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DESIGN AND DEVELOPMENT OF MINI KAPLAN TURBINE – A REVIEW

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Astract-

Hydropower is a renewable resource that can satisfy an important percentage of global energy. The world has a huge potential of small hydro Kaplan turbine power plants. The world energy demands are increasing. In this scenario the micro hydro Kaplan power plants gains special attention. The development of micro hydro Kaplan power plants on large scale will generate enough energy for the world inhabitants. This paper presents the modeling of the runner of a low head Kaplan for a specific site. To enhance its hydrodynamic efficiency by reducing weight, shape alterations, blade angle with combination of materials.

INTRODUCTION

The demand for increasing the use of renewable energy has risen over the last few years due to environmental issues. The high emissions of greenhouse gases have led to serious changes in the climate. Although the higher usage of renewable energy would not solve the problems over night, it is an important move in the right direction. The field of renewable energy includes, wind power, solar power and water power. The design of a hydraulic turbine is searched to satisfy a flow rate and a small waterfall.[2] A turbine is a rotary mechanical device that extracts energy from a fluid flow and converts it into useful work. A turbine is a turbo machine with at least one moving part called a rotor assembly, which is a shaft or drum with blades attached. Moving fluid acts on the blades so that they move and impart rotational energy to the rotor. Gas, steam and turbines have a casing around the blades that contains and controls the working fluid. The Kaplan turbine is an outward or inward flow reaction turbine. Here working fluid changes pressure as it moves through the turbine. Power is gained from both the hydrostatic head and from the kinetic energy of flowing water. Power is recovered from both the hydrostatic head and from the kinetic energy of the flowing water. The design combines features of radial and axial turbine.[3] The inlet is a scroll-shaped tube that wraps around the turbine's wicket gate. Water is directed tangentially, through the wicket gate, and spirals on to a propeller shaped runner, causing it to spin. The outlet is a specially shaped draft tube that helps decelerate the water and recover kinetic energy. The turbine does not need to be at the lowest point of water flow, as long as the draft tube remains full of water. A higher turbine location, however, increases the suction that is imparted on the turbine blades by the draft tube. The resulting pressure drop may lead to capitation. Variable geometry of the wicket gate and turbine blades allows efficient operation for a range of flow conditions. Kaplan turbine efficiencies are typically over 90%, but may be lower in very low head applications.[1]

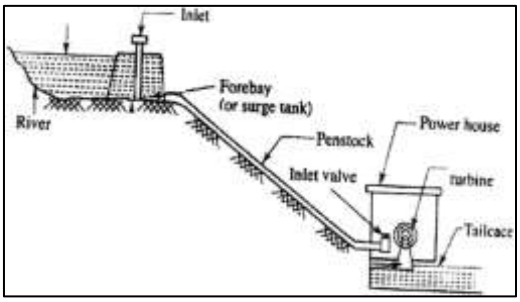

Fig.1 Schematic of a Micro Hydro Power Plant.

TURBINE SELECTION

Selection of the hydraulic turbines type is not always easy for the system design as we can use various turbine types in different applications. The selection of the turbine usually depends upon the following factors. [4]

- Net head
- Flow rate of water
- Rotational speed
- Cavitation problem
- Cost

The specified table completely describes the detail available for each type of the turbine on the basis of net head.

Table 1

TURBINE TYPE	HEAD RANGE IN METERS
KAPLAN AND PROPELLER	1 <HN< 40
FRANCIS	25 <HN< 350
PELTON	50 <HN< 1'300
CROSSFLOW	50 <HN< 200
TURGO	50 <HN< 250

REVIEW ON TURBINE MANUFACTURERS IN INDIA [6]

Table 1 gives the details about the review on turbines manufacturers in India. The need of energy had paved path to the development of several turbine manufactures in India but the interested parameter is that lower power rated turbine design is in scarcity.

Silver Boat Technologies Pvt. Ltd are known for the scheming and conniving of Pico and small hydel systems of a wide scaling of 1–100 kW. All the system fabrication is done by Silver Boat Technologies Pvt. Ltd in India and their turbines can be used for both grid and off grid conditions with higher efficiency and reliability. Ytek is an organization connecting themselves in the component development for micro hydro projects such as extending their help in designing of control equipment for system and also focuses on industrial automation. They cater on micro hydro projects situated in tribal regions of the country which are rich in potential and are off grid and thus, can be automated.

APE Power Pvt. Ltd also dealers in turbine development of micro hydro projects and have expanded their work on commissioning and execution of the micro hydro plants. Their turbine production starts from 5 kW turbines and ranges up to 100 kW turbines. In the state of Kerala, six high potential waterfalls were identified in the year 2001 by framing their project strategy in electrifying the rural community residing near Mankulam Panchayat in Idukki District.

Table 2

SR. NO.	TURBINE MANUFACTURER	OUTPUT POWER (KW)
1.	Silver Boat Technologies, Chennai	100
2.	Ytek Controls, Dehradun	5 - 100
3.	Ape Power Pvt. Ltd, West Bengal	5 - 100
4.	Wasserkraft, New Delhi	5 - 200
5.	Vaigunth Enertek Pvt. Ltd, Chennai	10 - 200
6.	Flowmore Ltd, Haryana	Upto 20,000
7.	Karshni Intertech Pvt. Ltd, Noida	5 - 100
8.	Pentaflo Hydro Pvt. Ltd, New Delhi	5 - 100
9.	Centre for Energy Initiatives, Bangalore	5 - 100

EFFECTIVENESS CRITERIA OF LOW HEAD MICRO-HYDROPOWER TURBINES SELECTION

The selection range of the turbines generally depends on many criteria, such as various ranges of the head, flow rate, shaft speed and specific speed. There are also other factors that need to be taken into account when selecting turbines, including the depth at which the turbine should be positioned, its performance and cost effectiveness. [7]

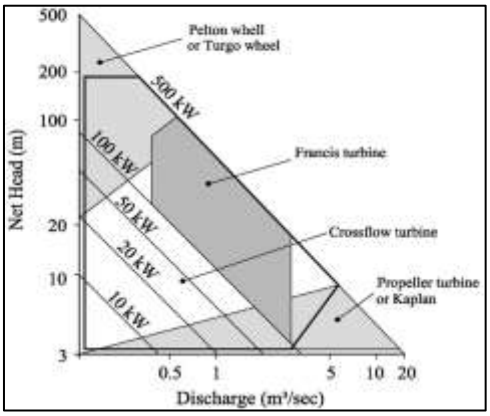

Fig.2 Turbine selection according to net head and discharge

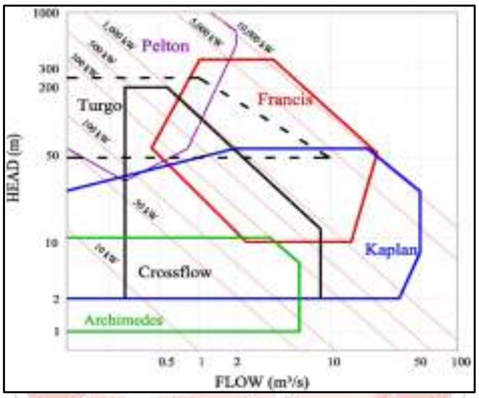

Fig.3 Turbine selection according to net head and flow rate

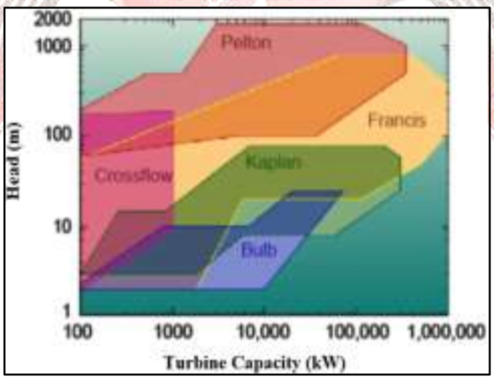

Fig.4 turbine selection according to head and turbine capacity

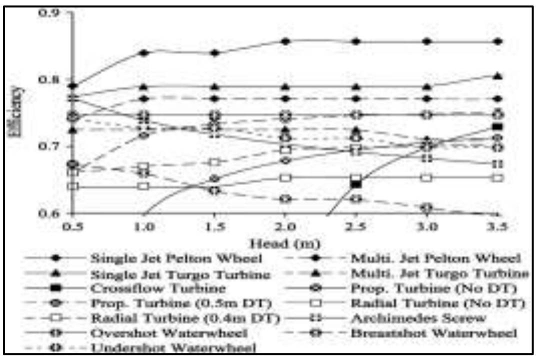

Fig.5 Efficiency comparison graph for various types of turbine

COMPONENTS OF AXIAL FLOW TURBINE

The basic Axial Flow turbine consists of five main parts. They are:

1. Spiral Casing
2. Runner
3. Guide Vane
4. Draft Tube
5. Drive Shaft

1. **Spiral Casing**: Casing may also be used for very low heads and are always used for high heads. Its areas of the waterway decrease as the case encircle the guides, because only a limited portion of the water flows clear around the enter the further part of the circumferences. The main purpose of the spiral casing is to provide a uniform flow to the guide vane.
2. **Runner**: Runner is the main component of the turbine that converts water power to the rotation of shaft power. For low head, the use of flow rate is increased and therefore the runner is designed pure axially. The runner is keyed to a shaft which is usually of forged steel. The water passes through the runner blades in axial direction both at inlet and outlet.
3. **Guide Vane**: The guide vanes duct must have a constant contraction to have a steady rise of water velocity. It is needed to a cross section of the guide blade so as to have a steady rise of water velocity. So, it is preferable to employ air-foil properties. The inlet end of the guide vane lies as a rule under as angle of from 60° to 70° to the tangent of the circle.
4. **Draft Tube**: The purpose of the draft tube is to reduce the outflow loss and thus to improve the efficiency of the plant. Draft tube is an integral part of mixed and axial flow turbine. The total power available is that due to the fall from head water level to tail water level.
5. **Drive Shaft**: The turbine shaft will transmit the rotary motion of the runner to the generator via the drive system. It most cases the shaft has circular cross-section and is subject to either pure torsion.[1]

CHARACTERISTICS OF KAPLAN TURBINE:

Except for the runner, other components of axial turbine are similar to the mixed-flow turbine.

a. **Characteristics of axial turbine:**
High speed which is 2 times of mixed-flow turbine when H and N is the same, small size. The runner blades can turn (double adjustment); the turbine has high efficiency when H and N change.

b. **Structure of runner**:
axial movable-blade turbine is usually used in large hydropower station with low head and large discharge. Main Parts: Blades, hub, main shaft, runner cone, rotating mechanism.

c. **Blade:**
Curved surface, air foil section, thick root, thin edge to bear the torque of water flow. Number of blades: Related to H, generally 4~8 pieces.

d. **Blade rotating angle F**:
F=0°; when optimum operating condition, the blades begin to turn when F>0, the blades turn to close when F<0. -15°>F<+20°.

e. **Hub:**
Connected with blades externally, installed rotating mechanism internally. It is installed inside the hub, controlled by governor, high-speed guide vane angle.

- α1 Stator inlet angle, set up to line up with incoming flow.
- α2 Stator exit angle. A value needs to be selected and then checked following the results of this calculation (determines power output)
- β2 Rotor inlet angle, set to line up with *relative* inlet flow at station 2.
- β3 Rotor exit angle. A value needs to be selected and then checked following results of this calculation (determines power output)
- *Q* Flow rate, guess a value and then use this calculation to see if it is reasonable
- *R*2*m*, *R*3*m* Mean radii at station 2 and 3, pick at start of analysis.[3]

CALCULATIONS

DESIGN THEORY OF 5KW AXIAL FLOW TURBINE
The design of the axial flow turbine is considered by the following formula

Turbine Output Power
The Turbine output power is calculated by the equation
$P_t = \frac{generator\ output}{\eta m \eta g}$
Where, P_t = required shaft power (KW)
η_m = Mechanical Efficiency (%)
η_g = Generator Efficiency (%)

Power from water
The flow rate can be calculated by the equation,
Power = $\gamma\ H_d\ \eta_o$
Where, P = Shaft Power (KW)
Q = Flow Rate (m^3/s)
H_d =Design Head (m)
η_o= Overall Efficiency (%)

Applicable Specific Speed
To determine the specific speed the following equation is suitable for low head turbines
$N_s = \frac{885.5}{Hd^{0.25}}$
Where, N_s = Specific Speed (rpm)
H_d = Design Head (m)

Applicable Turbine Speed
The turbine speed can be calculated by the equation,
$N = \frac{Ns\ Hd^{0.25}}{\sqrt{Pt}}$
Where, N= Turbine Speed (rpm)

Number of Poles for Generator,
The number of poles for the generator can be calculated by the following equation,
$p = \frac{60\ f}{N}$
Where, p= Number of poles
N = Turbine Speed (rpm)
f = Frequency (50 Hz)

Runner Diameter
The runner diameter can be calculated by the equation,
$D = \frac{84.5 * \Phi * \sqrt{Hd}}{N}$
Where, D = Runner Diameter
Φ = Periphery Coefficient

Periphery Coefficient
The periphery coefficient can be calculated by,
$\Phi = 0.0233 * N_s^{1.5}$

Blade Profiles,
In the space of the runner it can be divided into five cylindrical sections,
Section 1,$r_1 = \frac{d}{2} + 0.0015d$
Section 3,$r_3 = \frac{D}{2} + \sqrt{\frac{1+Dd^2}{2}}$
Section 2,$r_2 = r_1 + \frac{r3-r1}{2}$
Section 5,$r_5 = \frac{D}{2} - 0.015D$
Section 4,$r_4 = r_3 + \frac{r5-r3}{2}$

Guide Vane & Guide Vane Angle
The number of guide vane can be calculated by the equation,

$z = \frac{1}{4}\sqrt{D} + 6$
Where, z = Number of Guide Vanes

The guide vane angle can be calculated by the equation,
$\tan \alpha = \frac{Vf}{Cu}$
Where, α = Guide Vane Angle
V_f =Flow Velocity
C_u = Tangential Component of Absolute Velocity

Spacing of Blade,
Spacing of blade can be determined by the following equation,
$t_s = \frac{2\pi r}{z}$
Where, t_s = spacing of blade
z = Number of blades

Circulation,
Circulation can be determined by the following equation,
$\Gamma = t_s (V_{u1} - V_{u2}), V_{u2} = 0$
Where, Γ = Circulation
V_{u1} = Tangential Component of Absolute Velocity

Angle of Attack
According to equation, angle of attack in relation of the direction of velocity w_α can be determined,
$\eta_h = u^* w_\alpha \frac{t}{l}(k2 - \frac{Kx}{\tan \beta\alpha})$
The Profile N.A.C.A. 2412 which means the profile will exhibit the following values, m/1=2%; L/1 = 4%; t/1 = 12%; which is defined by the following equation,
$C_z = \frac{\delta Cz}{\delta \alpha}(\alpha - \alpha o)$
$C_x = C_{xv} + \frac{\delta Cx}{\delta Cz^2} Cz^2$
$\alpha_\alpha = \alpha - 57.3 \frac{Cz}{6\pi}$

Lattic Angle
$\beta = 90 - \beta_\alpha + \alpha_\alpha$

FABRICATION

A. Fabrication of Spiral Casing
It acts like casing to the guide vanes and runner setup. As the water passes through the spiral the velocity of the water increases so that more energy will be converted to rotate the shaft. The cross-sectional area of this casing decreases uniformly along the circumference to keep the fluid velocity constant in magnitude along it path towards the guide vane. This is so because the rate of flow along the fluid path in the volute decreases due to continuous entry of the fluid to the runner through the openings of the guide vanes. As it is observed from the figure6 manufacturer has taken 3ft, 40mm diameter GI pipe is cut into different parts by certain angles. Later gradually bending the parts and by using oxy acetylene gas cutting we have made the casing. It is like that 40 mm diameter at the inlet and cross section gradually decreases to the end such that it makes the water to flow from the inlet with high velocity.[1]

Fig.6 Spiral Casing

B. Fabrication of guide vanes
These are also known as stay vanes. As the name suggests these vanes are only adjusted to control the flow rate through the turbines but not for the rotation of the shaft. The basic purpose of the guide vanes is to convert a part of pressure energy of the fluid at it entrance to the kinetic energy and then to direct the fluid on to the runner blades at the angle

appropriate to the design. In of the inlet turbine guide vanes are fixed. In this turbine 16guide vanes are used. As shown in the figure7 manufacturer has taken the GI sheet and cut into pieces as per the dimensions and by using gas welding, grinding, these vanes were fabricated. Height of the guide vane is 3cm and length of the guide vane is 5cm.[1]

Fig.7 Guide Vanes

C. Fabrication of runner blades

In the figure no. 8 Manufacturer has made runner blade model by using the cardboard. With the help of the cardboard model he made the actual runner blades by using GI sheet as shown in the figure 8. In this turbine 3 runner blades are made from the GI sheet with the help of portable grinding machine and straight snip cutter. These 3runner blades are welded to the hub. After passing into the casing fluid strikes the runner blades axially and the impact causes the shaft of the turbine to rotate, producing torque. The continuous flow of fluid makes the runner blade to rotate such that shaft mounted on it will also rotates and producing torque.[1]

Fig.8 Runner Blades

D. Fabrication of draft tube

The draft tube is a conduit that connects the runner exit to the tail race. In this turbine a straight conical draft tube is used. The draft tube is such that outlet diameter is more than the inlet diameter. We have taken the GI sheet and made into piece of trapezoidal shape with Inlet diameter 18cm, out let diameter 22cm, Angle is 2.8° taper. By using oxy acetylene gas welding, we have taken it into conical section as shown in the figure 4. The outlet of the draft tube is immersed in the tail water such that to reduce the velocity of discharged water to minimize the loss of kinetic energy at the outlet.

Fig.9 Draft Tube

INSTALLATION OF THE KAPLAN TURBINE

During the installation of a Kaplan turbine we have taken 3hp 3phase centrifugal pump. Also, we have used the sump tank fabricated by galvanised iron sheet. The pen stock arrangement is made by connecting PVC pipe from pump to the inlet of the spiral casing. The casing is also provided with blade control mechanism to control the flow rate by changing the angle of wicket gates arrangement. We have taken separate casings for the pump and turbine set up. The runner blades are mounted to the hub by oxy acetylene gas welding. This shaft arrangement is supported by ball bearings. As it is made up of metal it will easily corrodes when there is no proper maintenance. In order to avoid this, we painted it with corrosive resistance paints. It is necessary to empty the tank and fill it with fresh water for at least once in a week. Since if the water contains solid impurities it will clogs at the pipe fittings. It is very important to place good supports in order to decrease the vibrations produce by pump and turbine shaft. It is very important to place good supports for reducing vibrations produced by pump and turbine shaft. [1]

INFLUENCE OF SURFACE ROUGHNESS AND WEAR:

The surface roughness includes the initial roughness strongly depends on the manufacturing techniques used, and the roughness which is changed by wear or erosion. Thereby surface quality causes increased energy losses during its operation. The losses are increased by increased roughness due to increased friction losses usually expressed in the head from the worn surface and an offset from the optimum hydraulic profile Friction losses should be special considerable, especially in the runner where the relative velocity is the greatest. For impulse turbines, wear on needle and nozzle would result in a decay of efficiency and possibly cavitation, see Fig. 3. In worn bucket, the boundary layer is thickened and disturbed due to an increased wave in less of the surfaces. For reaction turbines, the performance of a turbine is destined to degrade due to various reasons as years go by, shown in Fig. These factors include metal loss (cavitation, erosion, and corrosion), opening of runner seal, opening of guide vanes clearances, and increasing surface roughness. Erosive wear due to high content of abrasive material during monsoon and cavitation is the very important one. [5]

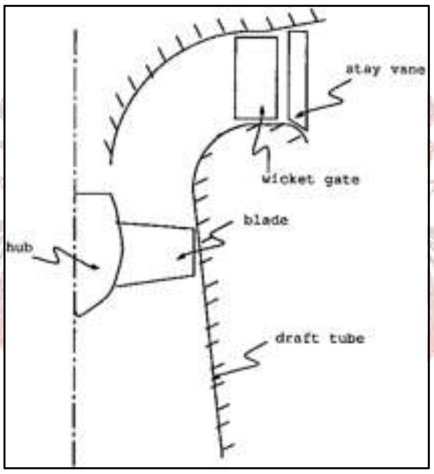

Fig.10 Blade and casing arrangement in a Kaplan turbine.[5]

INFLUENCE OF GAP CLEARANCES ON THE INTERNAL LEAKAGE

Volumetric losses are mainly caused by the existence of sealing gap and tip clearance of runners. The higher is the differential pressure across the space, the greater is the leakage. The leakage flow contributes negatively to the turbine performance in several ways. For Kaplan and bulb turbines, since the blades are adjustable, the runner is not shrouded, there must exist finite clearance between them, shown in Fig.5. The tip clearance is of the order of millimeter, but it is one of the most influential parts to performance of the turbines. These gaps can give rise to leakage flows, resulting in the formation of vortices. The effect induced by the presence of the tip clearance do not have a linear growth with its size. So it is important to determine the admissible tip clearance size found the tip clearance flows from the pressure side to the suction side of the blade produced the tip vortex cavitation, which affected the sheet cavitation on the leading edge of the next blade and enhances the blockage effect near the casing than the flows without tip clearance.[5]

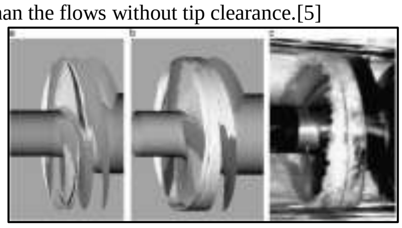

Fig.11 Influence of tip clearance flows on the development of cavitation. (a)Numerical result without tip clearance, (b)Numerical result with tip clearance and Experimental Visualization.[5]

CONCLUSION

In this paper we have discussed the calculations of mini Kaplan turbine parts. The axial flow Kaplan turbine can also be used for electricity highly demands which are far from the national grid system. It can be used for low head of water for simple technology, locally designed and built, by utilizing local materials with low cost. The analysis in ANSYS is very important prior to the fabrication of the turbine. The blade acts as a fixed cantilever beam during the modal analysis where the displacement is high but in safe limits at the edges of the runner blade for all mode shapes.

REFERENCES

[1.] Fabrication and Installation of Mini Kaplan Turbine Sasidhar Gurugubelli1, Chandu Gummalla2, Prasanth Gunipalli3, Venkatesh balasa4, Md Shafi51Assistant professor, lendi institute of engineering and technology, vizianagaram-5350052, 3, 4, 5 UG Scholar, lendi institute of engineering and technology, vizianagaram-535005

[2.] DESIGN AND PERFORMANCE TESTING OF 5KW AXIAL FLOW TURBINE FOR HYDROPOWER Ei Mon Department of Mechanical Engineering, Yangon Technological University, Myanmar

[3.] Design and Analysis of Low Head, Light weight Kaplan Turbine Ms. M. Ujwala1, Mrs. P. Chaithanya Krishna Chowdary2, Mr. L. Srinivas Naik31M.Tech Student, Anurag Group of Institutions, Venkatapu (V), Ghatkesar (M), Ranga Reddy(D), Telangana(S)2Assistant Professor, Anurag Group of Institutions, Telangana(S), India 3Associate Professor, Anurag Group of Institutions, Telangana(S), India

[4.] Modelling and Analysis of a very Low Head Kaplan Turbine Runner blade

[5.] A selected literature review of efficiency improvements in hydraulic turbines Xin Liu a, Yongyao Luo a, Bryan W. Karney b, n Weizheng Wang a a Department of Thermal Engineering, Tsinghua University, Beijing100084, China b Department of Civil Engineering, University of Toronto, 35 St. George St., Toronto, CanadaONM5S1A4

[6.] A review on turbines for micro hydro power plant C. P. Jawahar, □, Prawin Angel Michaela Department of Mechanical Engineering, Karunya University, Coimbatore, India Department of Electrical and Electronics Engineering, Karunya University, Coimbatore, India

[7.] Operation, performance and economic analysis of low head micro hydro power turbines forrural and remote areas:A review A.H. Elbatrana ,n,O.B. Yaakobb, Yasser M. Ahmeda, c, H. M. Shabaraaa Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia b Marine Technology Centre, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia c Faculty of Engineering, Alexandria University, Egypt.