Designing a Pelton Wheel Turbine for a Certain Head and Efficiency

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Problem Statement

A Pelton-wheel impulse turbine is a hydro mechanical energy conversion device which converts gravitational energy of elevated water into mechanical work. In this paper we are designing a Pelton-wheel turbine for 600 kW power output, and constant head of 150 meters. Assuming the overall efficiency as 85%.

Theoretical Evaluation

Pelton wheel is developed under considering two basic laws of physics,

1. Conservation of Energy
2. Newton's 2^{nd} law of motion

Conservation of Energy: energy can neither be created nor be destroyed. Although, it may be transformed from one form to another. If you take all forms of energy into account, the total energy of an isolated system always remains constant.

Newton's 2^{nd} law of motion: It states that, change in momentum of any object is direct proportional to applied force.

In a Pelton wheel turbine power plant, water falls from a certain head. At that head water has potential energy due to its position, but when the water starts to fall it gains kinetic energy. Due to its kinetic energy it creates an impulse (sudden force) on the turbine. This applied force creates a change in momentum on the turbine wheel. The wheel starts to rotate along its axis of rotation, and we get mechanical work.

Introduction of the Project

Turbine can be classified as hydraulic turbines and steam turbines. The hydraulic turbines are rotary machines which converts potential energy into kinetic energy or useful forms such as mechanical energy or electric energy [1]. There are two types of turbines in hydraulic turbines like reaction and impulse turbine .in impulse turbine water coming out of the nozzle at the end of the penstock and it is made to strike a series of buckets fitted on the periphery of the runner [2]. In reaction turbines water enters all around the periphery of runner finally water is discharged to the tail race through the draft tube.The best example for impulse turbine is Pelton turbine [3]. The Pelton turbine is tangential flow which requires less quantity of water. Pelton turbine consists of a circular disc on which a number of buckets are evenly spaced around its periphery. Each bucket consists of symmetrical halves having shape of semi ellipsoidal cup. The water comes out of the nozzle as jet and impinges on the bucket causing it to rotate [4].

Parts of Pelton wheel Turbine:

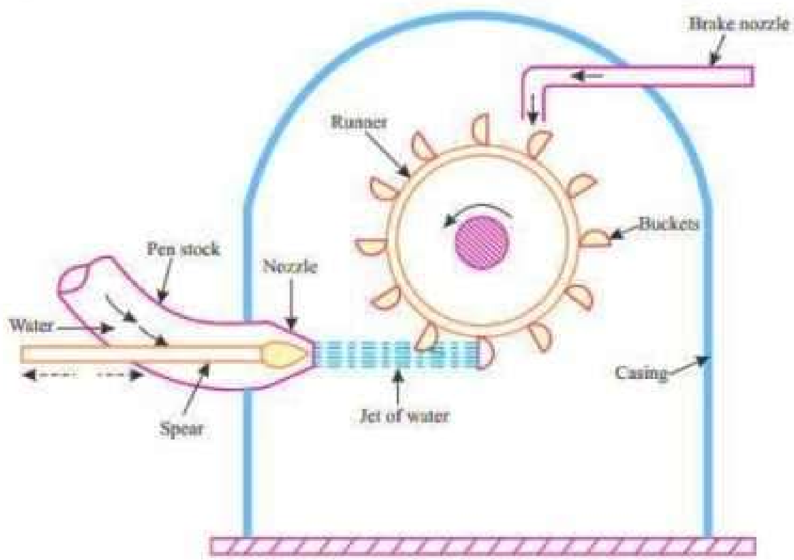

Figure 1: Different Parts of Pelton Wheel Turbine

- Nozzle and Flow Regulating Arrangement
- Runner and Buckets
- Casing
- Braking Jet

Description

In this project we are going to design a Pelton wheel runner, bucket, and bucket blade profile.

Parameter

Input parameters:

- Head of water, H = 150 m
- Power to be developed, P = 600 kW
- Speed of wheel, N = 360 rpm
- Overall efficiency, $\eta_o = 85\%$

Assumptions:

- Coefficient of velocity, $C_v = 0.98$
- Ratio of peripheral and jet velocity, $\frac{V_{peri}}{V_{jet}} = 0.46$

  Therefore, Peripheral velocity, $V_{peri} = 0.46V_{jet}$

Design Process

1. Diameter of wheel:

   Let,

$$D = Diameter\ of\ Wheel$$
$$V_{peri} = 0.46 V_{jet}$$
$$V_{peri} = 0.46 \times C_v \times \sqrt{2gH}$$

   Again,

$$V_{peri} = \frac{\pi N D}{60}$$
$$D = \frac{60 \times V_{peri}}{\pi N}$$

   Therefore,

$$D = \frac{60 \times 0.46 \times C_v \sqrt{2gH}}{\pi N}$$
$$D = 1.3\ m$$

2. Diameter of jet:

$$d = Diameter\ of\ Jet$$

   Overall efficiency,

$$\eta_o = \frac{P}{\rho g Q H}$$
$$Q = \frac{P}{\eta_o \rho g H}$$
$$Q = 0.48\ m^3 s^{-1}$$

   Now, discharge through the wheel, must be equal to the discharge through the jet.

$$Q = \frac{\pi}{4} d^2 V$$
$$d^2 = \frac{4Q}{\pi V}$$
$$d = 0.105\ m$$

3. Width of the bucket:

   We know that, Width of the buckets = $5 \times d$

$$= 5 \times 0.105$$
$$= 0.525\ m$$

4. Depth of the buckets:

   We know that, Depth of the buckets = $1.2 \times d$

$$= 0.126\ m$$

5. Number of buckets:

   We also know that, No of buckets = $\frac{D}{2d} + 15$

$$= \frac{1.3}{2 \times 0.105} + 15 = 21$$

6. Blade Profile:
   If the wheel is directly mounted to a generator then we can neglect mechanical loss. So,

$$\eta_o = \eta_h$$

   We know that,

$$\eta_h = \frac{2 \times V_{peri}\left(V_{jet} - V_{peri}\right)(1 + cos\phi)}{V_{jet}^2}$$

   Therefore, Vane outlet angle,

$$\phi = 44.7°$$

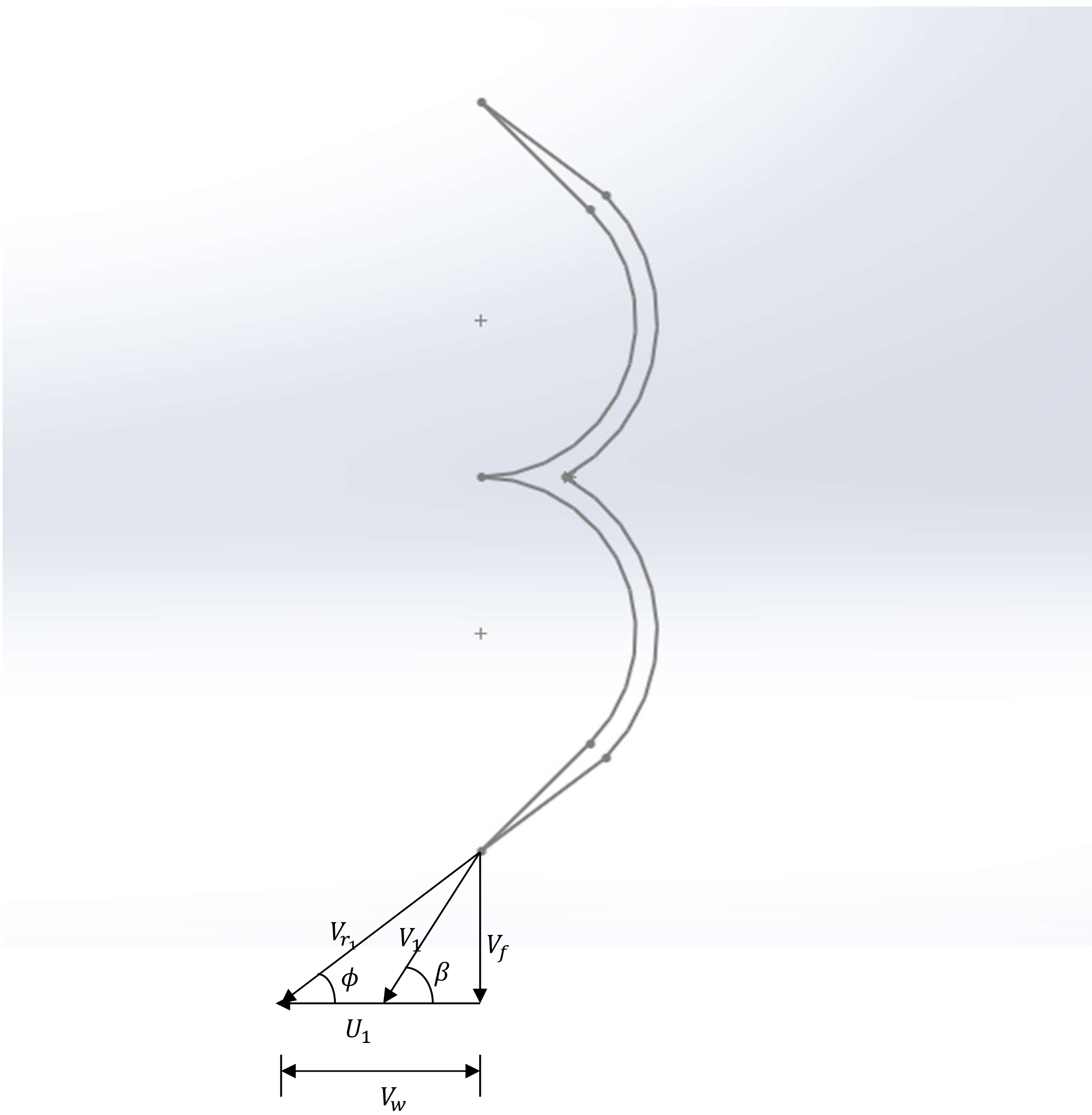

Figure 2: Blade Profile

Result and Discussion

From the design analysis we can say that we will have 600 kW power output and efficiency for 150 meter head, if the diameter of the wheel is 1.3 meter, diameter of the jet is 105 mm, bucket width 525 mm, bucket depth 126 mm, and vane outlet angle is 44.7 degrees.

Conclusion

Most of the new generation supply will come from conventional, thermal energy resources. Where hydroelectric power plays an important role in the future and provides maximum benefits. The Peloton turbine is very easy to install for hydro power plants in case of high head and low flow rate. In this paper we have been presented a complete design of such turbine for maximum efficiency.

References

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