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Design, Analysis and Improvisation of Helical Cross Flow Hydro Kinetic Turbine

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Abstract— *Pico-hydro power plants can be a future for the fulfillment of ever increasing demand of energy. This brief paper reports on study carried out for designing a work producing hydrokinetic turbine with the help of waste energy in flowing water. The lift type turbine is designed upon the basics of Gorlov turbine. Various other turbines and their parameters where studied and analyzed in CFD simulation software. Many different kinds of models were derived from the study conducted. These designed models were compared with each other and an optimized model was obtained. We conclude this paper by providing comparative system characteristics of the turbine.*

Keywords— Gorlov turbine, Venturi effect, Variable pitch concept, Variable Chord Length, NACA 0018.

I. INTRODUCTION

In current world scenario, there is a huge crisis of energy resources. Therefore, to achieve energy conservation to the highest amount of extent, we need to use renewable source of energy which is easily replenish able. This also reduces the amount of pollution which in turn lessens the effect of global warming.

After conducting a thorough study over all types of energy resources, out of the renewable type, hydroelectric power was found out to be a very good alternative for extraction and usage purposes.

II. PURPOSE

For the extraction of this hydroelectric power, we need to construct dams and hydroelectric power plants. Since the river water flow is dependent on rainfall, the flow is uncertain and construction and maintenance of these power plants is very costly. It would be beneficial if a kind of setup of auxiliary system for energy generation is provided. Such auxiliary system (Turbine) would help in power generation from the excess kinetic energy of water flowing in municipal domestic water pipelines (Diameter 2050mm).

III. PROBLEM DEFINITION

We need a work producing device in order to extract this amount of kinetic energy so as to it could be used for generation of electrical energy This work producing device has to be strictly a gravity driven turbine. i.e. the excess potential energy converted to kinetic energy inside pipelines has to be used. This turbine should not be used where pumping action would be required for the flow downstream.

The turbine should have following qualities:

- Efficient so as to extract maximum power from the flow of water.
- Robust so as to withstand flow of water with High KE.
- Light in construction so as to be easy for installation, handling.
- Easy to Assemble and Dismantle, so as to increase Serviceability.
- Corrosion resistant as it has to kept in water all the time.
- Flow of water should not get restricted as it might disturb the usage of water of people.
- Reduce effect of Cavitation as far as possible.

IV. WORKING

It is as follows:

- The gravity imparted pressure energy of the water in pipelineis converted into high kinetic energy of water
- The kinetic energy of water rotates the turbine.
- This rotation creates magnetic field in the generator and generator generates electricity.

V. CHOSEN AIRFOIL

NACA0018 (18% thickness to chord length) was chosen because

- Relatively better lift
- Less center of pressure travel
- Due to availability of lift and drag for large range of Reynolds numbers.
- Generate higher torque than asymmetric airfoils.

VI. MATERIAL

After performing detailed study of the different materials that have been used in the pre-existing hydro turbines, we formulated the properties that were required to be possessed by the material chosen for our turbine.

- It should possess high corrosion resistance.
- It should have good machining properties.
- It should have high strength.

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- It should have good welding properties.
- It should possess resistance to cavitation.
- It should be cheap and easily available.

After detailed research of all kinds of material which fit properly in the above properties, we decided upon our material which could be used for our turbine. We selected Aluminium alloy 5086 as our turbine material because it possessed the perfect balance between corrosion resistance, strength, cost, machinability and weld ability. It also possesses less density (i.e. low weight) than that of stainless steel and is less costly than stainless steel.

The properties of Aluminium 5086 are:

Properties	Aluminium 5086
Elastic modulus	71000N/mm^2
Poisson's ratio	0.33
Tensile strength	290N/mm^2
Yield strength	207N/mm^2
Thermal expansion coefficient	23.9 (10^-6/ºC)
Mass density	2660kg/m^3
Hardening factor	0.85

VII. TURBINE PERFORMANCE PARAMETERS

These are the parameters on which the performance of our turbine depends. These are non-dimensional performance parameters. These parameters are mostly used for Wind and Hydrokinetic turbines.

Tip Speed Ratio – The rotational speed of the turbine is described by the tip speed ratio which represents the rate of rotation of the turbine blade at the blade tip relative tothe speed of free stream velocity. It is given by $\lambda = \omega R/ U$

Efficiency – It is also called as power performance coefficient. It is ratio of shaft power output to kinetic power of water. It is given by $C_P = T\omega/0.5\rho U^3 A$.Here ρ is density of water and A is cross sectional area of turbine.

Reynolds Number-It was defined for a ratio for inertial forces to viscous forces of a fluid in the flow regime of a flow turbine. Reynolds number for a circular pipe is given by $\rho VD/\mu$.

VIII. TURBINE DESIGN PARAMETERS

The turbine consists of the following parameters while designing it. Following are the design parameters. These parameters were studied thoroughly and many different types of models were made.

Solidity Ratio- Solidity ratio refers to the amount of turbine swept area that is solid material versus that which is void space.It is given by equation $\sigma= BC/\pi D$. here B is the number of blades, C is the chord length, D is the diameter of the turbine.

Number of blades- The number of blades is directly proportional to solidity. For any turbine, as the number of blades increases, the chord length of a blade must be decreased to maintain a desired solidity ratio.

Aspect Ratio- Aspect ratio (*AR*) refers to the ratio of turbine height to diameter.

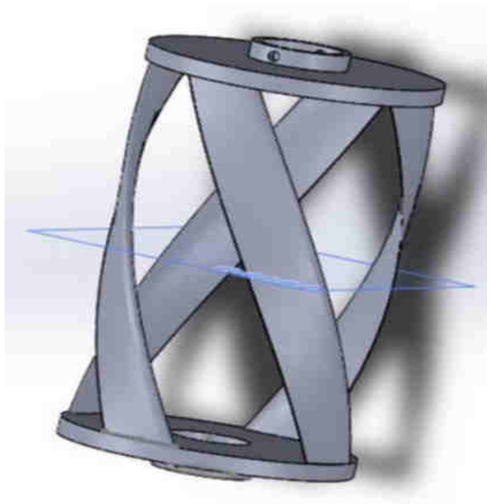
Helical pitch angle - Helical pitch angle (for a vertical axis turbine refers to the pitch angle that the blade makes with a horizontal plane.

IX. TURBINE DESIGN AND OPTIMIZATION

After a detail study of turbine design parameters, the turbine was designed for 2050mm NMMC pipeline andthe turbine performance parameters where calculated. For better performance the design was optimized.

Problems in design

The major problem was to fit the turbine perfectly into the water pipeline. This was overcome by setting a proper aspect ratio for the turbine. A detail study of airfoil was required to select proper airfoil as it is the main part of turbine design. After the study and detail analysis of the turbine. We analyse our area operation and studied various factors which affect the performance of the turbine. We designed basic turbine with noramal features then we applied our 3 innovative to improve the performace of that turbine.



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The innovative ideas are as follow

Design consideration:

1. Venturi type arrangement of pipe

1. We need to make provision so that without affecting thewater flow and pipeline pressure too much our turbine has to work efficiently.

2. By installing the turbine in throat section of turbine, the increase in velocity at the cost of line pressure helps to increase turbine velocity and this is validated by CFD

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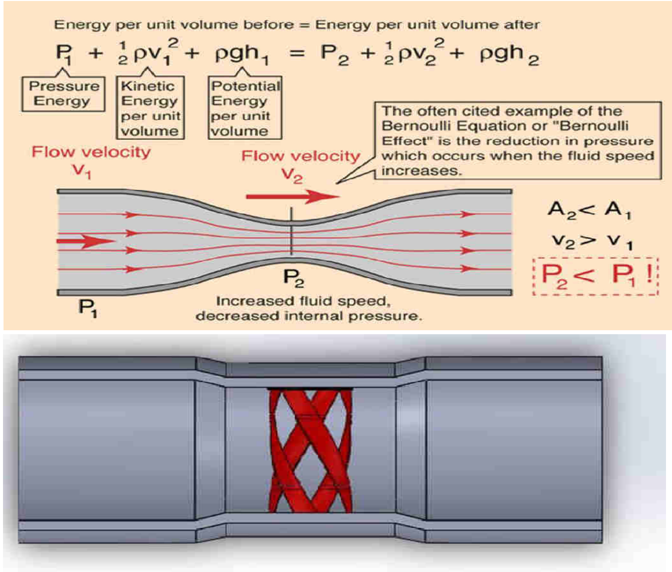
results.

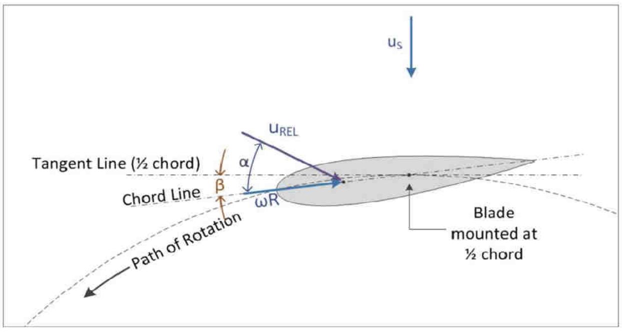


Bernoulli's principle

2. Variable pitch of the blade

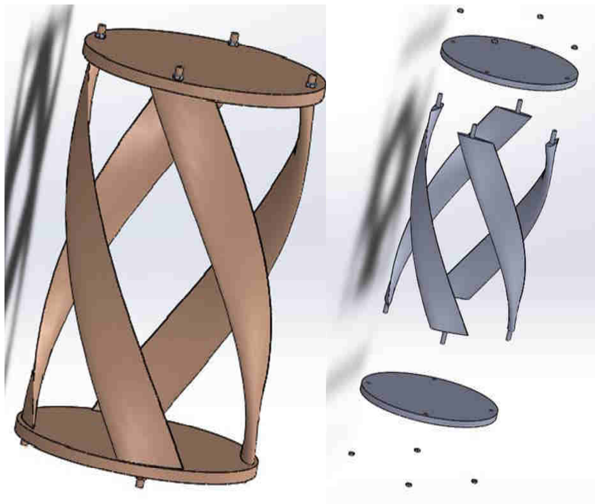
Blade pitch refers to the angle that the airfoil blade chord makes with a line tangent to the circle of revolution of the turbine. When referenced with respect to the half-chord point, a positive pitch, also referred to as toe-in, indicates that the blade front half-chord makes an angle toward the centre of revolution from the tangent line. For a negative blade pitch, or toe-out, the blade front half-chord angles away from the centre of revolution with respect to the tangent line. A diagram depicting positive blade pitch β is shown in Figure

Pitch angle : It is defined as the angle between the line tangent to the path of rotation and chord line (β).



Variable pitch concept

Need of turbine to have positive or negative pitch angle depends upon the intensity and magnitude of the flow. We can achieve our objective of maximizing efficiency by changing the pitch how output going to differ. We need to different set trial and error methods to know for what condition, which is better condition for particular operation. We made special provision on our turbine so that we can adjust our turbine to any pitch angle according our need. Instead of welding, we made the blade and strut separately and joined them with the help of bolting. Part of the bolt which is inside the strut has no threading so it facilitate the rotation of turbine blade by certain angles. Initially our turbine set to the zero angle i. e. pitch line will be parallel to the chord line. Pointed edge which is connected to it calibration of the angle is done on the strut so after losing the turbine we can adjust the turbine to any pitch angle. Bolt like arrangement which is connected to the blade by welding. Bolting part which is after strut section has threading where we can lock the position of the turbine with the help of nut. We have to do the same things with all the four blades at upper side and bottom strut. By doing this we can achieve the variable pitch of the turbine. It provides you flexibility. If suppose the flow of the pipeline changes, we can change the pitch angle. In case of the cross flow helical hydrokinetic turbine -2 degree is considered as suitable angle.



Exploded and assembled view of turbine assembly

3. Variable chord length along the spiral path

As we design the blade which has uniform chord length over the span of the spiral length. Our optimized design has different chord length. Near the pipe wall flowing water has to face frictional losses but at the Centre of the pipe there is least effect of friction. That part of the fluid has maximum kinetic energy. Centre part of the blade has scaled chord length as compare to the start and end part of the turbine section. So that part will generate maximum lift which is desirable. As the area increases so that impact area will be more and thereby lift which is generate will be high.

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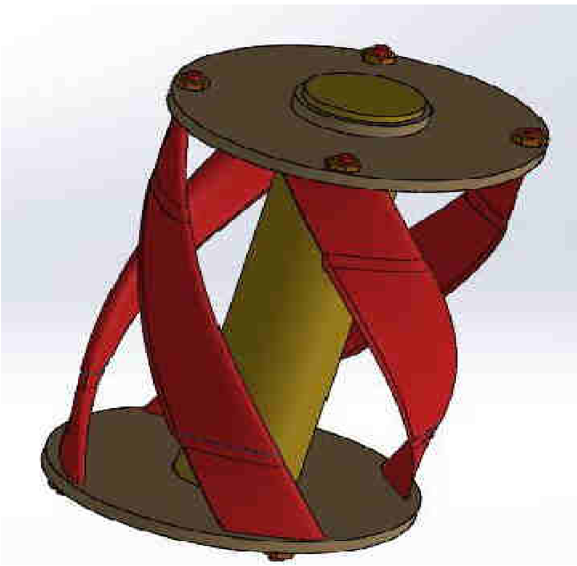
After applying all these innovation, we designed our optimized model

Design parameters

Parameters	Basic model	Optimized model
Pipe Diameter	2050mm	1900mm
Height	1600mm	1500mm
Diameter	1066mm	1000mm
Aspect ratio	1.5	1.5
Chord length(C)	222mm	274.889mm
Solidity ratio (σ)	0.198	0.35
No of blades (B)	3	4
Discharge (Q)	5.028m3/s	5.028m3/s
Velocity (V)	1.70m/s	1.853m/s
Pressure (P)	7kg/cm2	6.997kg/cm2

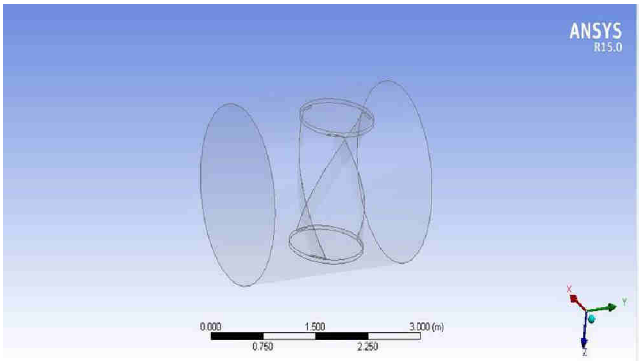


Optimized Turbine

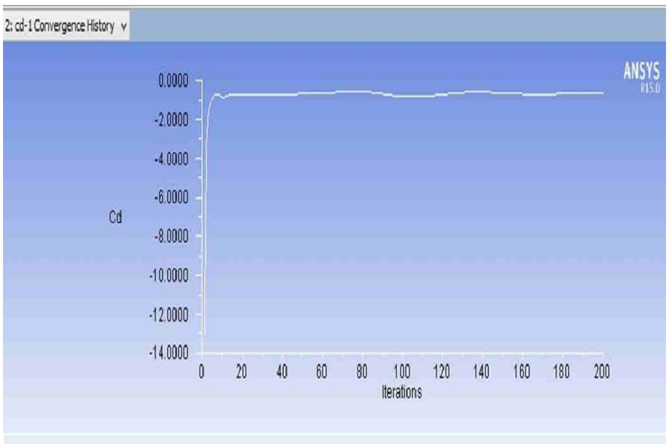
X. ANALYSIS OF TURBINE

We analyzed our turbine pressure and velocity variation in Ansys fluent. Following are the FEA details

Pressure-Velocity Coupling	SIMPLE
Discretization of Gradient	Green Gauss Node Based
Discretization of Pressure	Second Order
Discretization of Momentum	Second order Upwind
Discretization of Turbulent Kinetic Energy	Second order Upwind
Discretization of Specific Dissipation Rate	Second order Upwind
Pressure Under-relaxation Factor	Second order Upwind
Momentum Under-relaxation Factor	0.6



CFD model



Graph for co-efficient of drag

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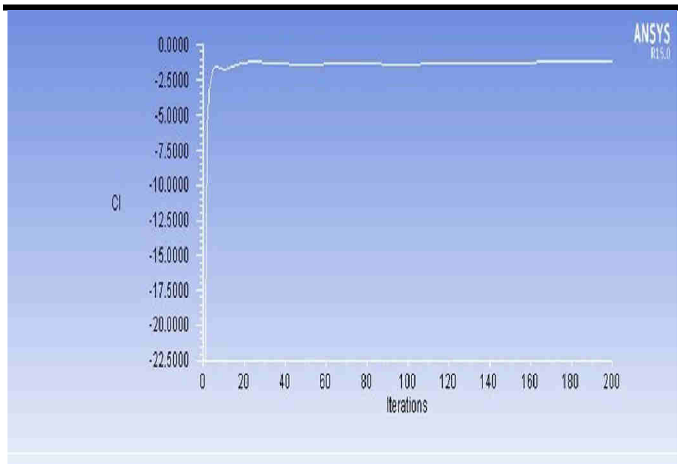
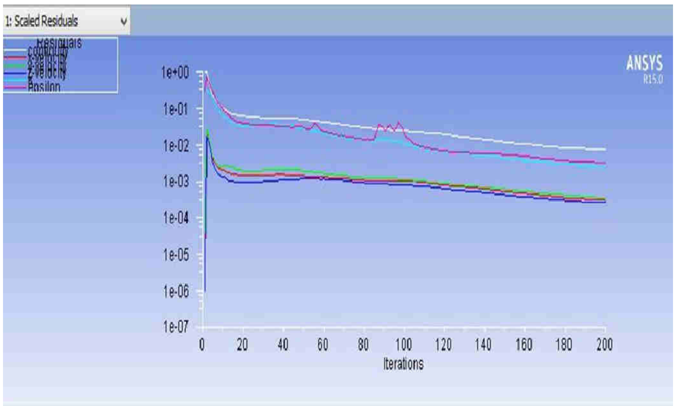
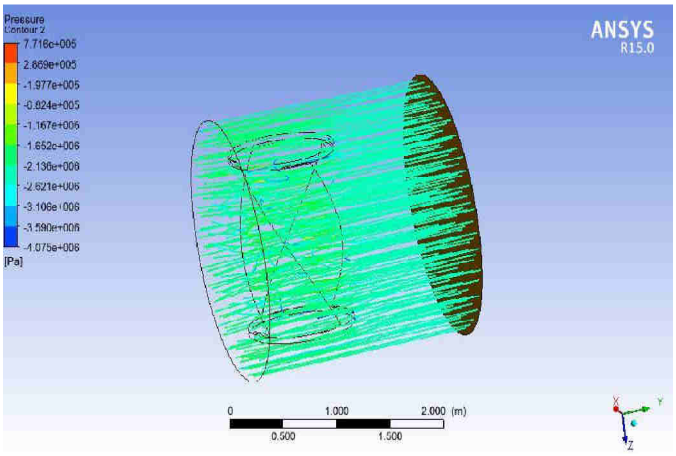


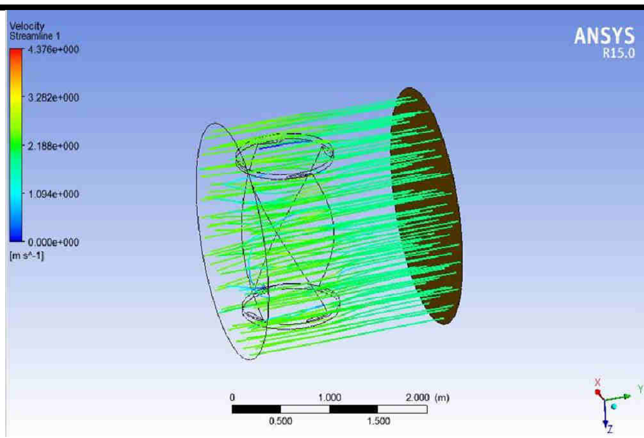
Graph for co-efficient of lift.



Scaled residuals



Pressure variation



Velocity variation

XI. RESULTS

System parameters	BASIC	OPTIMIZED
Power	857.116W	1297.44 W
Torque	134.386Nm	175.33Nm
Revolutions	60.905 RPM	70.66RPM

The above table specifies that the performance parameters of the turbine were increased due to the various optimizations.

XII. FUTURE SCOPE

We can employ such type of turbine to any open or closed flow channels. We are going to discuss about area where we can employ our turbine.

1. Tidal currents can be used for extraction of power from them.
2. We can design these pico-hydro turbines for streamswhere water moves with velocity and relatively small head.
3. Commercial company campus and domestic/ residential buildings require lot of waste water pipelines, so such type of turbine can be installed to extract the waste energy.
4. The modular design of turbine i.e. it can be assembled vertically, horizontally or in any other cross flow combination using a common shaft and generator or an array of multiple turbines will find many applications in commercial field.

XIII. CONCLUSION

1. From various design parameters; the best combination will give an efficient Turbine.
2. Successful Implementation will help in eradicating power demands.
3. With some Installation cost and negligible maintenance, a lifelong clean source of energy.

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