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# Exploring Kinetic Energy Harvesting from Indian Rivers and Canals: A Propeller Turbine Approach

## *Design and Investigation of Hydrokinetic Propeller Turbine*

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***Abstract:*** Presence of main rivers or canals are observed in most of the parts of India almost throughout the year with full of water current. However, development towards use of kinetic energy from rivers current is not explored. An innovative propeller turbine is introduced for utilization of river current of flowing fluid. The broad objective of the project is to explore efficient utilization of kinetic energy of water resources available in India in form of flowing river and canal by using innovative propeller turbine. The prime objective of the project is to investigate performance of propeller turbine. A laboratory scale turbine set up is fabricated using conventionally available structural members and rotor. The experimental investigations are carried out in the available irrigation canal. The results indicates that, the performance of the propeller turbine is comparatively good related other conventionally used Savonius turbine and Darrieus turbine.

***IndexTerms* - Hydrokinetic energy, Propeller turbine design, River current energy, Canal energy extraction, Kinetic energy utilization, Renewable energy sources, Turbine performance analysis, Experimental investigation, Fluid dynamics, Energy conversion efficiency, Sustainable energy technologies, Renewable energy generation, Turbine blade design, Turbulence effects, Turbine rotor dynamics**

## I. INTRODUCTION

### 1.1 History of Turbine

With an increasing demand of energy resources, conventional energy is the one of most vital energy resources that become more expensive and scarce. Thus there is a need to generating power from renewable sources that help reduce the demand of fossil fuels and to save non-renewable sources for future generation. Renewable energy are natural energy which does not have a limited supply. Renewable energy is can be used again and again, and will never run out. Wind power energy is the most common form of renewable energy. Here, electricity is generated by the blades turning turbines which run a generator. Wind power has a potentially infinite energy supply and a number of advantage to its use. Further, generating wind does not produce toxins or pollutants to environment and thus assists in the fight against global warming. Wind turbines are mainly Horizontal Axis Wind Turbine (HAWT) and Vertical Axis Wind Turbine (VAWT).

### 1.2 Hydrokinetic Turbine

A "Hydrokinetic" turbine is an integrated turbine generator to produce electricity in free flow environment. It does not need a dam or diversion. In stream Energy Generation Technology or IEGT places turbines in rivers, manmade channels, tidal waters, or ocean currents. These turbine use the flow of water to turn them, thus generating electricity for the power grid on nearby land. In effect, IEGT is like a planting windmills in the water and is environmentally friendly. While hydrokinetic includes generation from an ocean tides, currents and waves, many researchers believe its most practical application in the near term is likely to be in rivers and streams. Hydrokinetic turbine to be used for specific site of lower Head as run of river, which has head less than 1.2 meters.

### 1.3 Limitations/Disadvantages of Conventional Hydro turbines

The conventional hydro turbine has the following limitations.

- Dams are extremely expensive to build and must be built to a very high standard.
- The high cost of dam construction means that they must operate for many decades to become profitable.
- Dams alter the natural ecology of rivers, potentially killing fish, stopping migrations, and disrupting peoples' livelihoods.

### 1.4 Advantages of Propeller Type Turbine

- No dam is required.
- The turbines can be installed in a variety of ways, multiple banks set on pilings driven into the river beds or mounted on existing river structures such as bridge piers. These turbine operate in a "free flow" environment

that does not require the damming or diversion of rivers. This approach does't disrupt natural ecosystems or interfere with aquatic and marine life.

- Many natural and man-made sites are fully ready for hydrokinetic turbine.

These applications do not need dam or retain water to create hydraulic head. In zero head turbine required only few meters. Using the flow of a river or the naturally occurring tidal flow to create electricity may provide a renewable energy source that will have a minimum impact on the environment.

From the hydro kinematic turbine expected CP of the axial flow turbine is high. So, future work can be devoted to the experimental performance analysis of axial flow turbine.

### 1.5 Selection of Propeller Type Turbine

- The axial flow propeller turbine has great potential for higher cp compare to other zero head turbines as shown in Figure 1.4 and also its working range is quite wide ranging from 3 to 7 TSR. Also it has good starting characteristics.
- No aliment is required as in case of vertical axis turbine.
- Maximum amount of water flow strikes on rotor, so, there is greater potential to extract mechanical power from rotor.
- Low maintenance because of simple design.

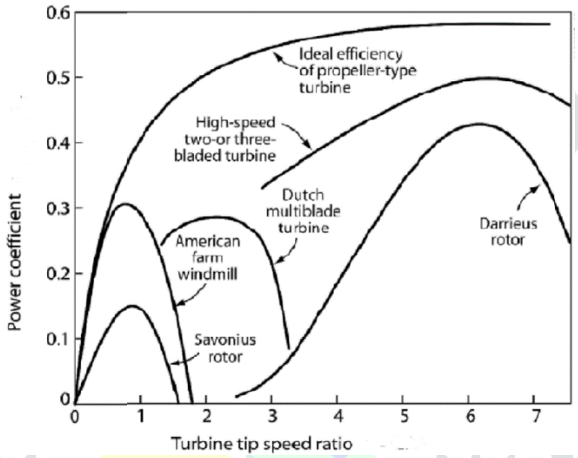


Figure 1.1 Performance of Various rotors

**Conclusion**

A set of $C_P$ v/s λ curves is shown in Fig.1.1, which illustrate the superiority of Propeller turbine against other rotor options in terms of efficiency. The theoretical maximum value of the power coefficient CP is known as the Betz limit, which has a numerical value of 0.59.at higher tip speed ratio, turbine provides smooth starting characteristics and high power coefficient.

### 1.6 Objective of Work

From literature survey, it is concluded that, following parameters are not focused more and more investigation is require in this area. So, following objectives are decided for present investigation.

- To investigate effect of load on the efficiency on the turbine.
- To investigate effect of free stream velocity on performance of turbine.
- To investigate effect of TSR and Co-efficient of power on performance of turbine.

## II. Literature Review

### 2.1 Literature Survey

Ali Arslan et al. [1] investigated the design and Manufacture of a Micro Zero Head Turbine for Power Generation, 2011. The main aim was to design and manufacture a micro zero head turbine which could produce sufficient power to light a couple of energy saver bulbs up to a wattage of 50 to 60 that can suffice the lighting requirements of far flung villagers and dwellers having access to natural streams of water but no electricity supply. It resulted in design and fabrication of one such turbine which was able to generate a power of approximately 50 watts at a free stream velocity of 1.2 meter/second. Findings of this research were quite in harmony with theoretical results which may be used for increasing the size of micro turbine along with a proportionate rise in generated power. As a result of extensive in house experimental design of a micro zero turbine and the design and manufacture of final assembly as shown in the above research the following findings:

- Turbine blade design and number of blades are the vital parameter for extracting optimum power from a micro zero head turbine.
- The velocity of water flow decreases from top (being the highest) to bottom, therefore the depth of stream may not have significant influence on the power generated.
- The free stream velocity itself will be the major source of creating torque which could ultimately provide sufficient rpm for power generation in a typical setup.
- These turbines could be installed where the flow velocities were as low as 1 meter/second. However higher flow speeds would give higher rpm of the turbine leading to higher values of power.
- The design of such a power turbine is very simple and could be manufactured and constructed at a local workshop for use in far flung areas. Its cost is negligible because of absence of requirements of dams.

- Research was focused on generating a low power value; however, research design could be scaled up for higher values of flow velocities and bigger size of turbine blades to generate sufficient power that could serve an entire house hold. They concluded by stating that such turbines could be used at regions where there is abundance of free water streams; small and large. The sizes of the turbines could be various as per the power requirements of users.

In Seong Hwang et al [2], an advanced vertical axis turbine to enhance power generation from water energy. The turbine, known as a cycloidal water turbine, is a straight-bladed type adopting a cycloidal blade system that actively controls the rotor blades for improved turbine efficiency, according to the operating conditions. These characteristics enable the turbine to self-start and produce high electric power at a low flow speed, or under complex flow conditions. A parametric study has been carried out by CFD analysis, with various characteristics including different number of blades, chord length variations, variety of tip speed ratios, various hydrofoil shapes, and changing pitch and phase angles. Optimal parameters have been determined, and the performance of the turbine has achieved approximately 70% better performance than that of a fixed pitch turbine. An experimental study has also been carried out which shows that the results correlate quite well with the theoretical predictions although the power output was reduced due to the drag forces of the mechanical devices. Another numerical optimization was carried out to improve the rotor performance by adopting an individual blade control method. Controllable pitch angles were employed to maximize the rotor performance at various operating conditions. The optimized result obtained using genetic algorithm and parallel computing, shows an improvement in performance of around 25% compared with the cycloid motion.

PriyonoSutikno et al. [4] research was carried out in order to develop a hydro turbine to be used for specific site of lower Head as run of river, which has head less than 1.2 meters. The new development of Very Low Head Turbine has been done in this research use the simple civil construction and resulting the economically viable. The recent development of computer-based tools with more efficient algorithms has allowed a substantial improvement in hydraulic turbine design. The definition of an initial geometry capable to assist certain characteristics of turbine performance is a first step for useful numerical turbine analysis. This paper presents an application of the minimum pressure co-efficient and free vortex criterions for axial-flow hydraulic turbines cascade geometry design.

Mitsuhiro Shiono et al [5]in this study, the hydrographic experiment was conducted using seven types of helical blade water turbines, devised for this study, for obtaining the starting torque and load characteristics. The results obtained are summarized as follows: (1) Helical blades have quite a smaller rate of pulsation and a more favorable starting characteristic than straight blades (2) In helical blades, the starting characteristic does not show any significant difference due to the use of different blade inclination angles but is greatly affected by solidity.(3) The highest water turbine efficiency is seen at 0.4 solidity.(4) The larger the blade inclination angle is, the higher the torque and the water turbine efficiency become. This characteristic is close to that of straight blade water turbines. Based on the results above, the helical blade water turbine is better in starting, while the straight blade water turbine is better in energy production. Moreover, it is considered appropriate to use helical blade water turbines with unlimitedly large blade inclination angles.

Kai Shimokawaet. al.[6]work on Experimental study on simplification of Darrieus-type hydro turbine with inlet nozzle for extra-low head hydropower utilization and conclude that (1) Provided the inlet nozzle is installed to obtain effective generated torque in the high efficiency blade rotating positions, it is possible to simplify the runner casing drastically with Keeping the turbine performances higher. (2) The performance of simplified Darrieus-type hydro turbine is affected by downstream water level. In the case of higher water level than the runner height, the operation at the best efficiency point is achieved even if the runner casing is simplified. On the other hand, when the water level becomes lower than the runner height, turbine efficiency extremely decrease, additionally it is impossible to operate at high efficiency point (3) The degradation of turbine performance by decrease of the water level becomes more sensitive in large flow rate condition because flow loss depends on the runner rotating speed. (4) Given the practical use of Darrieus-type hydro turbine in low head sits, the weir established in the downstream pond is necessary to keep preferable water level in conditions of low flow rate.

Fernando Ponta et.al [7] worked on Water-Current Turbines (WCTs) are non-polluting electricity generation plants that harness the kinetic energy of natural water courses, using several kinds of rotors. At the School of Engineering of the University of Buenos Aires, researchers are developing a WCT whose particular characteristics improve technical and economic performance. A channeling device, integrated into the ovation system, is used to modify own conditions in the neighborhood of the rotor. This system was developed from theoretical modeling and small-scale model testing in a hydrodynamic test canal. The principal advantages of this kind of machine include reduced need for fixed civil works, ease of transport and relocation and autonomous, self-regulated operation, and it is expected to be a low-cost and long-lifetime system

### 2.2 Conclusion from Literature Survey

It is concluded from the literature survey that very few work recorded related to experimental investigation related to use of axial flow turbine in open flow channel application. Also no work is recorded related to study the effect of blade vane angles on performance of turbine for hydro kinetic applications. So, it is decided to investigate effect of blade angles and effect of inlet and outlet duct on performance of turbine.

## III. DESIGN MODELING AND ANALYSIS

### 3.1 Computational Theory

The concepts of axial flow theories are used to understand the performance of a Hydrokinetic performance investigation of propeller type turbine. This computational theory is

***Actuator Disc Theory*** *is known as axial momentum theory. The concept of Actuator Disc Theory was introduced by Rankine for Hydrokinetic performance investigation of propeller type turbine with some assumptions. The flow is assumed to be incompressible and homogeneous. The rotor is considered to be made up of infinite numbers of blades. Static pressure in front and behind the rotor is considered to be equal to the atmospheric pressure. Frictional drag over the blades and wake behind the rotor are neglected. Actuator disc model generally attributed for the Betz limit. By using this theory, Co-efficient of power can be turn out as:* $C_P = 16/27 = 0.59$

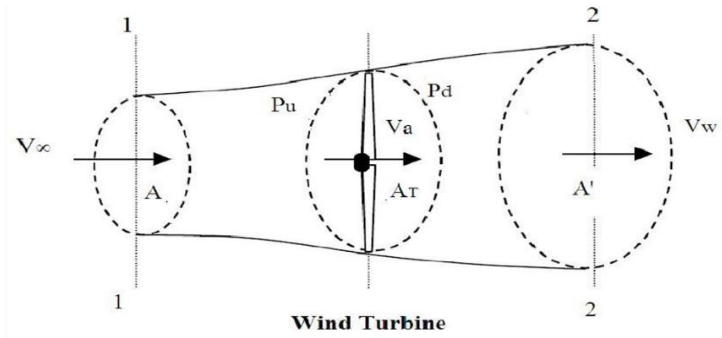


Figure 3.1 the axial stream tube model

### 3.2 Considerations for Fluid Dynamic Analysis

Performance analysis of an axial flow type hydrokinetic rotor can be carried out utilizing the conventional methods of wind and tidal energy studies. A typical turbine unit employed in electricity generation may consist of a rotor structure along with components such as, gearing, bearing, electrical generator, power conditioning, and end load unit Figure 3.2.The prime objective of the system is to convert mechanical energy into electrical form. Therefore investigation of the rotor's performance is of great importance [10].

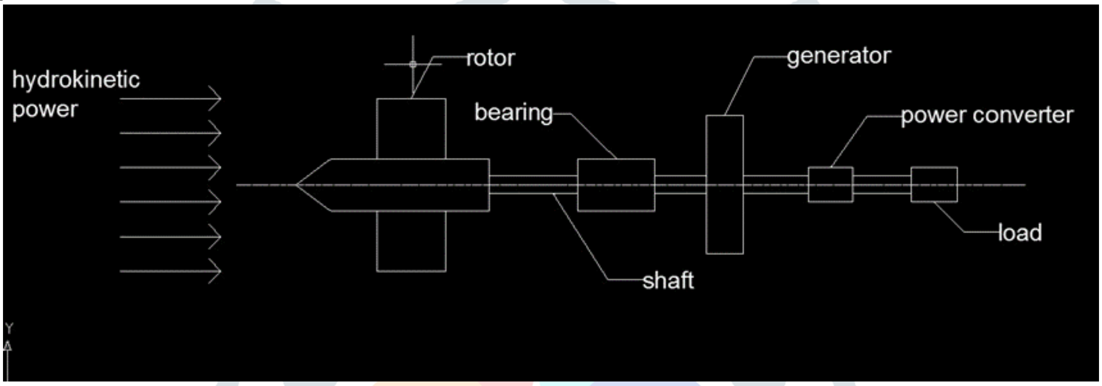


Figure 3.2 Schematic arrangement of Turbine system

The hydrokinetic power input $P_{hyd}$ (W) can be related to the rotor's mechanical power capture $P_{rot}$ by a term commonly known as power coefficient $C_P$, which is a measure of the turbine's hydrodynamic efficiency.

$$P_{rot} = C_P \times P_{Hyd} \tag{3.1}$$

For the turbine with effective swept area of A ($m^2$) placed in a fluid body having velocity V (m/s) and density ρ ($Kg/m^3$), this expression can be written as,

$$P_{rot} = C_P \times \frac{1}{2} \rho A V_\infty^3 \tag{3.2}$$

The mean radius of rotor and frontal area of rotor can be found by,

$$R_M = \frac{D_T + D_H}{4} \tag{3.3}$$

$$A_F = \frac{\pi}{4}(D_T^2 - D_H^2) \tag{3.4}$$

Angular velocity of rotor is calculated by,

$$\omega = \frac{2\pi N}{60} \tag{3.5}$$

The two dimensionless quantities: power coefficient Cp and the tip speed ratio λ are used for illustrating the effectiveness of a turbine's power extraction at various rotational conditions. Here, tip speed ratio λ is an index of rotor's rotational speed ω (rad/sec) against the fluid velocity V. This is define as

$$\lambda = \frac{r \times \omega}{V} \tag{3.6}$$

Where, r is the rotor radius in meters. Another term, torque coefficient CT is equally important in indicating the performance of a turbine. This is defined as

$$C_T = \frac{C_P}{\lambda} \tag{3.7}$$

### 3.3 General Mathematical Model

Figure 3.3 shows a velocity diagram for the axial flow turbine. The triangle ABC and EHG are called the velocity triangle at inlet and outlet. These velocity triangles are drawn as given below.

**Velocity Triangle at Inlet**

Take any point A and draw a line AB=$V_{r1}$ in magnitude and direction which means line AB makes an angle θ with horizontal line BC. Next draw a line AC=$u_1$ in magnitude. The line AB represents the relative velocity at inlet. If the loss of energy at inlet due to impact is Zero, then AB must be in the tangential direction of the vane at inlet.

□ABC = Represents Inlet velocity angle (relative)

AB = Represents relative velocity at inlet = $V_{r1}$

BC = Represents absolute velocity at inlet = $V_1$
AC = Represents the tangential velocity of vane at tip (inlet) = $u_1$

**Velocity Triangle at Outlet**

If the vane surface is assume to be very smooth, the loss of energy due to friction will be zero. The water will be gliding over the surface of the vane with a relative velocity to $V_{r1}$ and will come out of the vane with a relative velocity $V_{r2}$. This means that the relative velocity at outlet $V_{r1}= V_{r2}$. And also the relative velocity at outlet should be in tangential direction to the vane at outlet.

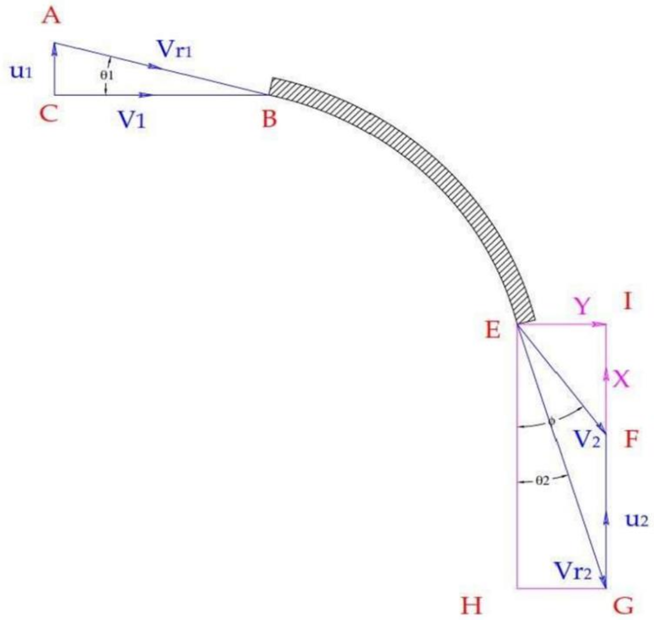


Figure 3.3 Velocity diagram for axial flow turbine

Draw EG in the tangential direction of vane at outlet and equal to $u_2$, the tangential velocity at outlet. Join EF. Then EF represents the absolute velocity at outlet in magnitude and direction. Here,

EF = Represents absolute velocity at outlet = $V_2$
GF = Represents tangential velocity at tip (outlet) = $u_2$
EG = Represents relative velocity at outlet= $V_{r2}$

The peripheral velocity or tangential velocity at inlet and outlet are equal. Then,

$$u_1 = u_2 = R_M \times \omega \quad (3.8)$$

Velocity at inlet and outlet are equal.

$$V_{r_1} = V_{r_2} \quad (3.9)$$

Area of flow at inlet = Area of flow at outlet.

$$A_F = \frac{\pi}{4}(D_T^{\,2} - D_H^{\,2}) \quad (3.10)$$

$$\text{Powers develop by the runner } (P) = \rho A V_1 [V_{W_2} \times u_2 - V_{W_1} \times u_1] \quad (3.11)$$

**3.4 Sample Calculation**

All calculations are done using M.S .Excel considering the following the data.
Free stream velocity ($V_\infty$) = 0.6 m/s
Vane angle ($\theta 1$) = 55°
Tip diameter of rotor (DT) = 0.36m
Hub diameter of rotor ($D_H$) = 0.104m
Density of fluid (ρ) = 1000 $Kg/m^3$
Speed of rotor = 40 RPM

- Mean radius of rotor (RM) is found using the RM = 0.116m
- Frontal area (AF) and Angular velocity (x) are calculated using equation 3.4 and 3.5 respectively.

  AF = 0.093 $m^2$
  x = 4.189rad / s
- Tangential-velocity ($u_1$) at inlet and outlet are calculated using equation 3.8.

  $u_1 = u_2$ = 0.486m / s
- Relative velocity at inlet ($Vr_1$) and outlet ($Vr_2$) are calculated using equation 3.12.

  $Vr_1 = Vr_2$ = 0.729m / s
- Tangential velocity component of absolute velocity(X) is calculated using equation 3.13.

  X = 0.185m/ s
- Axial velocity component of absolute velocity (Y) is calculated using equation 3.14

  Y = 0.285m/ s

- Absolute velocity(V2) at tip at outlet is calculated using equation 3.15

$$V_2 = 0.339 m / s$$

- Angle made by absolute velocity with tangential direction(∅)is calculated using equation 3.16

$$\emptyset = 57.01°$$

- Whirl component of absolute velocity at outlet($VW_2$ )is calculated using equation 3.17

$$VW_2 = 0.185 m / s$$

- Tip Speed Ratio (TSR) is calculated using equation 3.6

$$\lambda = 1.18$$

- The power developed (P) and maximum power ($P_{Max}$) can be found using equation 3.18 and 3.19 respectively.

$$P = 5.360 W$$

$$P_{Max} = 12.228 W$$

- Finally the coefficient of power ($C_p$) is found out using equation 3.20

$$C_P = 0.438$$

The input parameters given in table are used for calculation of coefficient of power and Tip Speed Ratio.

| Sr. No | Input Parameter | Value |
|---|---|---|
| 1 | Free stream velocity $V\infty$ (m/s) | 0.61 |
| 2 | Tip diameter of rotor $D_T$ (m) | 0.39 |
| 3 | Hub diameter of rotor $D_H$ (m) | 0.104 |
| 4 | Frontal area of rotor $A_F$ ($m^2$) | 0.093 |
| 5 | Density of fluid ρ ($Kg/m^3$) | 1000 |
| 6 | Hydrokinetic power $P_{Max}$ (Watt) | 12.228 |

Table 3.1 Input parameters of coefficient of power and tip speed ratio

Calculation are done using proposed theory, the obtained results are shown in the table;

**Analytical result**

| Sr. No | RPM of rotor | $u_1=u_2$ (m/s) | $Vr_1=Vr_2$ (m/s) | $V_2$(m/ s) | *Φ* | $Vw_2$ (m/s) | *P* (Watt) | *TSR* | *CP* |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 10 | 1.047 | 0.576 | 0.467 | 28.833 | 0.409 | 2.967 | 0.29 | 0.243 |
| 2 | 20 | 2.094 | 0.610 | 0.397 | 36.819 | 0.318 | 4.615 | 0.59 | 0.377 |
| 3 | 30 | 3.142 | 0.661 | 0.356 | 46.593 | 0.244 | 5.319 | 0.88 | 0.435 |
| 4 | 40 | 4.189 | 0.729 | 0.339 | 57.018 | 0.185 | 5.360 | 1.18 | 0.438 |
| 5 | 50 | 5.236 | 0.807 | 0.343 | 66.712 | 0.136 | 4.924 | 1.47 | 0.403 |
| 6 | 60 | 6.283 | 0.895 | 0.362 | 74.807 | 0.095 | 4.133 | 1.77 | 0.338 |
| 7 | 80 | 8.378 | 1.089 | 0.426 | 85.929 | 0.030 | 1.757 | 2.36 | 0.144 |

Table 3.2 Analytical result

After finding the values of coefficient of power (CP) at different Tip Speed Ratios (λ) the graphical representation of the results is shown in Figure 3.4.

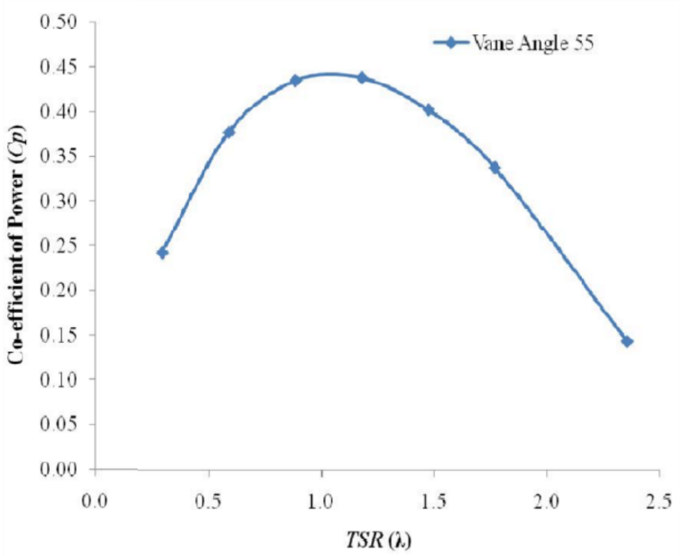


Figure 3.4 Analytical result

As the TSR increases, the co-efficient of power (CP) increases up to certain value. But then after though the TSR increases co efficient of power (CP) decreases. The trend of the graph of the analytical results for vane angle 550 shown in Figure 3.4 It can be clearly seen from the graph that maximum co-efficient of power (CP) is of 0.44 is recorded at 1.01 TSR.

## IV. EXPERIMENTAL SETUP

### 4.1 Components of Experimental Set-up

#### 4.1.1 Frame

A frame is a structural system that supports other components of a physical construction. It supports the other component such as, bearing, shaft, dynamometer, supporting plate for the bearing, impeller. It is made from the M.S. material. The design is selected as per our experimental set up and parameters which we are going to be use. It's also depending on the water discharge and the force generated by the water flow. It is the main part of project which has to withstand a load as well as also maintain the position of impeller and dynamometer.

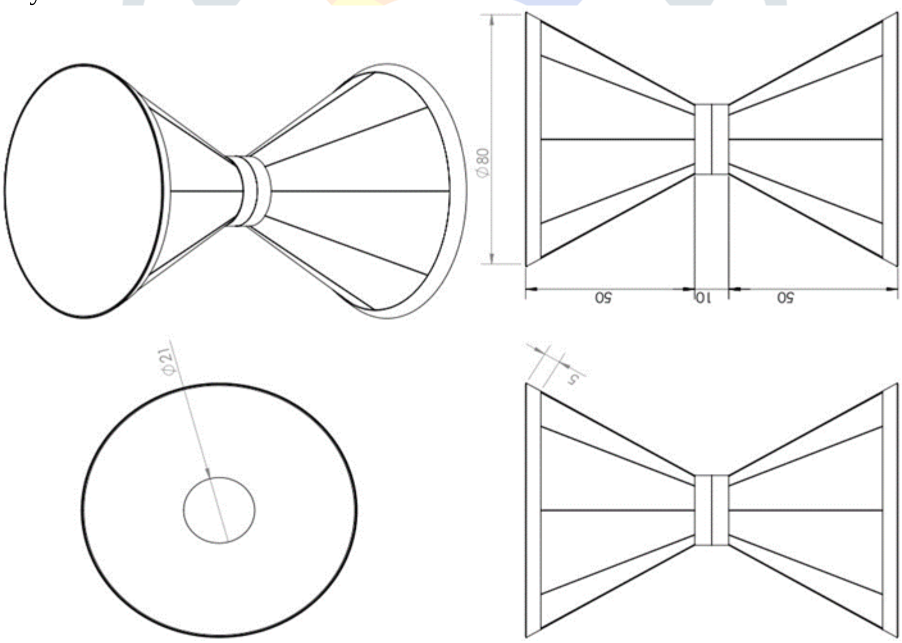


Figure 4.1 Structures for the Experimental Set Up

Figure 4.1 shows the different views of the structure of experiment set for conducting tests axial flow turbine. The structure for the axial flow turbine is fabricated using mild steel right angle plate. The mild steel plates are connected by means of bolt and nuts. The size of the frame depends upon the diameter of the impeller of the turbine. The diameter of impeller, d is fixed. The length is approximately taken as three times of the diameter of the impeller and height of the frame is taken as equal to diameter of the impeller from the ground level.

#### 4.1.2 Dynamometer Arrangement

A dynamometer is a device for measuring moment of force (torque) and power. For example, the power produced by an engine, motor or other rotating prime mover can be calculated by simultaneously measuring torque and rotational speed (RPM).

Types of dynamometer are as follows.

- **Absorbing Dynamometer**

In absorbing dynamometer, the work done or energy of the prime mover is converted into head usually against friction while being measured. In other words, it is a breaking system in which some provision is made for measuring friction torque on the drum. Examples are pony brake, rope brake, and dynamometer. This dynamometer can be used to measure moderate power produced by various types of prime movers. The figure 4.2 shows the dynamometer arrangement.

- **Transmission Dynamometer**

In transmission dynamometer, the work done or energy of the prime mover is measured before it is utilized to drive the machine. In the other words, the work done is not absorbed while being measured. Examples are belt transmission, epicycloids and torsion dynamometer. These dynamometers are suitable for measuring large power produced by various prime movers.

In the experiment setup, there are two weight balances are taken, one of its fixed spring balance and the other is adjustable weight balance. One end of the string is wound around the shaft of the turbine and other end of the string is connected to the fixed weight balance and adjustable weight balance.

For increasing load on the shaft, adjustable bolt arrangement is used by tighten the bolt we can increase the weight so we can easily measure the spring balance reading and weight balance reading.

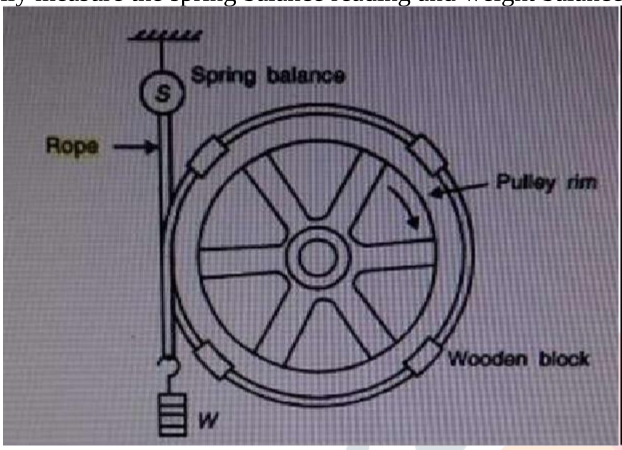


Figure 4.2 Dynamometer Arrangements

**4.1.3 Impeller**

A propeller is a type of Impeller that transmits power by converting rotational motion into thrust. A pressure difference is produced between the forward and rear surfaces of the airfoil-shaped blade, and a fluid (such as air or water) is accelerated behind the blade. The Figure 4.3 shows the impeller for the experiment setup.

As per requirement, a light weight heavy duty impeller, made from the plastic, which get from the air conditioner. It is selected the ring frame fan for sustain load or to withstand against the water force to the impeller. To make as per setup design, cut all blades of impeller and after that finished the lower surface of the blade for fit up maintain a radial shape to the bottom part of the impeller. To achieve an angular motion of the blade setup, bottom portion of the blade joint with the help of L type angle at the hub.

Then after, it is necessary to fixed nut bolt arrangement at the top of the ring. As per this modification we can change the angle of blade with the help of nut bolt arrangement fitment top and bottom both side.

Figure 4.3 Impeller of Turbine

### 4.1.4 Pedestal Bearing

A pillow block bearing or bearing housing is a pedestal used to provide support for a rotating shaft with the help of compatible bearings & various accessories. Housing material for a pillow block is typically made of cast iron or cast steel. Pillow blocks are usually referred to the housings which have a bearing fitted into them and thus the user need not purchase the bearings separately. Pillow blocks are usually mounted in cleaner environments and generally are meant for lesser loads of general industry. These differ from "Plummer blocks" which are bearing housings supplied without any bearings and are usually meant for higher load ratings and corrosive industrial environments. However the terms pillow block and Plummer block are used interchangeably in certain parts of the world.

The fundamental application of both types is the same which is to mount bearings safely enabling their outer ring to be stationary while allowing rotation of the inner ring. . However various grades of metals can be used to manufacture the same. For the experiment the internal diameter of the bearing is 20 mm. Bearing housings are usually made of grey cast iron.

Figure 4.4 Pedestal Bearing

### 4.1.5 Shaft

Usually circular shafts are preferred in almost all situations because they are very stable. Also, when strata should be built, its use the advantages of rectangular or elliptical shafts and use their cross sectional areas. In the experiment, 11 mm diameter and length of 700 mm long shaft is selected which is made from the M.S. material. The main function of the shaft is to transmit the rotation motion of the fan to the dynamometer so we can easily measure the power of the turbine.

## V. Experimental Investigation

### 5.1 Experimental Set-Up and Procedure

Figure 5.1 shows the experimental set-up of axial flow turbine with rotor and structure. The Structure is fabricated using angle plate and nut bolt arrangement. Outline of physical model the detail of experiment set up is given in table 5.1. Rotor shaft is mounted on two bearings with Plummer block. A self-aligned bearing is used to support and to avoid unwanted frictional torque.

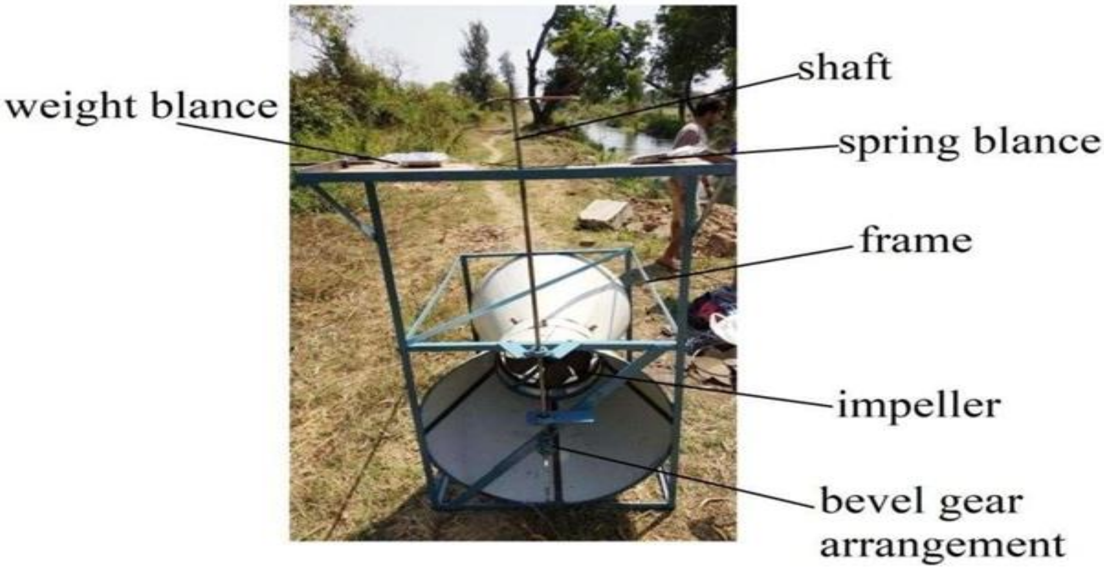


**Figure 5.1** Experiment Setup of Axial flow rotor and structure

A rope brake dynamometer is used for measuring the torque and subsequently power developed by the axial flow turbine rotor. Free stream velocity of water can measured by using current velocity meter, water stage recorder, Pitot tube, etc. In the present work, because of unavailability of such instruments, it is necessary to used simple distance-time measurement technique. The spring balance and weight balance (accuracy of 10 Grams) are connect by a nylon string of 1 mm diameter. Friction is an important parameter that affects the measurement of torque of the rotating Axial Flow rotor. Friction in the bearings and nylon string wound on the rotor shaft must be minimized.

| Sr. No. | Name of the components | Dimension (mm) |
|---|---|---|
| 1 | Diameter of rotor | 390 |
| 2 | Diameter of hub | 80 |
| 3 | Diameter of shaft | 11 |
| 4 | Top width of structure | 800 |
| 5 | Bottom width of the structure | 800 |
| 6 | Length of the structure | 1200 |
| 7 | Height of the structure | 800 |

Table 5.1 Axial flow turbine rotor geometry detail

The experiment setup is placed in direction of a stream line flow of water in the canal. Initially the turbine rotor is allow to rotate without any load and then rotor is loaded gradually to record spring balance reading, weights, and rotational speed of the rotor. For each load rotation speed is calculated 3 times, and this is done for the purpose of getting the maximum possible accuracy in the results.

The experiments related to propeller type turbine are conducted in Ukai- Kakrapar Yojana, and Dist- Kadodra. The details of canal are given in table 5.2.

| Canal | Width (mm) | Water level (mm) | Average velocity of water (m/s) |
|---|---|---|---|
| Ukai-Kakrapar Yojana, Dist Kadodra. | 3600 | 800 | 0.61 |

### 5.2 Experimental Results and Discussion

The experiments were conducted to identify the maximum coefficient of power and torque for propeller type turbine. The input parameters given in table 5.3. Are used for calculation of coefficient of power and torque. The measured free steam water velocity 0.61m/s the experiment is conducted in the canal and the reading of spring balance and revolution of rotor are obtained at different loading condition. The values fixed for experiments are shown in table 5.3.

| Sr. No. | Parameter | Value |
|---|---|---|
| 1 | Diameter of rotor (*m*) | 0.39 |
| 2 | Velocity of water(*m/s*) | 0.61 |
| 3 | Vane angle | 55° |
| 4 | Shaft radius (*m*) | 0.005 |
| 5 | Density of fluid ($Kg/m^3$) | 1000 |
| 6 | Diameter of hub (*m*) | 0.08 |

Table 5.2 Input parameter

| Sr. No. | Load(W) (*Kg*) | Spring Balance(S) (*Kg*) | Revolution (n) | Time(t) (*Sec*) |
|---|---|---|---|---|
| 1 | 0.27 | 0.00 | 30 | 9.4 |
| 2 | 1.035 | 0.00 | 30 | 9.58 |
| 3 | 10.17 | 0.25 | 30 | 11.66 |
| 4 | 20.83 | 0.72 | 30 | 13.47 |
| 5 | 32.535 | 1.41 | 30 | 14.38 |
| 6 | 44.1 | 2.03 | 30 | 16.25 |
| 7 | 57.195 | 2.55 | 30 | 21.63 |
| 8 | 64.575 | 4.25 | 30 | 25.35 |

Table 5.3 Result obtained from experiments

| Sr. No. | RPM of rotor | Torque (N-m) | Protor (Watt) | $P_{hyd}$ (Watt) | $C_p$ | ω (rad/sec) | TSR (λ) | Net load (N) |
|---|---|---|---|---|---|---|---|---|
| 1 | 573 | 0.51 | 30.58 | 12.48 | 2.36 | 60.04 | 19.18 | 2.64 |
| 2 | 561 | 1.97 | 115.67 | 12.48 | 9.26 | 58.74 | 18.77 | 10.15 |
| 3 | 462 | 18.97 | 917.31 | 12.48 | 73.50 | 48.38 | 14.99 | 97.31 |
| 4 | 399 | 38.46 | 1606.16 | 12.48 | 128.73 | 41.76 | 12.94 | 197.27 |
| 5 | 375 | 59.53 | 2336.55 | 12.48 | 187.22 | 39.25 | 12.16 | 305.28 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 6 | 330 | 80.47 | 2779.43 | 12.48 | 222.71 | 34.54 | 10.70 | 412.70 |
| 7 | 249 | 104.52 | 2724.00 | 12.48 | 218.26 | 26.06 | 8.07 | 536.01 |
| 8 | 213 | 115.38 | 2572.28 | 12.48 | 206.11 | 22.29 | 6.90 | 591.73 |

Table 5.4 Result obtained from calculated parameters for experimental results

**5.3 Sample Calculation**

Load (W) = 44.1 kg;
Spring balance (S) = 2.03 kg;
Radius of rotor(R) = 0.195 m.
Revolution of turbine shaft (n) = 330 RPM;

(1) Torque $(T) = (W - S) \times R \times 9.81 = 80.47\ Nm$

(2) $P_{Rotor}(P) = \frac{2\pi n T}{60} = 2779.43\ Watt$

(3) $P_{Hyd}(P_{Max}) = \frac{1}{2}\rho A V_\infty^3 = 12.48\ Watt$

Where A is the rotor area = $\frac{\pi}{4}(D_T^2 - D_H^2)$

(4) Coefficient of power$(C_P) = \frac{p}{p_{MAX}} = 222.71$

(5) Rotational speed$(\omega) = \frac{2\pi n}{60} = 34.54$ rad/s

(6) Tip speed ratio $(\lambda) = \frac{R \times \omega}{V_\infty} = 10.70$

(7) Net load $(N) = (W - S) \times 9.81$

$= 412.70$ N

From the experiment result graph for Power Vs Speed is plotted. As the net load is decreased there is an increase in rotor speed and accordingly the rotor power is obtained. As the rotor speed increases the power of the rotor increases up to certain value. But then after though the speed of the rotor increases the power decreases. As shown in Figure 5.4, it is observed that, maximum power 45 Watt at 330 RPM.

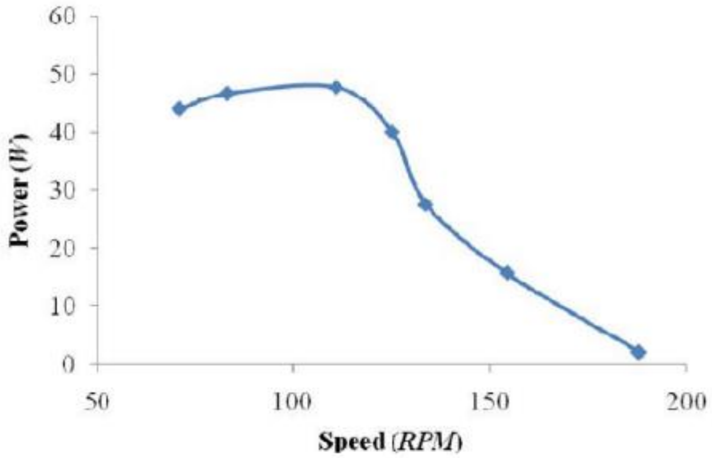


Figure 5.4 Power with reference to Speed

Figure 5.5 shows the experimental values of $P_{rotor}$, and how it varies with net Load. It can be observed that power is increased up to certain value of the net load and then after it decreases. It can be seen that maximum power of turbine o f 45 Watt is recorded at 410 N.

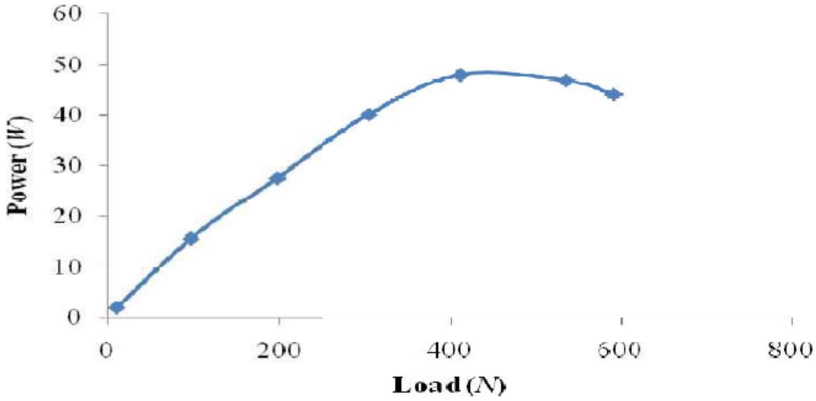


Figure 5.5 Power with reference to Net Load

As the $C_P$ increases, the TSR increases up to certain value. But then after though the Coefficient of power increases the TSR decreases. As shown in Figure 5.6, it is observed that, maximum Co-efficient of power.

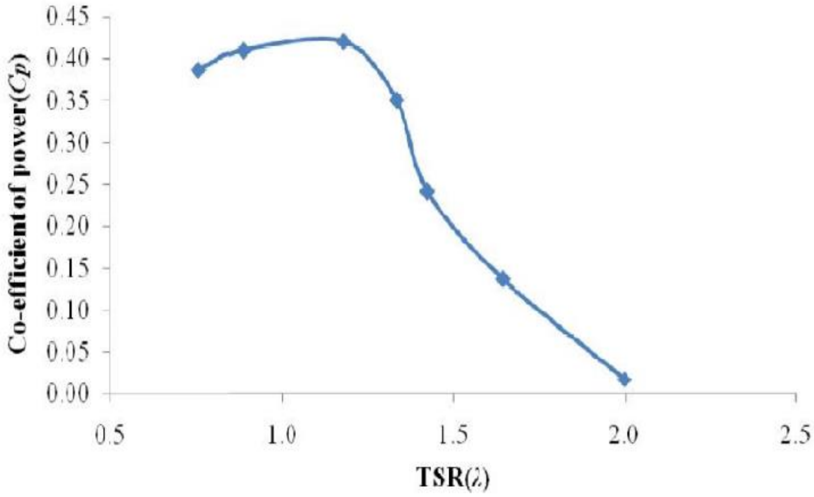


Figure 5.6 Co-efficient of power with reference to TSR

## VI. CONCLUSIONS

In this study, theoretical and experiment investigation was conducted using Hydrokinetic Performance Investigation of Propeller Type Turbine, devised for this study, for obtaining optimum design.

- Figure 6.1 shows, Experimental investigation indicates that as the co-efficient of power (CP) increases, the TSR increases up to certain value. But then after though the Coefficient of power (CP) increases the TSR decreases. It is also seen that, maximum Coefficient of power (CP) of 0.45 at 1.2 TSR.
- It is observed that the starting torque characteristic of axial flow turbine is better than other hydrokinetic vertical axis turbine like Darrius turbine.

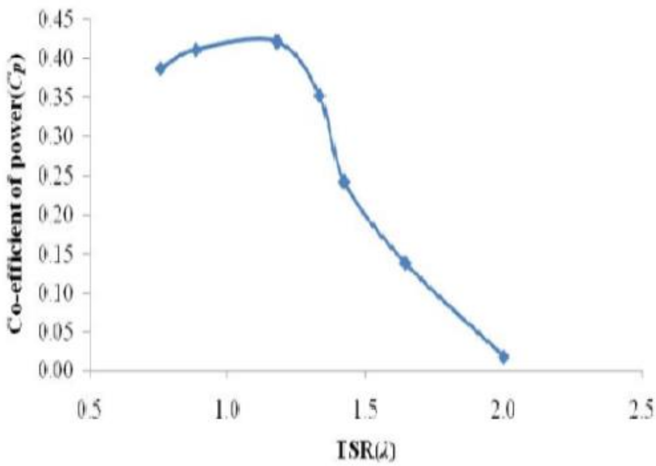


Figure 6.1 Experimental investigation

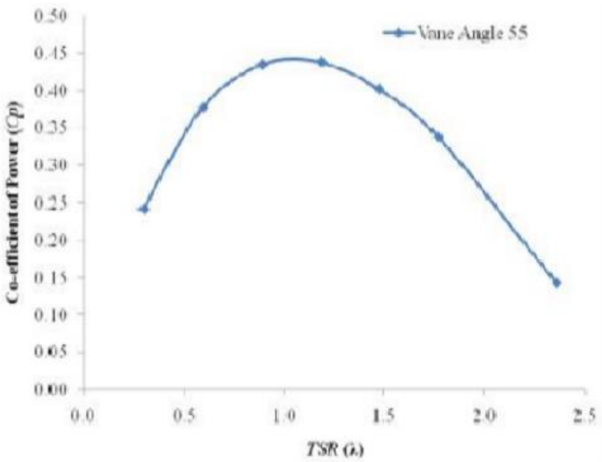


Figure 6.2 Theoretical investigation

- Figure 6.2 shows, Theoretical investigation indicates that as the TSR increases, the coefficient of power (CP) increases up to certain value. But then after though the TSR increase, co-efficient of power (CP) decreases. The trend of the graph of the analytical results it can be clearly seen from the graph that maximum co-efficient of power (CP) is of 0.45 is recorded at 1.01 TSR.
- The experimental investigation of hydrokinetic vertical axis turbine with inlet and out- let duct successfully developed power nearly about 45W at nearly 330 RPM. Some power was lost in a friction between gear arrangements. It is also observed that coefficient of power is nearly increased about to 0.45 at nearly 1.2 tip speed ratio.

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