Design and Manufacture of a Micro Zero Head Turbine for Power Generation

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***Abstract*– A zero head water turbine has been used as a source of power generation where construction of a dam for the head is not required. It works on natural flow of water to generate a specific power output. The power is however limited by flow of water which is sufficient to keep generate a suitable number of revolutions per minutes for the blades. Present research was aimed to design and manufacture a micro zero head turbine which could produce sufficient power to light a couple of energy saver bulbs upto 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.**

***Keywords*–** Power Generation, Design, Turbine and Results

I. INTRODUCTION

Micro-hydel power (MHP) technology has matured over a period of time. Centuries back, man learnt how to make use of water for power generation and even presently, in some countries primitive hydraulic devices could be found. Now a day's MHP are being developed using modern design tools and technologies. These are being used for power generation at far flung places [2] where naturally flowing streams of water exist in abundance [3]. Such power generation initiatives are being duly supported by the local governments.

Additional advantages of a Micro zero head turbine are high efficiency in low speed currents, little resistance to the onward force of a tide and it also allows marine life to harmlessly escape from the rotor blade. Investigations regarding the influence of design parameters in low head axial flow turbines like blade profiles, blade height and blade number for micro-hydro application continue to be inadequate, even though there is a need and potential for the application of such turbines [1]. Investigations have been made to analyze the cost of various components of low head run-of-river small hydropower projects based on the actual quantity and the prevailing market price of each item [5].

II. DESIGN OF PROTOTYPE

Primary consideration for Micro Zero head turbine design was that it should fit a limited space ranging from 1 to 4 feet width of the free stream of water flow in far flung areas and must have minimum of the following geometric specifications:-

a. Perpendicular distance from shaft centre to force exerting on blade = 130mm
b. Pulley radius = 110mm
c. Blade dimension = 100 x 100 mm²
d. Blade shape = semi circular
e. Number of blades = 08
f. Flow velocity = 0.5 m/s, 1m/s, 1.2m/s, 1.5m/s

These dimensions were a result of required power generation and subsequently it was to be tested experimentally. Other design parameters included variable flow rates to provide different power values, out flow of one blade not to obstruct the other and availability of continuous

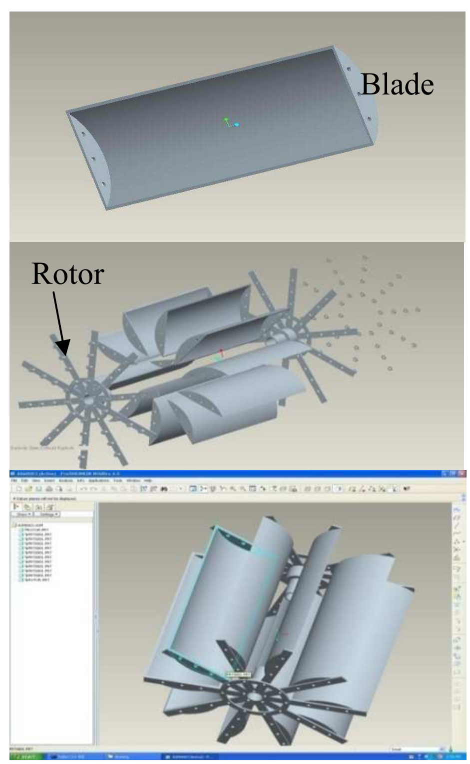

Fig. 1. Blade and rotor assembly

value of torque at a certain rpm for same value of power generation. The calculated geometric dimensions were used to arrive at prototype design as shown in fig-1 which shows the design of individual blade, an exploded view of the rotor and blade assembly and final assembly of the complete turbine blade and rotor.

A. Design of Blade

Shape of blade was made as a semi-circular bucket so that maximum flow rate may enter from the free stream and its thickness was based on strength to thickness ratio. Use of semicircular blade was expected to provide the following properties:-

a. The velocity profile of water stream is normally high at the top surface and decreases downwards as shown in fig 2.
b. A semi-circular shape was expected to allow more flow of water to enter bucket as compared to one that could be striking a flat plate. This property was also established by past research [4].

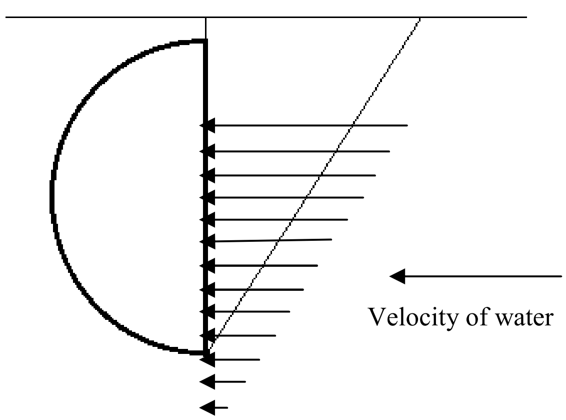

Fig. 2. Velocity profile on blade [4]

B. Geometric Model of Blade

For exact calculations of the geometry of a blade one has to consider the velocity V of water and angle α which Force applied by water profile makes with the centre line of blade. Therefore the component of velocity acting on bucket perpendicular could be represented as is VCosα. So when bucket is at centre line where α = 0, the relationship of applied force of water could be given as:

$$Fi = \rho VA(V-u)$$

Where u is bucket speed, ρ is density of water, V free stream velocity, u being bucket tangential velocity and A was the bucket area expected to be designed. The next important parameter was the angle between two buckets for finding the exact number of blades for providing optimum value of torque for a stabilized power output.

This angle was calculated by assuming that the bucket directly facing water is not rotating and is perpendicular to free stream of water initially. At this point all the water would be entering the bucket and bucket velocity is assumed to be zero. Whereas any consecutive at that instant could be at an angle to the water stream. Initial force of water striking the bucket could be termed as Fi that could be calculated through the following relationship:

$$Fi = \rho VA(V-0) \quad (u = 0 \text{ when bucket is stationary})$$
$$= \rho AV^2$$

However the fore being applied to the second bucket which is at an angle at α could be found by the following relationship. Please note that value of u would be zero for this case also because both the buckets are stationery:

$$Fr = \rho VA(VCos\alpha-0)$$
$$= FiCos\alpha$$

These relationships would result in finding the angle between two consecutive buckets and torque values could be evaluated for a required power output. The schematics of two consecutive buckets are shown in Figure 3.0 and the values of Torque for various rpm of the micro turbine are shown in Figure 4.0. It may however be noticed that for a micro turbine and power output of 50watts approximately with head velocity of 1.2meter/second the highest value of torque obtained was at 25 degree between two consecutive buckets as seen from Fig. 4.

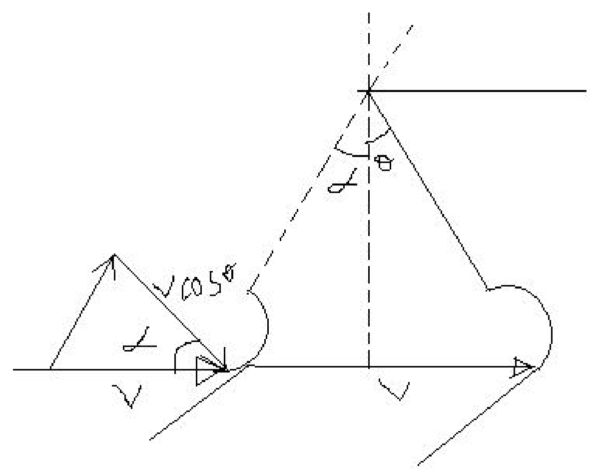

Fig. 3. Calculation of torque by number of blades

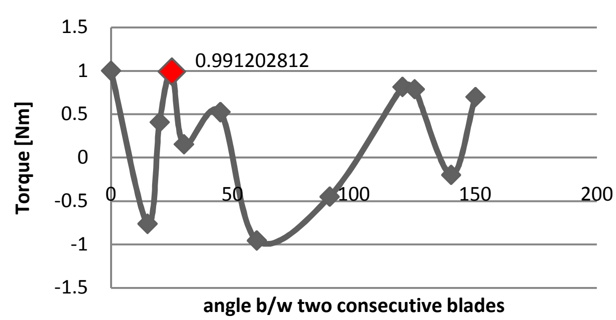

Fig. 4. Torque-Power relation

Based on the above calculations, the total length of blade from shaft centre to tip of blade was estimated to 200mm. Its distance from shaft centre to pitch diameter was observed to be 150mm for one blade. However for estimating the total number of blades the circumference of the complete circle of the micro turbine came out to be 816.4mm. Based on this data the approximately 8 blades were estimated for the required torque and power generation. Typical geometric specifications of a blade are shown in Fig. 5.

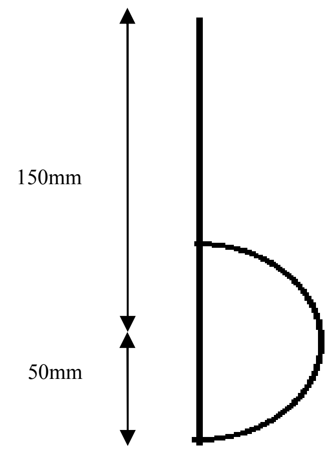

Fig. 5. Blade dimensions

III. MATERIAL AND MANUFACTURING

Material Selection: For the current design, Aluminum 6061-T6 was chosen which had the following properties:-

a.	Density	2.7g/cc
b.	Ultimate Tensile Strength	310 MPa
c.	Tensile Yield strength	276 MPa
d.	Modulus of elasticity	68.9 GPa
e.	Poisson Ratio	0.33

Model Preparation: Ultimate design of the turbine was expected to have following parts:-

a. Blade profile.
b. rotor
c. Bearings.
d. Shaft.
e. Pulley.
f. Floating case.

The micro head turbine assembly was manufactured as per design and an electric power generation system was installed on it for converting mechanical torque to electrical power. Final assembly of the design and manufactured turbine with power output attachments are shown in Fig. 6 and Fig. 7.

After manufacturing and assembly the turbine was tested. The methodology of testing and its results are discussed in the subsequent paras.

Fig. 6. Aluminum zero head turbine

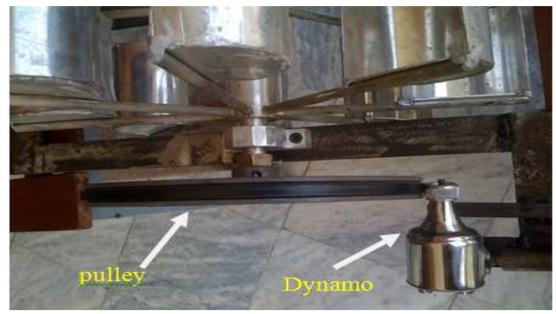

Fig. 7. Power attachments

IV. TURBINE TESTING

The turbine was tested in a free water stream environment. Force applied on the buckets, torque generated, power output and electrical load which could be powered by the turbine was evaluated for various flow velocities. The relationships observed are shown in Fig. 7.

It may be observed that the power values increased exponentialy at a higher gradient. This trend was followed by powered electrical load and Force generated by the water stream at higher velocities. The exact values of these parameters are given at the end of this paper in table 1.0. The testing is however shown in Fig. 9.

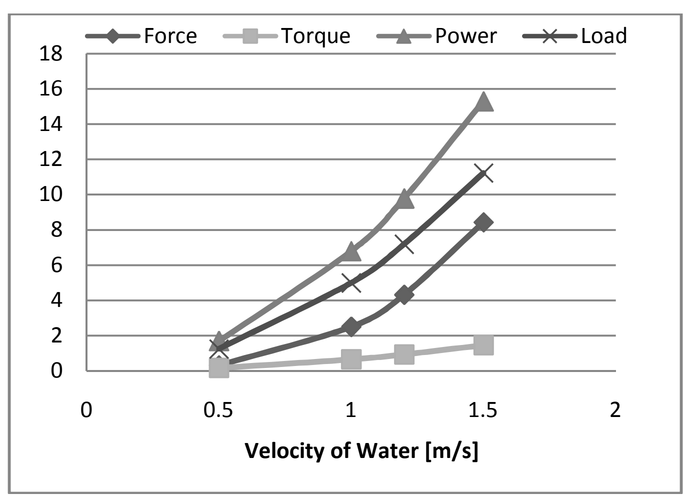

Fig. 8. Results at different flow rates.

Fig. 9. Practical demonstration

V. FINDINGS

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 we arrived at the following findings:.

a) Turbine blade design and number of blades are the vital parameter for extracting optimum power from a micro zero head turbine.
b) 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.
c) 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..
d) 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.
e) 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
f) Present research was focused on generating a low power value, However, present 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.

Table-1 Velocity-Power Relation

V (m/s)	U (m/s)	Force (N)	Torque (Nm)	rpm	rad/s	Power (Watt)	Load (Kg)	Power given by stream (Watt)
0.5	0.25	1.2475	0.162175	100	10.472	1.698297	1.247	0.312
1	0.5	4.99	0.6487	100	10.472	6.793186	4.99	2.5
1.2	0.6	7.1856	0.934128	100	10.472	9.782188	7.185	4.311
1.5	0.75	11.2275	1.459575	100	10.472	15.28467	11.227	8.42

VI. CONCLUSION

Present research may be 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. This type of turbine could be an economical source of power generation where electric power could not be provided due to absence of power transmission lines and requirements of huge investments on infrastructure. Such initiatives if supported by local governments could provide the fruits of electric power to dwellers of distant lands.

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