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Hydraulic Turbines and Effect of Different Parameters on output Power

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ABSTRACT

As the energy demand of industry grows exponentially, fabrication of hydraulic energy system becomes a crucial point of concern. Many research activities about hydraulic have been carried out by experimental methods and by theory and simulation. Hydro energy parameters have been used to study the relation between the hydro energy parameters and subsequent relative output energy. Numerical simulation and theory with experimental analysis generate realistic and useful results. The results obtained by theoretical calculations are identical to the experimental results, performed in prototype model. Numerical simulation on hydro energy and effect of hydro energy factors/constraints are systemically investigated, by using several data for exponent on prototype and by numerical investigation. In this work different parameters have been used to spawn water, which contains potential energy. The water injected on blades of hydraulic turbines. The water energy effecting parameters (height, quantity of water etc) has been examined by taking combination of parameters. The outcome obtained by theoretical calculations is identical to the experimental results.

Key words: Hydraulic energy, Height, quantity of water.

INTRODUCTION

The use of hydraulic turbines for the generation of power has a very strong historical tradition. The first truly effective inward flow reaction turbine was developed and tested by Francis and his collaborators around 1850 in Lowell, Massachusetts [1]. Modern Francis turbines have developed into very different forms from the original, but they all retain the concept of radial inward flow. The modern impulse turbine was also developed in the USA and takes its name from Pelton, who invented the split bucket with a central edge around 1880. The modern Pelton turbine with a double elliptic bucket including a notch for the jet and a needle control for the nozzle was first used around 1900. The axial flow turbine with adjustable runner blades was developed by the Austrian engineer Kaplan in the period from 1910 to 1924. Hydraulic turbines are not only used to convert hydraulic energy into electricity but also in pumped storage schemes, which is the most efficient large-scale technology available for the storage of electrical energy. Separate pumps and turbines or reversible machines, so called pump turbines, are used in such schemes. During their long history there has been continuous development of the design of hydraulic turbines, particularly with regard to improvements in efficiency, size, power output and head of water being exploited. Recently, the use of modern techniques like computational fluid dynamics (CFD) for predicting the flow in these machines has brought further substantial improvements in their hydraulic design, in the detailed understanding of the flow and its influence on turbine performance and in the prediction and prevention of cavitation inception. The efficient application of advanced CFD is of great practical importance, as the design of hydraulic turbines is custom-tailored for each project [2].

The world of hydraulic turbines is based on the energetical and cavitational characteristics, obtained by laboratory measurements and applied to the industrial prototype. The manual drawing of these characteristics is a long and, sometimes, subjective process. Particular software will increase the speed and the quality of the process [3].

Because of the ecological and environmental restrictions in energy production, the use of small hydropower resources will be economical in the future. Standard pumps could be considered a low cost alternative for hydraulic turbines used in small hydropower plants [4].

Among all the renewable energy sources available, small hydropower is considered as the most promising source of energy. In many parts of the country, especially hill states streams coming down the hills posses' sufficient potential energy that can be utilized. The hydraulic turbine used to convert the potential energy of water to mechanical energy. Flowing water is directed on to the blades of a turbine runner, creating a force on the blades. Since the runner is spinning, the force acts through a distance (force acting through a distance is the definition of work). In this way, energy is transferred from the flowing water to the turbine [5].

Prototype Model & Its Description: A working model has been made and the experiment has been successfully conducted under the presence of the lab assistance and readings have been taken and verified. Dimensions of the Model are:
Shaft Dia -8mm
Shaft Length – 1ft
Turbine Blades - 8
Blade Length – 2inch
Nut Bolt – 16mm

Theoretical Formulation: A hydropower resource can be evaluated by its available power. Power is a function of the hydraulic head and rate of fluid flow. The head is the energy per unit weight (or unit mass) of water. The static head is proportional to the difference in height through which the water falls. Dynamic head is related to the velocity of moving water. Each unit of water can do an amount of work equal to its weight times the head.

The power available from falling water can be calculated from the flow rate and density of water, the height of fall, and the local acceleration due to gravity [6].

$$P = \eta \rho g Q H \qquad (1)$$

Where: P is the mechanical power produced at the turbine shaft (in Watts).
η is the hydraulic efficiency of the turbine, ρ is the density of water in (1000 kg/m3).
g is the acceleration due to gravity in (9.81 m/s^2).
Q is the volume flow rate passing through the turbine in (m^3/s).
H is the effective pressure head of water across the turbine in (m).

For an impulse turbine of a Pelton-wheel type, the mechanical power can be changed by means of changing η, Q, and H inputs because ρ and g are constant.

The force exerted by the water jet on buckets (vanes) of the runner in the direction of motion is given as:

$$F_X = \rho a V_1 [V_{w1} + V_{w2}] \quad (2)$$

Here, ρ = Density of the water. a = Cross section area of water-jet in $m^2 = p/4d^2$,
d = diameter of jet in m.
V_1 = Velocity of the jet at the inlet of bucket splitter,
$V_1 = \sqrt{2gH}$ m/s.
H = Net head acting on the Pelton-wheel in m.
g = Acceleration due to gravitation m/s^2.
V_{w1} = Velocity of the whirl at inlet in m/s.
V_{w2} = Velocity of the whirl at outlet in m/s.

The work done by the jet on the runner per second is as:

$$W_j = F_X \times u = \rho a V_1 [V_{w1} + V_{w2}] \times u \text{ Nm/s} \quad (3)$$

Here,
u = Tangential linear velocity of the bucket wheel at pitch circle in m/s.

The energy supplied to the jet is in the form of kinetic energy which is given as $1/2mv^2$.

Now, Kinetic Energy (K.E.) of the jet per second is given as:

$$\text{K.E.} = 1/2 \rho a V_1 \times V_1^2 \quad (4)$$

Hydraulic Efficiency η_h = Work done by jet per second ÷ K.E. of jet per second.

$$\rho_h = \rho a V_1 [V_{w1} + V_{w2}] \times u \div 1/2 \rho a V_1 \times V_1^2 \quad (5)$$

In terms of V_1

$$\rho_h = 2(V_1 - u)[1 + \cos\beta]u \div 1/2 \rho a V_1 \times V_1^2 \quad (6)$$

$$\{V_{w1} = V_1 - u\}, \quad V_{w2} = (V_1 - u)\cos\beta - u\,\}$$

For maximum efficiency u is = $1/2V_1$, $\eta_{h\max} = 1 + \cos\beta/2$ (7)

Here, β = Angle of Vane at outlet

RESULTS AND DISCUSSION

Hydraulic energy is one of the prominent techniques for generating power vital for industrial applications. In this article, effort has been made to evaluate effect of parameters on hydraulic energy, which would work on the principle of basic equations, and suitable for a wide range of hydraulic energy. Statistical exploration with the help of empirical equations and computer technique on hydraulic energy has been systemically investigated by means of permutation of energy parameters. It has been originate that the effect of height, discharge etc influences notably the hydraulic energy. By adjusting the parameters such as height, discharge etc. we are able to pull off mandatory hydraulic energy.

In this paper effect of different parameters on energy output by using computer technique is elaborated by using experimental data. The experimental parameters which are used in this model are water flow rate varies from 1120 to 1200 cc/sec, height of water level varies from 11cm to 25 cm.

Figure 1, shows the variation of energy output (W) versus water head for different values of the water head. The energy output increases by increasing height. The maximum value of energy output is 1.32 W and minimum value is 2 W with other fixed parameters are listed in prototype model.

Figure 2, shows the variation of energy output (W) versus fluid flow (cc/sec) for different values of the fluid flow. The energy output increases by increasing fluid flow. The maximum value of energy output is 1.32 W and minimum value is 2 W with other fixed parameters are listed in prototype model.

Figure 3, shows the variation of energy output (W) versus angle of inclination for different values of the inclination angle. The result shown in figure 3 is experimental result. The energy output increases by increasing inclination angle. Theoretical value of energy output calculated in this work is within the range of experimental values.

Figure 4, shows the variation of energy output (W) versus different density fluid. The result shown in figure 4 is experimental and theoretical. The energy output (experimental power output by prototype model) increases by escalating density and dipping viscosity. Theoretical values of energy output calculated in this work are found within the range of experimental values.

The value of power output by prototype model shown in model description is varies from 1.02 to 2.53 Watts. The theoretical results obtained from the given mathematical equations and computer technique is found out within the range of experimental values calculated by prototype model. There is approximately 5-10% difference between theoretical and experimental values, because of frictional, drag force etc.

- **Constant discharge = 1120cc/s**

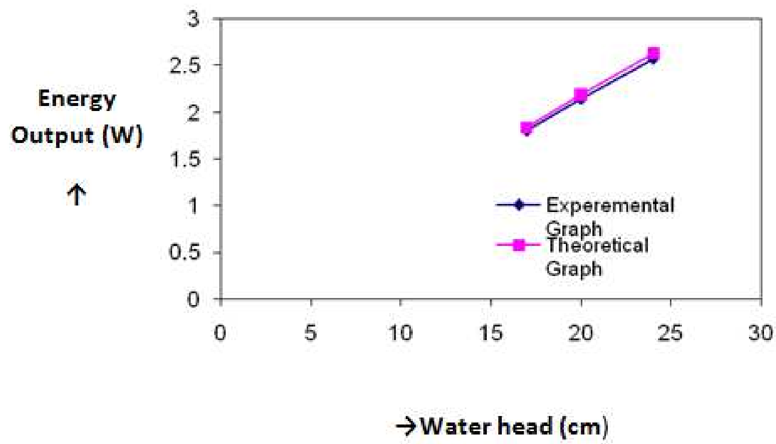

Fig.1.Variation of energy output (W) versus water head (cm) for different values of water head and discharge of water is 1100 cc/sec.

- **Constant Height=11cm**

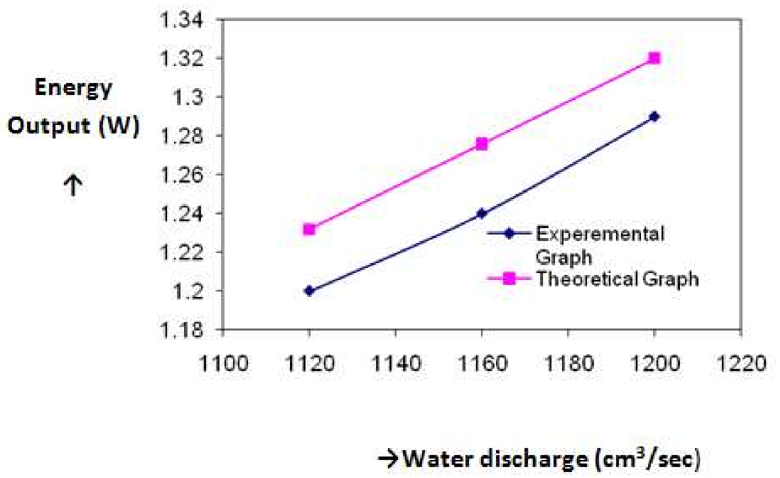

Fig.2.Variation of energy output (W) versus water discharge (cm^3/sec) for different values of water discharge and height of water is 11 cm.

- **Constant discharge = 1120cc/s and height 11 cm**

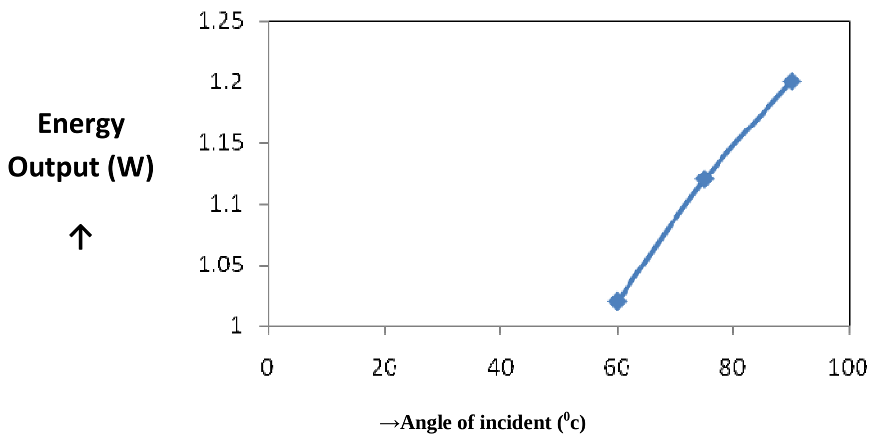

Fig.3.Variation of energy output (W) versus angle of inclination (^{0}c) for different values of angle of incident by considering height and discharge of water is 11 cm and 1100 cm^3/sec.

- **Constant discharge = 1120cc/s and height 11 cm**

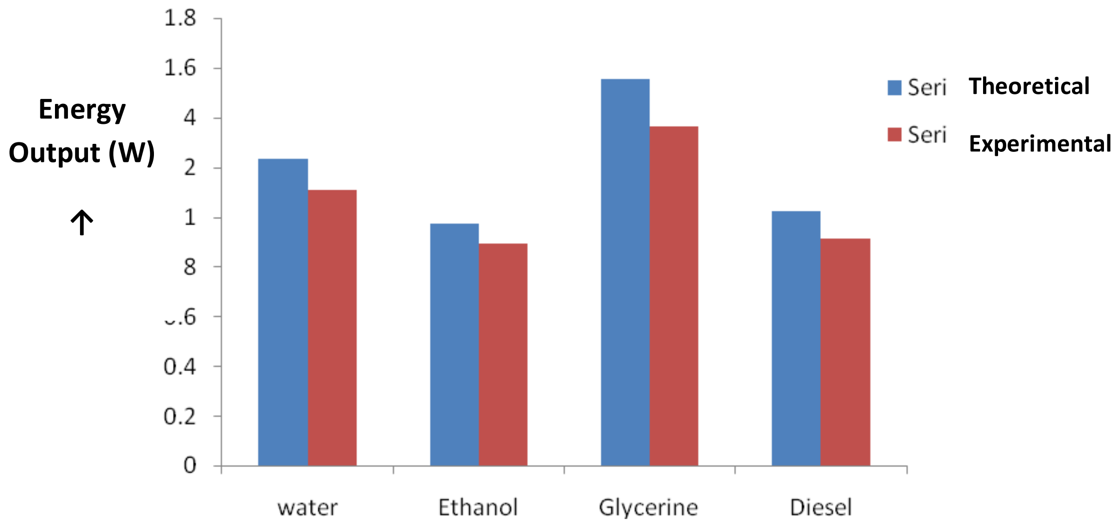

Fig.4.Variation of energy output (W) versus different fluid medium by considering height and discharge of fluid is 11 cm and 1100 cm^3/sec.

CONCLUSION

The potential of hydraulic power generation is immense, a historical source of energy, water can be used both as a source of electricity and for irrigation and agricultural uses. In today's world, where a greener source of energy is the need of the hour, hydraulic energy is a promising resource, waiting to be harnessed to its true potential. The study of hydraulic turbine and its characteristics showed that how it can be properly designed and used to get the maximum output, even with the variable speeds.

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