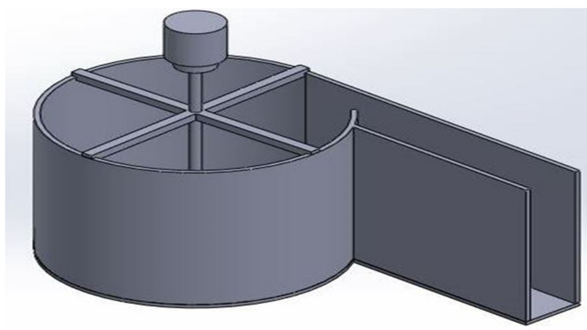

Figure: Assembly of turbine.

B. Simulation

Simulation is defined that it is an attempt to model a real-life of hypothetical situation on a computer so that it can be studied to see how the system or a component or a device works. By changing variables in the simulation, predictions may be made about the behaviour of the system. It is a tool to virtually investigate the behaviour of the system under study conditions.

Solid works simulation is an easy-to-use portfolio of structural analysis tools that use the finite element analysis (FEA) method to predict a products real-world physical behaviour by virtually testing CAD models, the portfolio provides linear, non-linear static and dynamic analysis capabilities.

Here we performed flow simulation to study the work conditions and determine the values or results.

We performed the simulation in two cases:

1) CASE-1: In case-1 the design is taken as per the research article on Performance and Flow of a Gravitation Vortex Type Water Turbine. There is no change in the design but, we created the lid at the top to make it water tight.

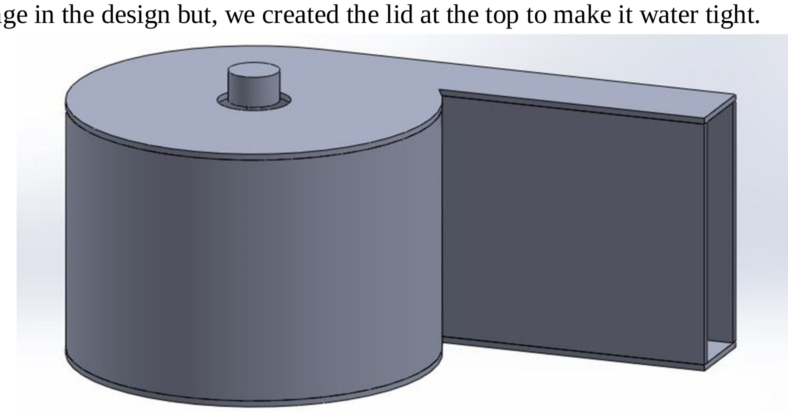

Figure: Model for case-1

The result are obtained for the case-1 are as shown in the figure

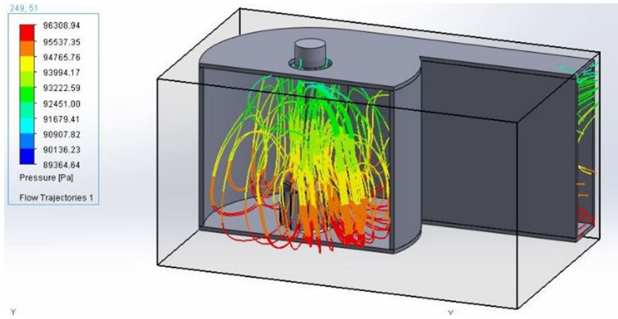

Figure: Flow trajectories for case-

Here we considered the velocity in the direction of the flow which is calculated in the theoretical calculations, to check whether the design is acceptable or not.

2) CASE-2

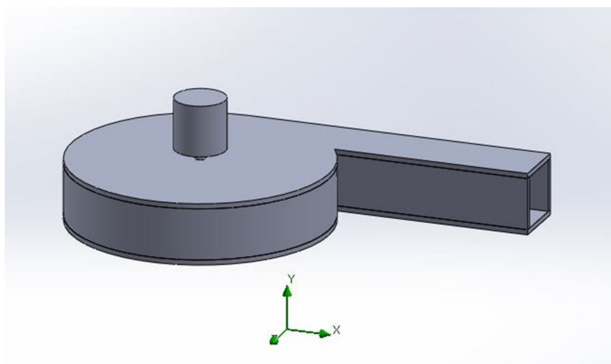

Figure-24: Model for case-2

In case-2 we had changed the design. In this we reduced the height of the turbine basin to reduce the usage of material and the results obtained in this case are as shown in the figure below.

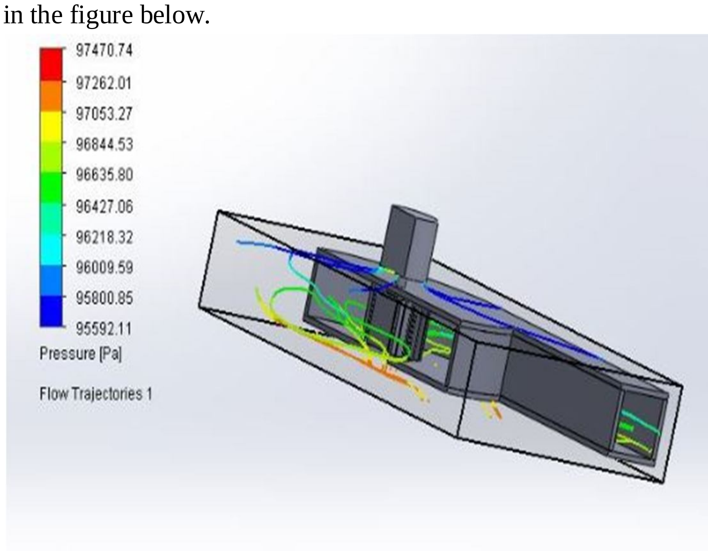

Figure: Flow trajectories for case-2

Here in case-2 the results obtained are not suitable because the velocity in Y-direction is very less as compared with the case-1 so we fabricated the turbine by considering the case-1.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 7 Issue IV, Apr 2019- Available at www.ijraset.com

V. FABRICATION OF GRAVITATION VORTEX WATER TURBINE:

For fabrication of gravitation vortex water turbine we used the following materials as follows:

A. List of Materials

1) Ply wood
2) Fibber sheet
3) Sun glass
4) M.S flat of 5mmthickness
5) Fevicol SR-998 (synthetic rubber adhesive)
6) Nut and bolts
7) Fevicol-SH (synthetic resin adhesive)
8) Dr.Fixit Silicon Selent
9) SS pipe of
10) MS angular
11) SS Square pipe
12) SS 2mm gauge GI sheet
13) Pipe of 90mm diameter
14) M-Seal
15) Fevi-Kwik
16) Plastic pipes of 4inch and 2inch diameters
17) 90̊ 2inch diameter pipe elbows
18) Bearing
19) Bead pulley of
20) Machine pulley of
21) DC dynamo motor (9V-12V)
22) Timing thread
23) LED light(3.5V)
24) LED light strip
25) Wires

B. Fabrication Process

1) Step-1

Figure: Marking on ply wood

The ply wood of 6*3feet of 27mm thickness is taken and the design of the turbine is marked on it and a slot is cut along the marking to fix the fibber sheet and a drain hole is also drilled at the centre.

2) Step-2

Figure: Sun glass

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 7 Issue IV, Apr 2019- Available at www.ijraset.com

The sun glass is sticked up on the surface of the play wood for making it water proof and to give a good appearance.

3) *Step-3:* Now the fibbed sheet is cut into 350mm height and 3feet width pieces to fit in to the slot
4) *Step-4:* All the pieces Are fitted into the slot and pieces are joined together with the other pieces to form the turbine basin as shown in the figure.

Figure: Fixing the fibber sheet in the slot.

5) *Step-5*

Figure: Silicon sealant & a glue gun

The joints at the bottom of the fibre are now made water proof by applying the silicon sealant and to make them water tight and a pvc elbow of 4inch diameter is connected at the bottom of the drain hole for the outlet of the water.

Figure: Applying the sealant with fingers to make a water tight sealing

6) *Step-6:* Now the turbine blade is made by using the MS pipe of 90mm diameter as centre and 2mm SS GI sheet pieces as blades

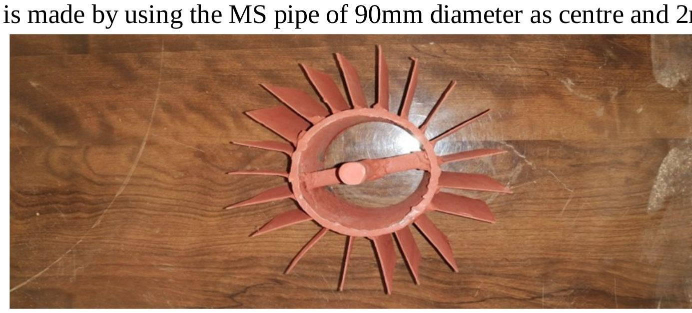

Figure: Designed blade

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 7 Issue IV, Apr 2019- Available at www.ijraset.com

7) *Step-7:* Now the stand for the entire set up is made by using the Singulars and SS square pipe.

Figure: Stand

8) *Step-8:* Now the blade is welded to the SS pipe and wooden pieces are inserted upon the pipe and bearing is welded to the shaft at a required height for supporting the shaft and to rotate the blade freely.
9) *Step-9:* Now the bead pulley is fixed on the top of the shaft and the DC dynamo motor is fixed at on side of the wooden block at an equal height of the pulley. now the bead pulley and the dynamo motor pulley are connected by means of the timing thread, as shown in the figure so when the bead pulley rotates the dynamo motor also rotates.

Figure: Fixing the wooden blocks and bearing to the shaft.

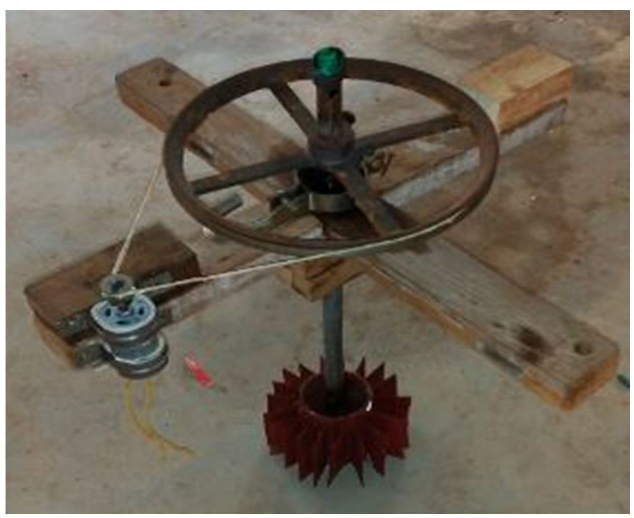

Figure: Blade and dynamo unit

10) *Step-10:* Now the entire blade and dynamo unit is fixed to the clamps on the top of the water basin and the fabrication is completed.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 7 Issue IV, Apr 2019- Available at www.ijraset.com

VI. OPERATION

In the vortex power plant, water is introduced into a circular basin tangentially; creating a free vortex and energy is extracted from the free vortex by a turbine as shown in figure.

Figure: Working image of gravitation vortex water turbine

The system operates as follows

A. River water is channelled at the bank of the river and conveyed to a circulation tank has a circular orifice at its base
B. The combination of localised low pressure at the orifice and the induced circulation at the tangential entry influences strong vortex flow.
C. Potential energy is entirely converted to rotational kinetic energy at the vortex core. This is then extracted by means of a vertical axis turbine.
D. Water is then returned to the river through the tail race.
E. The turbine, which is located at the top the vortex, is turned by the rotary motion of water in the vortex.

This type of power plant can be installed at rivers or streams as the hydraulic head requirement is as low as 1 m. water may be fed to the vortex turbine through an open channel or, in some cases, through a closed conduit or pipe , which is more suitable for smaller systems. Although the vortex structure is very basic and simple, analysis of the operation is not, and involves complex computational fluid dynamics (CFD) modelling. Many of the studies published on the topic make use of computerised modelling and are fairly difficult to understand.

VII. ACTUAL CALCULATIONS:

From the experimental setup h_3, h^1, h_4 , B_3 , B_4 are taken
Discharge (Q) = 0.01995 m^3/sec
B_3 = inlet stream width = 0.098 m
B_4= outlet stream width = 0.105m
h_3=inlet stream height = 0.195m
h_4 = outlet stream height = 0.09m
Shaft speed (N) = 120 rpm
Dynamo speed (N) =225rpm
Height of vortex h_v =220 mm

1) Effective head:

$$H = h^1 + h_3 + \frac{v^2{}_3}{2g} - h_4 - \frac{v^2{}_4}{2g}$$

$$V_3 = \frac{Q}{B_3 h_3} = \frac{0.01995}{0.095*0.195} = 1.076\ m3/sec$$

$$v_4 = \frac{Q}{B_4 h_4} = \frac{0.01995}{0.105*0.195} = 2.11\ m3/sec$$

$$H = 0.165+0.195+ \frac{(1.076)^2}{2*9.81} -0.09- \frac{(2.11)^2}{2*9.81}$$

$$= 0.165+0.195+ 0.059-0.09-0.2271$$

= 0.102m

Power (p)

$$P = r * g * Q * h_v$$

=1000*9.81*0.01995*0.102

=19 watts

By considering vortex height:

Vortex height h_v =220mm = 0.220m

Power (p):

$$P = r * g * Q * h_v$$

=1000*9.81*0.01995*0.220

= 43 watts

VIII. CONCLUSION

The following results were determined by our performance analysis of a gravitational vortex water turbine:

A. By doing this analysis we determine that the power produced by this turbine is of 43V, which helps in use of domestic purpose.
B. The turbine is tolerant of muddy and polluted water, as the vortex action carriers small solid particles through the turbine. So the maintenance of this kind of turbine is less as compared to other type of turbines.
C. The turbine is claimed to be eco-friendly . The turbine, which operates at a low speed does not cut the natural stream of water so does not harm aquatic and marine life.

IX. FUTURE SCOPE

A. Hydropower is an important renewable energy resource in worldwide, The gravitational water vortex power plant is an economic and clean energy system allowing for the conservation of low head streams for generation of power.
B. These hydro power plants have good potential for providing electricity to remote communities.
C. Imagine you could use any kind of small head difference in a river or canal. The power produced by this turbine might surprise you.
D. We created a technology that can make use of all these small waterfalls or canals in a way that safe for the environment. That's why we have a project that improves the world just that little bit in power generation.
E. This project can be used in any urban or rural areas for power generation with low investment cost.
F. This turbine will generate energy in 24/7 at an incredibly low cost of energy, so the cost of power generation will be less with low maintenance.

REFERENCES

[1] Brown, S. Muller, and Z. Dobrotkova, "Renewable energy markets and prospects by technology," International Energy Agency (IEA) Information Paper, International Energy Agency (IEA), Paris, France.
[2] International Renewable Energy Agency (IRENA), "Renewable energy technologies—cost analysis series, volume 1: power sector," IRENA Working Paper 3/5, 2012.
[3] H. Locker, Environmental Issues and Management for Hydropower Peaking Operations, United Nations, Department of Economic and Social Affairs (UN-ESA), 2004.
[4] R. Venkateswaran, "Small hydro potential in India," in Proceedings of the International Conference on Association for Small Hydropower, Hangzhou, China, June 2007
[5] H. Raghunath, Hydrology: Principles, Analysis and Design, New Age International, New Delhi, India, 2nd edition, 2009.
[6] J. Perez-Diaz, J. Sarasua, J. Fraile-Ardanuy, J. Wilhelmi, and J. Sanchez, "A control system for low-head diversion run-ofriver small hydro plants with pressure conduits considering the tail water level variation," in Proceedings of the International Conference on Renewable Energies and Power Quality (ICREPQ'10), Granada, Spain, March 2010.
[7] International Energy Agency, Hydropower and the Environment: Present Context and Guidelines for Future Action, Subtask 5 Main IEA Report, Volume 2, International Energy Agency, Amsterdam, The Netherlands, 2000
[8] Y. Gogus , "Pumped water energy storage," in Energy Storage Systems, vol. 1, pp. 281–301, Encyclopedia of Life Support Systems, 2011.
[9] B. Brook, Pumped Hydro Energy Storage—Cost Estimates for a Feasible System, Bravenew Climate, Adelaide, Australia, 2010.
[10] M. R. Mohan, S. R. Paranjothi, and S. Prince Israel, "Use of pumped-hydro as peak-load management plant in optimal scheduling of power systems," Electric Machines and Power Systems, vol. 25, no. 10, pp. 1047–1061, 1996
[11] Intergovernmental Panel on Climate Change, "Special report on renewable energy sources and climate change mitigation, chapter 5: hydropower," Special Report of IPCC, Cambridge University Printing Press, 2012.
[12] A. Bauen, "Future energy sources and systems—acting on climate change and energy security," Journal of Power Sources, vol. 157, no. 2, pp. 893–901, 2006.