Effect of Jet Angle on the Performance of a Turgo Turbine

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Abstract -- Hydroelectric power generation is one of the most popular among the renewable energy. The purpose of this paper is to observe the performance test of Turgo impulse turbine. The turbine power is 500 W and the permanent magnet generator is used .The proposed runner diameter, runner speed and number of blade are 262 mm, 461 rpm and 20. Performance tests are conducted by changing the jet angles (10°, 20° and 30°) at Renewable Energy laboratory in Mechanical Engineering Department. According to the test results, the maximum turbine power, generator output power and turbine efficiency are 635W, 475W and 81% at jet angle 20°.

Indexed Terms: efficiency, impulse, jet angle, runner

I. INTRODUCTION

Hydropower was considered as one of the most desirable source of electrical energy due to its environment friendly nature and extensive potential available throughout the world. Among several renewable resources, hydropower is an important and sustainable renewable energy in the world today that can be exploited to the maximum due to its attractive economics and the availability of basic technology.

The hydroelectric power plant has to be installed with adequate turbine type in order to achieve the maximum output and higher efficiency. Impulse turbines operate at high pressures created by high-head dams. The high hydraulic pressure creates a high velocity jet of water that transfers its impulse momentum to the turbine's cup shaped blades.

In an impulse turbine, the runner operates in air and is turned by one or more jets of water which make contact with the blade. The water remains at atmospheric pressure before and after making contact with the runner blades. In this case, pressure energy is converted into the kinetic energy of a high speed jet of water in the form of a nozzle [12Ano]. Then, it is converted to rotation energy in contact with the runner blades by deflection of the water and change of momentum. The nozzle is aligned so that it provides maximum force on the blades.

The Turgo turbine is similar to the Pelton but the jet strikes the plane of the runner at an angle (typically 10° to 30°) so that the water enters the runner on one side and exits on the other. The Turgo turbines are used in medium head and high head of water between the head of 15 m to 300 m. Turgo turbine transforms kinetic energy of water jet to rotational energy with the help of a nozzle.

The high speed of water jet directed on to the turbine blades and the turbine is rotated at high speed after striking the water to the turbine blades. Then the shaft is rotated and the electricity is generated in generator. The Turgo turbine runner is same as Pelton runner but it is split in half. For the same power output the Turgo turbine runner is one half the diameters of the Pelton runner, and the specific speed is twice the Pelton runner.

The Turgo turbine can handle a greater water flow than the Pelton turbine because the exiting water does not interfere with buckets. If the number of jet is increased the specific speed of the turbine is also increased. This is widely used in pico hydro power plant because the cost of the turbine is low and it can easily manufacture in minimum cost. Turgo turbines are mostly used in rural areas electrification in pico hydro power plants.

II. METHODOLOGY

The specification data for the Turgo turbine are as follows:

Required Power,	P = 500 W
Available head,	H = 10 m
Overall efficiency,	η_o= 70 %
Coefficient of velocity,	C_v= 0.98
Speed ratio,	K_u = 0.46

Jet ratio, $m = 10$
Number of jet, $z_0 = 1$ jet

A. Water Power:
The power supplied by a water jet depends upon the head and the rate of water flow.

(1) power supplied by the jet $= \rho g Q H$

B. Overall Efficiency:
An appraisal of the performance of a hydraulic turbine is made by its overall efficiency.

$$\eta_o = \frac{\text{shaft power}}{\text{water power}} = \frac{P}{\rho g Q H} \quad (2)$$

C. Jet Diameter:
The diameter of jet is determined at the maximum discharge by using continuity equation.

$$d_j = 0.545 \sqrt{\frac{Q}{z_0 \sqrt{H}}} \quad (3)$$

D. Jet Ratio:
The ratio of pitch circle diameter of the wheel to the jet diameter is known as jet ratio.

$$m = \frac{D}{d_j} \quad (4)$$

E. Number of Buckets, Z
The number of buckets on the peripheral of Turgo wheelies determined as follows.

$$Z = 0.5m + 15 \quad (5)$$

F. Bucket Design:
Bucket design is shown in the following TABLE 1.

Table 1: Design of Bucket

Items	Symbol	Dimension	Value	Unit
Length	L	3.4 d_j	80	mm
Width	B	2.34 d_j	60	mm
Depth	H	0.585 d_j	20	mm
No of buckets	Z	20	20	-

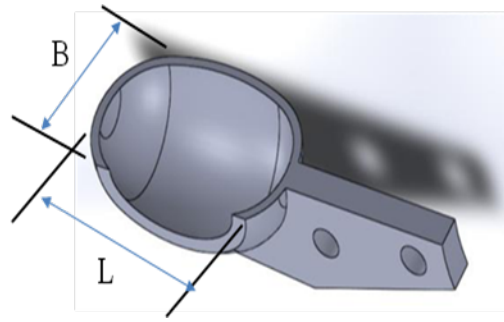

Fig. 1: Bucket Design

III. MANUFACTURING PROCESS

A. Manufacturing the Buckets with the 3D Printer:
All the parts created using a 3D printer need to be designed using some kind of CAD software. This type of production depends mostly on the quality of the CAD design and also the precision of the printer. There are many types of CAD software available. The model to be manufactured is built up a layer at a time. A layer of powder is automatically deposited in the model tray. The print head then applies resin in the shape of the model. The layer dries solid almost immediately.


Fig. 2: Manufacturing of Buckets

B. Assembly of Bucket:


Fig. 3: Assembly of Buckets

After manufacturing the 20 buckets for the Turgo turbine, the two discs are prepared and the holes are drilled to mount the buckets as shown in Fig.3.

IV. EXPERIMENT

A. Experiment Apparatus:

The main characteristic of the Turgo turbine is the water jet of circular cross-section which passes through the buckets, which are arranged at the periphery of the runner. Turgo turbine consists of two main parts which are buckets and nozzle. The buckets are placed at equal spacing around circumference of the runner. And the runner is generally mounted on the shaft with bearings and the buckets are either casted integrally with the disk or fastened separately. This is its adaptability to a variety of water sites and power needs. It is simplicity and low cost, makes very suitable for small power development.

Fig. 4: Constructed Turgo Turbine

B. Experimental Set-up:

The experimental facility is made of water pumping system and a test stand with the Turgo impulse turbine with a generator. A Turgo impulse turbine has been installed in a hydraulic circuit. PVC pipe with diameter of 50 mm was used for the experimental test rig and the water was re-circulated within the tank. A bypass pipe was connected from the main pipe to regulate excess flow and pressure. A permanent magnet generator is used for power generation system. Experimental Set -up of Turgo Turbine as shown in Fig. 5.

Fig. 5: Experimental Set-up of Turgo Turbine

C. Performance Test:

The experiments are carried out on the Turgo turbine to find out the performance at various flow rates with different jet angle. Performance Tests are described in Fig. 6.

Fig. 6: Performance Test of Turgo Turbine

D. Experimental Results:

When the turbine is operating, the voltage and current can be measured. So, the electrical power can be calculated from the P= VI. Fig.3 shows the comparison of electrical power for various flow rates. Since the turbine speed is maximum at jet angle 20 degree, the electrical power is maximum at jet angle 20 degree.

Fig.8 shows the efficiency on various flow rates for jet angle 20 degree. The efficiency is maximum when the flow rate is fully open condition. The value of maximum efficiency is 81% at the flow rate of 8 m^3/s.

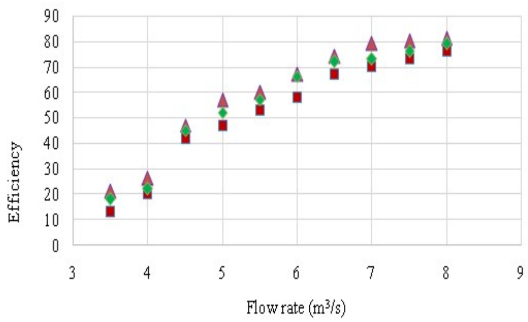

Fig. 7: Electricity Vs Flow Rate

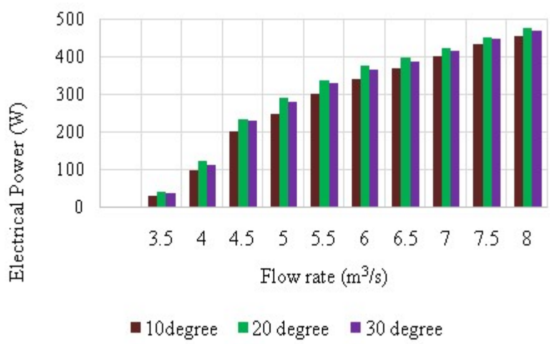

Fig. 8: Efficiency Vs Flow Rate

V. CONCLUSIONS

Experiments have been carried out at the Renewable Energy Laboratory of the Department of Mechanical Engineering, Mandalay Technological University. The permanent magnet generator is used for power generation system. The maximum generator output power is 475 W at the gate valve fully open conditional jet angle 20 degree.At jet angle 20°, the relative velocity of jet increases due to the pressure decrease. There is no back flow in this condition. So it can generate the required speed of the runner.

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