Retraction

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E Hernández

Grupo de Investigación en Desarrollo Tecnológico, Mecatrónica y Agroindustria – GIDETECHMA, Facultad de Ingeniería Mecánica, Universidad Pontificia Bolivariana seccional Bucaramanga, Floridablanca, Colombia

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It has come to the attention of IOP Publishing that this article should not have been submitted for publication because of its substantial replication of an earlier-published paper: D. Agar, M. Rasi 2008, On the use of a laboratory-scale Pelton wheel water turbine in renewable energy education, Renewable Energy 33 Issue 7, July 2008, pages 1517-1522. Consequently, this paper has been retracted by IOP Publishing.
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1 Grupo de Investigación en Desarrollo Tecnológico, Mecatrónica y Agroindustria – GIDETECHMA, Facultad de Ingeniería Mecánica, Universidad Pontificia Bolivariana seccional Bucaramanga, Floridablanca, Colombia.

E-mail: emil.hernandez@upb.edu.co

Abstract. Impulse turbine has been constructed to be used in the program of Hydraulic Machines, Faculty of Mechanical Engineering at the Universidad Pontificia Bolivariana, sede Bucaramanga. For construction of the impulse turbine (Pelton) detailed plans were drawn up taking into account the design and implementation of the fundamental equations of hydraulic turbomachinery. From the experimental data found maximum mechanical efficiency of 0.6 ± 0.03 for a water flow of 2.1 l/s. The maximum overall efficiency was 0.23 ± 0.02 for a water flow of 0.83 l/s. The design parameter used was a power of 1 kW, as flow regulator built a needle type regulator, which performed well, the model of the bucket or vane is built on a machine type CNC (Computer Numerical Control). For the construction of the impeller and blades was used aluminium because of chemical and physical characteristics and the casing was manufactured in acrylic.

1. Introduction

The Engineering Mechanic Programme at the Pontificia Bolivariana University was initiated in 2002, and a hydraulic machine is an important component of the curriculum which aims to provide an understanding of the physical principles involved in energy generation. To this end, the construction and test of an impulse turbine was devised to demonstrate the technology of Pelton turbines in hydropower plants. Hydroelectric generation plays an important role in global energy supply. For example, in 2010 it accounted for almost 16% of global electricity generation [1]. It’s a renewable energy source because Earth’s water cycle is driven by solar energy. The Pelton turbine, which was patented by Lester Pelton in 1880, is commonly used in hydroelectric generation in geographical locations where high water head is available but volume flows are small.

The water flow is directed by one or more nozzles to strike the ridge of each vane tangentially in succession and in turn delivers the water’s kinetic energy in impulses. Therefore, the turbine is classified as an impulse turbine. In principle, the ridge acts to divide the water jet in order to achieve better mechanical efficiency. With an optimised jet and cup geometry, more than 90% of the power of the water jet can be transformed into mechanical power at the turbine shaft [2]. Since the Pelton wheel rotates in-air, the action of the water and wheel rotation is easily observed by the experimenter. Direct observation of efficiency changes is an attractive characteristic from an educational perspective and it is said that Pelton himself got the idea for his turbine from such a direct observation [3].
2. Theory

The total extractable power of a water jet $P_h$ can be found from [4]

$$P_h = \rho gh \omega$$  \hspace{1cm} (1)

Where $\rho$ is the density of water, $g$ the acceleration due to gravity (9.81 m/s$^2$), $h$ the available head of the water source and $Q$ the volumetric water flow rate. The speed of the water jet $C$ is found from the flow rate and the cross-section area $A$ of a circular nozzle with diameter $D$

$$C = \frac{Q}{A} = \frac{4Q}{\pi D^2}, \hspace{1cm} (2)$$

The mechanical power $P_a$ available at the turbine shaft can be determined by measuring the torque $T$ on the shaft at a corresponding angular speed $\omega$. The torque is found by measuring the tangential force $F$ on a brake lever with moment arm length $l$ (see figure 1).

$$P_a = T \omega \hspace{1cm} (3)$$

The angular speed $\omega$ is equal to the tangential speed of the turbine $U$ divided by the pitch radius $R$ of the Pelton wheel

$$\omega = \frac{U}{R} \hspace{1cm} (4)$$

The mechanical efficiency of the turbine describes how effectively the available kinetic energy of the water jet is transformed into turbine motion and from (1) and (3) is

$$\eta_m = \frac{P_h}{P_a} \hspace{1cm} (5)$$

Cup and jet design are important parameters and it can be shown [5] that maximum theoretical mechanical efficiency is achieved when the tangential speed of the turbine is roughly one-half the speed of the water coming from the jet or
When the turbine shaft is coupled to an electric generator which supplies electricity to a variable resistive load \( R \) (see figure 2), the electrical power \( P_e \) of the load is

\[
P_e = IV
\]

In which \( I \) is the load current and \( V \) the voltage across the load. The electrical efficiency \( \eta_e \) of the generator and the overall efficiency \( \eta_0 \) of hydroelectric generation are then

\[
\eta_e = \frac{P_e}{P_a}
\]

\[
\eta_0 = \frac{P_e}{P_h}
\]

3. Methodology

The Pelton turbine consists of a cylindrical hub onto which 16 vanes (see figure 3) have been fastened using screws and right angle aluminium brackets. The hub and vanes were made of aluminium for easy machineability and resistance to the oxidation. The pitch radius of the turbine, which is the distance from the centre of the shaft to the centre of the impact point of the water jet (160 mm in this case), should be roughly 10 times the diameter of the jet (16 mm in this case) so that adjacent vanes do not interfere with the water flow [2]. For the turbine under discussion measured rotation speed have been in the range of 100 – 500 rpm with turbine power in the range of 20 – 150 W.

Figure 3. Pelton wheel.

Has been conducted experiments with the Pelton turbine using three different water volume flow rates, referred to as \( Q_1 \), \( Q_2 \) and \( Q_3 \). The water pressure \( p \) at the nozzle is measured for each \( Q \) value with the turbine shaft rotating freely.

The relationship between the tangential force on the shaft and the speed of rotation is then determined using the brake lever for each \( Q \) value. This relationship is generally found to be of a linear nature in the range of variables described (figure 3).

With the drive belt connected to the DC generator and the brake lever removed from the turbine shaft, the current and voltage of the resistive load are measured, while simultaneously measuring the rotational speed of the turbine. This is repeated for several values of load resistance. The measurement yields the electrical power produced by the generator as a function of rotational speed.

Using experimental data, the mechanical, electrical and overall efficiency of the hydroelectric plant are calculated for each \( Q \) value.

4. Results and discussion

Table 1 lists the \( Q \) values used, followed by the corresponding hydraulic power calculated from equation (1) using a net head available of 4 m. The corresponding maximum mechanical and electrical...
efficiencies are on the right side of the table along with the maximum total efficiency of the laboratory-scale hydroelectric plant.

Table 1. The three Q values used in the experiment.

| Q [l/s] | Ph [W] | Pa [W] | Pe [W] | \( \eta_m \) [W] | \( \eta_o \) |
|---------|--------|--------|--------|-----------------|-------|
| \( Q_1 \) = 2.5 | 98 | 44.1 | 19.6 | 0.45 | 0.20 |
| \( Q_2 \) = 2.1 | 82.3 | 49.4 | 18.9 | 0.60 | 0.23 |
| \( Q_3 \) = 1.5 | 58.8 | 29.4 | 8.82 | 0.50 | 0.15 |

Figure 4. The mechanical efficiency of the Pelton turbine as a function of the speed of rotation.

5. Conclusion

A laboratory-scale Pelton turbine for hydroelectric generation has been constructed and used in the educational curriculum of the Engineering Mechanical Programme at the Pontificia Bolivariana University. From the experimental results, the turbine was found to have a maximum mechanical efficiency of 0.6 \( \pm \) 0.03 for a flow rate of 2.1 l/s. The Pelton turbine demonstrate the principles of hydropower and are well suited in the education of students of Mechanical Engineering.

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