Design And Fabrication Of Prototype Of Gravitational Water Vortex Power Plant

Fahad Raza[1], Luqman Ahmed[2]
[1]Department of Aerospace Engineering
College of Aeronautical Engineering, NUST
fahadrazapcs@gmail.com

[2]Department of Aerospace Engineering,
College of Aeronautical Engineering, NUST
luqmanahmed@cae.nust.edu.pk

ABSTRACT

As we know energy demand is increasing day by day, so it is a dire need of this era to get know about new and modified sources of renewable energy. Renewable energy can be obtained by water, wind and solar energy etc. But my main focus is on hydro energy especially through vortex. The design of the runner for the turbine was performed by myself with help of a set of equations. The main purpose behind this power plant is to generate electricity for those who cannot afford very high rates of electricity, especially employees of mountain ranges. It has no harmful effects on marine life. Although a lot of agencies are working on this technique. However, there are still deficient literature sources available for the technique to push on the modeling stage. The extreme value of efficiency which was achieved by the previous strugglers was approximately 30% while the commercial agencies affirmed about efficiency of 50% with power generation of 500W to 20kW. Hence, the purpose is to clinch the blank of vortex power generation unit technique advancement with the help of a cloud of research directions and previous works will be established as deeds to enhance the development of GWVPP.

Keywords: GWVPP, Renewable Energy, Power Generation, Electricity, hill stations.

1. INTRODUCTION:

Gravitational vortex water power plant is a useful approach which produces power from substitute and regenerated originator of energy production. In this vortex power plant, the fluid taken as water is inserted into a basin having circular shape at tangent to blades of turbine which forms a freely vortex and potential is taken out from the free vortex with the help of turbine. The most important assets of such kind of power plant is to produce power from very low hydraulic pressure and which is an atmosphere beneficial. The low hydraulic heads need was no more than 1 m, that kind of power production unit can be established at the stream or river to enlighten for the some residences. It is a unique and not well-developed technique to generate power from small level and slightly pressurized water energy resources. There is confined literature sources present on the modeling and formation and visible geometry of vortex runner and generator. Previous researchers give their attention on the basin geometry, inlets and outlets diameters and manufacturing of efficient turbine design. However, there are still deficient literature sources available for the technique to push on the modeling stage.

As turbine, inlet and outlet and basin configuration are considered. I surveyed many papers of well-known authors, who have contributed to design blades of turbines. The main purpose is to make more and more efficient.

Marian G-M, Sajin T. were paid their contributions toward the positioning of turbine. They concluded that vortex produced in rotating water is directly proportional to rotational speed of runner and height of vortex also influences the efficiency of GVPP. Turbine carries out more and more power near to draining orifice of basin. The results obtained after experiments agreed well with the previous observations. Aravind Venukumar did theoretical research on GWVPP. He mainly focused on design of turbine blades. He found that more than 150W of power will be produced by it. That's why creating a irregular circular movement of fluid flow layers, Artificial Vortex (ArVo) power generation employs the common liability of circular current generation of water by setting a latest fluid flow-pattern. While creating least eruption to the mocked forced vortex or cyclone, a V.A turbine was composed, and fabricated so as to retrace the flow of fluid. In other words we can say that in ArVo power generation, by utilizing a strong Gravitation Water Vortex in a rotation tank (ArVo tank) the kinetic energy of flowing water was centralized. This energy was spotlighted in the form of rotational power to the runner in the middle of the water vortex. Then runner transforms this rotational power of fluid vortex together with a generating motor to produce power.

Subash et. al. put his efforts towards GWVPP. His research methodology was experimental. He worked on turbine positioning and turbine blade numbers. He found that maximum energy output was taken out near draining orifice, power will be reduced as blades number will rise. Gravitational water vortex turbine is an ultra-low head turbine that could be accomplished as low head as 0.75m with same production like traditional hydroelectric turbines specified with feasible atmospheric generation.

Sagar et. al. put his efforts towards GWVPP. His research methodology was experimental. He worked on turbine location and structure of the basin. He found that secured positioning of runner is 60% - 70% of height of GVPP , conical basin has maximum collectively power output and maximum efficiency was 36.84%. Energy demand in the world is always rising, specifically in progressing domains due to a lot of production factories and high level residential areas. For its clean generation, regenerative power source is looked as hydropower which Is becoming the most demandable source of power.

Christine et. al. put his efforts towards GWVPP. His research methodology was experimental. He worked on number of blades and size of blades of runner. He concluded that efficiency is directly proportional to quantity of blades and size of blades and maximum efficiency was 15.1%. Worldwide energy utilization is keep growing appreciably, pointing such problems as rising energy by emission of gasses related to greenhouse, lessened the supply security, and enhancing fuel expenditures. Renewed sources, like hydropower, provide a compensative source of energy to fulfill the emerging supply.

Swiderski J., et al. made the research worked on the unique layout flow pattern for hydro turbines. Influencing editor of geometry was yoked through a set of data files by using the software of 3D viscous flow analysis. Researchers showed the main overview of the design pattern as well as archetype of the rendering optimal design. It clarified that researchers are accounting it for design goals in the small hydropower field assuming that the CFD results are worth full.

RESEARCHES	RESEARCH METHODOLOGY	RESEARCH PARAMETERS	FINDINGS
Marian et. al.	Theoretical	Position of multiple turbines	• Vortex ∝ rotational speec • Vortex height affect the efficiency of GWVPP
Aravind Venukumar	Theoretical	Turbine blades design	• Produced more than 150W of power.
Sagar et. al.	Experimental	Position of turbine	Optimal position of turbine is 65% to 75% of GWVPP's height
Christine et. al.	Experimental	Size and number of blades of turbine	Efficiency ∝ size and numbe of turbine blades

Table 1. Comparison of findings of differents researchers about runner design.

Wanchat et. al. put his efforts towards GWVPP. His research methodology was experimental. He worked on variable outlet diameter of basin. He concluded that the range of outlet diameter is 0.20m to 0.35m and size of turbine and maximum efficiency was 30%. A gravitation vortex type water turbine which is the most importantly consists of a blade runner and a basin. It produces electricity by inserting a flow stream of water into the basin and then by using the gravitation vortex which is generated when the water goes out from the bottom orifice at the base of basin. This water turbine is able of producing power by using a low head water reservoir and a low water flow rate with comparably easy structure.

Shabara et. al. put his efforts towards GWVPP. His research methodology was experimental and also did CFD analysis. He worked on variable outlet diameter of basin. He concluded that outlet velocity is proportional to the inverse of exit diameter of the basin, exit velocity should be maximum with highest inlet point and size of turbine and maximum efficiency was 40%. Small hydropower plants can be looked forward to have a good dormant to accommodate electricity to under developed colonies. That document displays the work to converge the vortex pool to maximize the energy transmission and hence produce electricity from low water heads of between 0.7m to 3m.A numerical study was made out by using the software to find out the main parameters influencing the efficiency of the energy transmission.

Christine et. al. put his efforts towards GWVPP. His research methodology was experimental. He worked on inlet flow rate and inlet flow channel. He concluded that by maximizing the inlet flow rate, efficiency will be maximized and the allocation of height channel is at 1/3 of height of basin.

RESEARCHES	RESEARCH METHODOLOGY	RESEARCH PARAMETERS	FINDINGS
Wanchat et. al.	Experimental	Outlet diameter varied	• Maximum efficiency = 30% • Outlet diameter between range of 0.20m and 0.35m
Christine et. al.	Experimental	Inlet flow rate H-channel	• Highest efficiency at maximum inlet flow rate • Optimal H-channel at one-third of basin's height

Table 2. Comparison of findings of differents researchers about inlet and outlet design..

Wanchat and Suntivarakorn put his efforts towards GWVPP. His research methodology was about simulation. He worked on structure of basin. He concluded that by best flow field was that in which inlet guides were the part of cylindrical basin

Sagar et. al. put his efforts towards GWVPP. His research methodology was about simulation. He worked on dominant basin parameter. He concluded that Water inlet should be small as much as can be made, inclination of basin should as big as possible, the location of inlet stream should be high and should not exceed from the optimized value. That writing is despicable to only a study that centers on rising the efficiency of the water free vortex runner by setting up the baffle plates on propellers. In order to determine feasible size and proportion for the baffle plates, that study accounted the CFD program to make baffle plates which is of 45cm in diameter and of 32cm in height. The conclusions depicts that 5 baffle plates, with a propeller baffle area of 50%, provided the maximum extent of torque. Propellers, with no baffle plates, were also formed and were examined along with a turbine with 50% baffle plates at the flow rate of 0.04 – 0.06m^3/s. The results proved that the propellers with a 50% baffle plate proportion aided to rise the torque of 10.25% on an average and overall efficiency of 4.12% on an average.

RESEARCHES	RESEARCH METHODOLOGY	RESEARCH PARAMETERS	FINDINGS
Wanchat and Suntivarakorn	Simulation	Basin's structure	Cylindrical basin with inlet guide has the best flow field
Sagar et. al	Simulation	Basin's dominant parameter	W-in should be small as possible Cone angle should be as big H-channel should be high Shouldn't exceed optimum value

Table 3. Comparison of findings of differents researchers about Basin design.

I have searched a lot of literature about the runner designs and encountered with three types of water turbines. Kaplan, Pelton and Francis turbines. And came to a result that Kaplan is the highly suitable turbine because it gives maximum value of power at low head. According to literature, I came to know that there a lot of parameters which affects the performance of the turbine. Like number of blades, shaft diameter, leading and trailing edge angle of blades, composition material, direction of flow interaction and radius of curvature of blades.

Pelton	• For high head • at low mass flow rate • flow direction is tangential.
Francis	• For appropriate head • moderate flow rate • flow direction is mixed.
Kaplan	• Operated at low head (upto 25m • very high mass flow rate • flow direction is axial

Table 4. comparison of water turbine

But at bachelors level, I designed the runner of simple curved plates by calculating the affecting parameters described earlier. Mainly these parameters can be seen through the velocity diagrams of turbine blades.

2. PARAMETERS IDENTIFICATION

The first step is identification of the parameters which affects the GWVPP. By going through the literature review, input and output parameters are segregated on the basis of their behavior on the working of GWVPP.

The main assumptions, selected to solve it analytically, were as follows.

1. The pressure and head losses should be kept as negligible.
2. The velocity is uniform along the length of the runner, with which the water strikes the runner.
3. The flow in the water vortex should be considered inviscid and irrotational.
4. Boundary conditions at inlet and outlet of system
   - Inlet: Normal velocity with αair:0 and αwater:1

- Outlet: Opening with opening pressure and αair:1 and αwater:0
- Upper surface: Opening with opening pressure and αair:1 and αwater:0

The input parameters are inlet and outlet blade angles (α1 and α2), inner and outer diameter of runner, height of the water source(H), volumetric flow rate (Q), height of water inlet and upper surface of runner (h) and vortex radius (r). The output parameters are theoretical power and theoretical efficiency. By setting some ranges, I came to know about the variation of trends between input and outputs.

3. CALCULATIONS OF PARAMETERS

As these trends were came by using the impulse turbine equations. The velocity diagrams were considered to find out the values of velocity components the turbine and behavior of the vortex flow. The angular velocity component (VΘ) is kept equal to zero. The total velocity of the fluid is along the tangential component (Vo) . The velocity diagrams as follows.

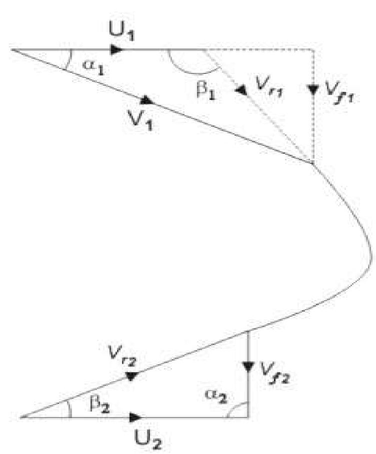


Fig 1. Velocity diagram of runner blades.

The equations to calculate the velocity components

$$Vo = 0$$

$$V\theta = K + 2\pi r \qquad (1)$$

$$K = \frac{Q}{h} \qquad (2)$$

$$Nt = {}^{39\sqrt{H}}/_{OD} \qquad (3)$$

K denotes the vortex strength, r shows the vortex radius and **Nt** shows the rpm of the generator.

Equation (2) shows that vortex strength is directly proportional to the volumetric flow rate.

Equations for the inlet parameters of the blades given below.

$$Vt = \sqrt{2}gH$$

$$V1 = Vt + V\theta$$

$$U1 = \pi * OD * \frac{Nt}{60}$$

$$Vf1 = V1 \sin \alpha 1$$

$$Vr1 = V1 \cos \alpha 1$$

$$\beta 1 = \tan^{-1}(\frac{Vf1}{Vr1 - U1})$$

Similarly, the equations for outlet are follows as

$$U2 = \pi * ID * \frac{Nt}{60}$$

$$V2 = Vf2 = Vf1$$

$$\beta 2 = \tan^{-1}(\frac{Vf2}{U2})$$

$$Vr2 = Vt \cos \beta 2$$

To calculate the radius of curvature of blade

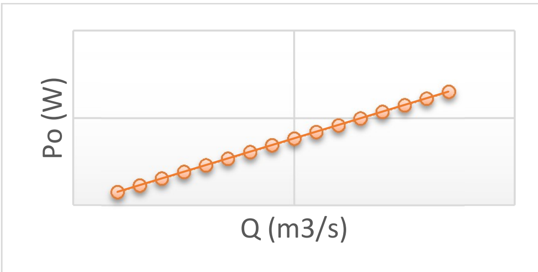
$$R = \frac{OD^2 - ID^2}{2 * OD * \cos \beta 1} \qquad (4)$$

In general the basic relations of theoretical power and theoretical efficiency in terms of basic terms

$$P = \rho Q g H \quad (5)$$

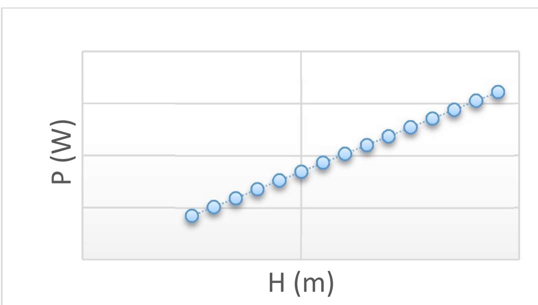
$$\eta = \frac{39}{60}\frac{[((\sqrt{2g}\ )+\frac{Q}{2\pi rh})(\pi * Cos\beta\ )]}{g\sqrt{H}} \quad (6)$$

Equation (5) shows that Power is mainly affected by both Q and H as shown in graphs below.



Graph 1. Relation between power and voumetric flow rate

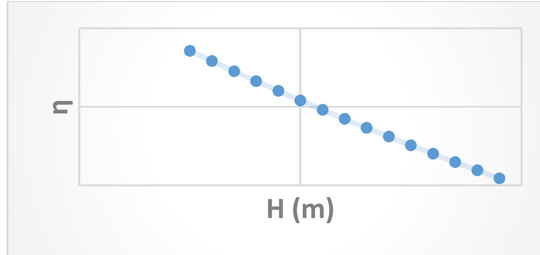
This graph shows the relation between power output and volumetric flow rate. As we rise flowrate, the bulk of water on the runner also rise and more momentum is shifted to shaft and generate more power.



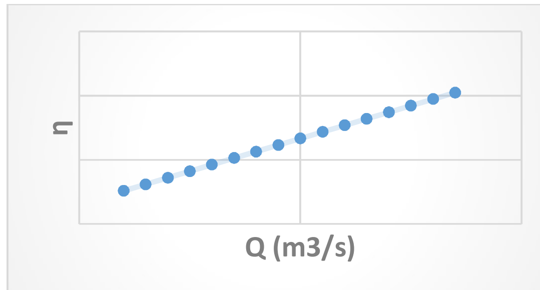
Graph 2. Relation between power and Head height

This graph shows the relation between power output and head height. As we rise head of water, it ultimately rises the power output because more amount of potential energy is gained by water and it converted into kinetic energy.

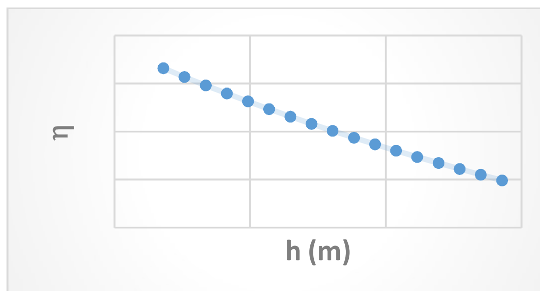
Similarly equation (6) shows that efficiency is depending upon H, Q, h, r and β1 as given below in graphs.



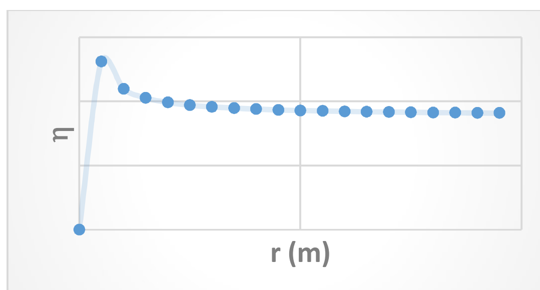
Graph 3. Relation between efficiency and Head height



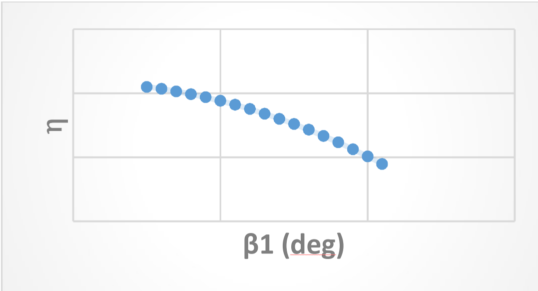
Graph 4. Relation between efficiency and volumetric flow rate



Graph 5. Relation between efficiency and vortex height



Graph 6. Relation between efficiency and vortex radius



Graph 7. Relation between efficiency and blade inlet angle

By keeping the some constrains, as fixed inner and outer diameter of runner, blade inlet angle and position of the turbine. Other inputs are variable.

4. CAD MODELLING

After applying the constraints, the CAD model of components of the GWVPP are designed in CATIA V5 and Solidswork.

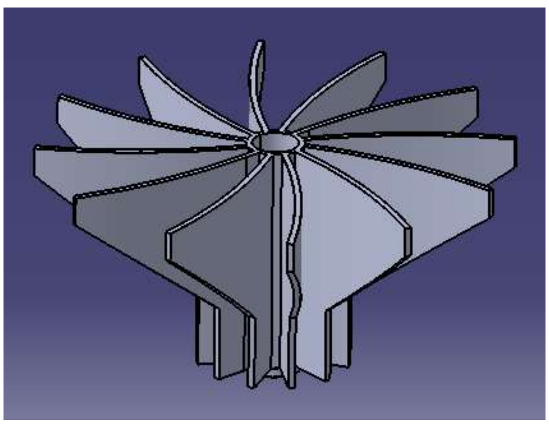


Fig 2. CAD model of Runner

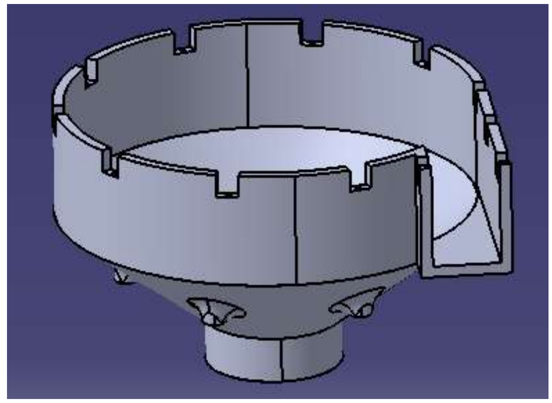


Fig 3. CAD model of Casing

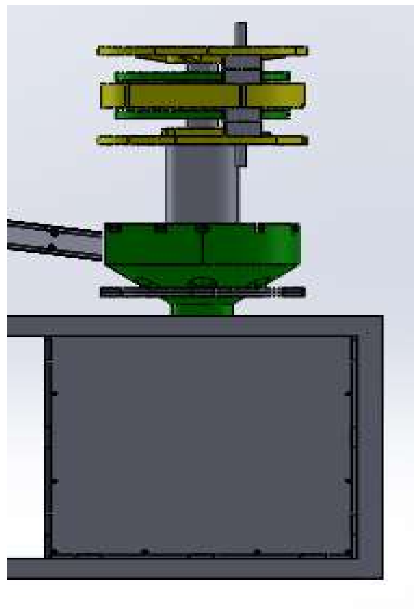


Fig 4. Final Assembly of GWVPP

5. FABRICATION PROCESS

After setting the parameters, moved towards the fabrication process. First step was material selection and cost constraint. By checking the properties of different materials, I wanted to fabricate my set up with mild steel. But cost constraint allowed me to go for 3D printing option. Next issue was the dimensions of my model parts which were greater than the chamber of 3D printer. The dimensions of bed of 3d printer was 190mm*190mm*170mm. By scaling down of the dimensions of parts upto 3:1. The material used for it was PLA. The runner was made with 100% filling to bear the maximum momentum transferred by water vortex. Similarly, the runner was made with 60% filing. The main shaft was made up of brass. Second step was the manufacturing of a low rpm generator. There were 10 coil sets of 1000 turns per set, were implemented in the generator. These sets of coils were kept separated by filling the glue between them. To create the magnetic field, two set of N-38 magnets, 10 per each acrylic disc, were applied on both sides of the coils. Magnets were kept in such a way of opposite poles to create the magnetic field. These discs were also coupled with the shaft. There is also a container of 250mm* 250mm*300mm at the outlet. The components made by 3D printing are given below.

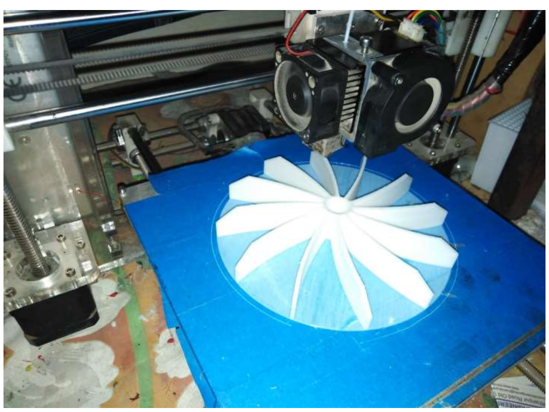


Fig 5. Fabrication of Runner is doing by 3D-printer

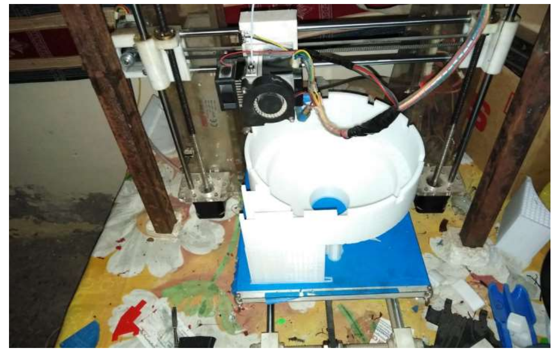


Fig 6. Fabrication of Casing is doing by 3D-prnter

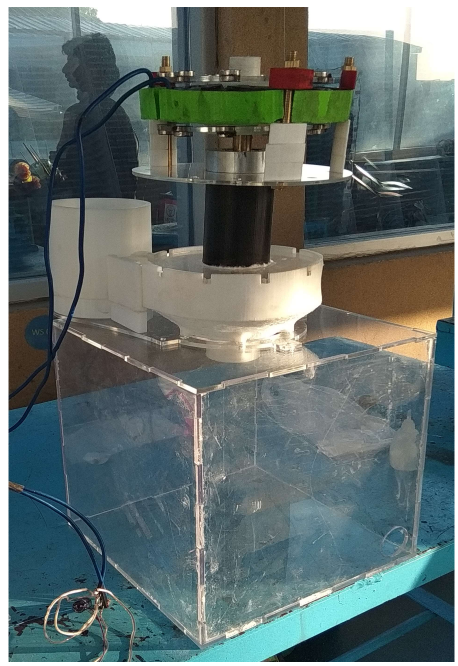


Fig 7. Final assembly model of GWVPP

6. EXPERIMENTAL TESTING

After the fabrication of apparatus, the main task is to search the site which is capable to give a flow rate of a range of 0.4-0.8 L/s. After achieving the required volume flow rate, the main vision is to enlighten 3 to 4 bulbs with the output came out of the generator. To analyze experimental and analytical results, the value outputs (current and voltage) with the help of Digital Multi-Meter. The power will be calculated with the help of this equation.

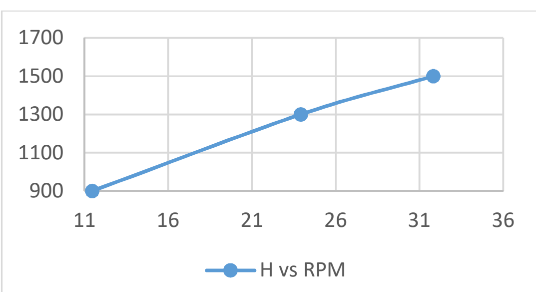
$$P = V * I$$

The different results were obtained by varying the mass flow rate. The variation of data in the tabular form is given below.

Q (m^3/s)	f (Hz)	RPM	Exp. Power (Watt)	Theo. power (watt)	Exp. η	Theo. η
0.0004348	15	900	18	48.863	0.3684	0.8942
0.0005	21.67	1300	33.4	117.24	0.2849	0.8945
0.00076928	25	1500	42	240.17	0.1791	0.8947

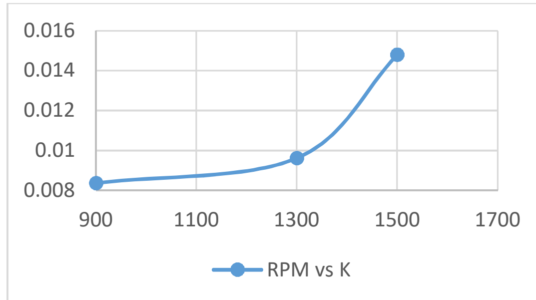
Table 1. Analytical and Theoretical values of efficiency and power w.r.t. relevant flow rate.

The graphical representation of data is shown as



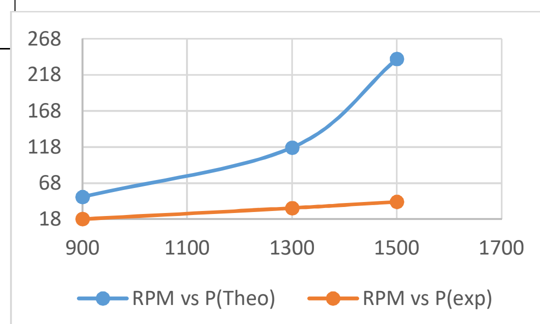
Graph 8. Relation between head height and rotational speed

This graph shows that head height and rotational speed of the runner are directly proportional. As we rise the head height, it rise the potential energy of water. It converts into kinetic at point of contact with runner with risen velocity.



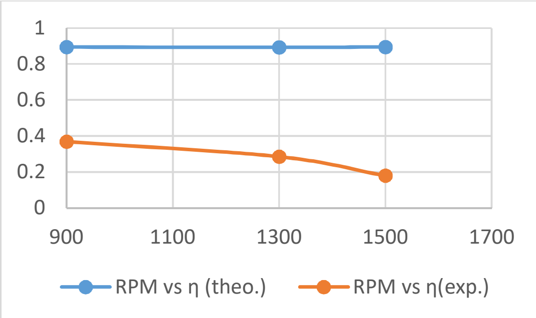
Graph 9. Relation between vortex strength and rotational speed

This graph shows about vortex strength of water achieved about the runner at varying rotational speed in the result of varying volumetric flow rate. It seems to be rise exponentially.



Graph 10. Relation of RPM with theoratical and experimental power

This graph show the variation of power along rotational speed, theoretically and experimentally. The difference between theoretical and experimental power is increasing as we rise RPM. It is concluded that optimized value of RPM for this apparatus lies before 900 rad/s.



Graph 11. Relation of RPM with theoratical and experimental efficiency

7. Discussions

By seeing the trends of graphs from 8 to 11, it has been shown that the number of revolutions per minute is directly proportional to the head height. Similarly as the rotational speed of the system rise, the vortex strength of the system also rise. As we talked about the variation of power (theoretical and experimental) and efficiency (theoretical and experimental), there are some certain factors which tends to make a change in the system outputs. The main reason behind such variation of efficiency from 89% to lie between 18% to 38% is the ideal assumptions which were taken by me to solve the system analytically. But the story was completely different for the case of experimental results. There are some friction losses in the system. Some error due to change of magnetic flux. The density of the water was taken as constant which is ideally wrong. To minimize the error between experimental and analytical values we have to make our system more and more close to ideal conditions.

8. CONCLUSIONS

GWVPP is capable of generating power from low level water head. So such type of power plant is feasible for those areas which are closed to the water bodies like rivers. The Optimized turbine position is kept at 65% to 75% of the height of basin. The ultimate efficiency is lied in range from 20% to 40% which depends on the number of blades, volumetric flow rate and size of the blades. According to literature the efficiency of cylindrical basin is less than that of conical cylinder because more momentum of water is transferred to blades in case of conical one which provides more rotational speed to runner blades and rotate the shaft with high speed. Simply, inlet flow rate magnificently influences the efficiency of GWVPP. Inlet flow rate and efficiency both are directly proportional.

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