Lab#7: Operating Characteristics of a Pelton Turbine

CE 336

Department of CECEM

Group Report

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Purpose of Study

The purpose of this experiment is to analyze the operating characteristics of a Pelton turbine. In the experiment the turbine will be subjected to different conditions and this would vary the efficiency and power of the turbine at different speeds. Turbines are devices that are for clean energy or any general power generating source and provide valuable information to be understood.

Introduction

Turbines work by utilizing energy in order to produce work. Pelton turbines in particular convert the total head of fluid into a great velocity head at exit. The turbine was unaccompanied by a spring and tension was increased to determine power. The turbine was used in 8 sets and data was used in order to determine torque, brake power, volumetric flow rate and efficiency.

Theory

The Pelton turbine used in the experiment has the basic parameters that are used to define the operational characteristics are:

$$Q_v = \frac{\forall}{t} \ [m^3/s] \qquad (1)$$

Where Q_v is the volumetric flow rate through the turbine, ∀ of water flowing through the turbine at a time t. When the volume of water flows through the turbine, there is a brake force working on the turbine F_b and the torque T that rotates the rotor is given as:

$$T = F_b \times r \ [N\text{-}m] \qquad (2)$$

Where r is the radius of the brake pulley, given as 0.03m. F_b applied on the turbine is given by the readings on the two spring balances, w_1 and w_2, so:

$$F_b = w_2 - w_1 \ [N] \qquad (3)$$

Mechanical power P_b produced by the turbine that is rotating at a speed n is given as:

$$P_b = 2\pi \times n \times T \text{ [Watts]} \qquad (4)$$

Hydraulic power P_h supplied by the water is given as:

$$P_h = \gamma Q_v H_i \text{ [Watts]} \qquad (5)$$

This is where H_i is the pressure head derived from the pressure difference P_i across the turbine such that:

$$H_i = \frac{P_i}{\gamma} \text{ [m } H_2O] \qquad (6)$$

The Bourdon pressure gauge measures the pressure difference relative to the atmospheric pressure. Then overall efficiency of the turbine can be found using the given:

$$\eta_t = \frac{Power_{out}}{Power_{in}} \times 100\% = \frac{P_b}{P_h} \times 100\% = \frac{2\pi\ n\ T}{\gamma Q_v H_i} \times 100\%$$

<u>Equipment</u>

- FI-25 Pelton Turbine apparatus
- Hydraulic Bench FI-10
- Hand-Held digital tachometer to find the speed of the turbine
- Stopwatch to record volumetric flow rate

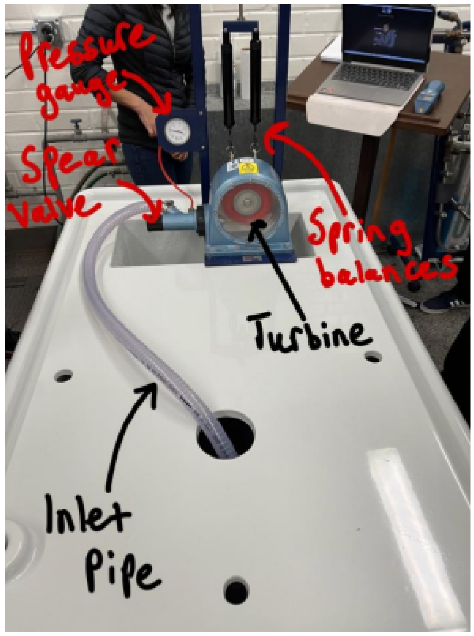

Figure 1

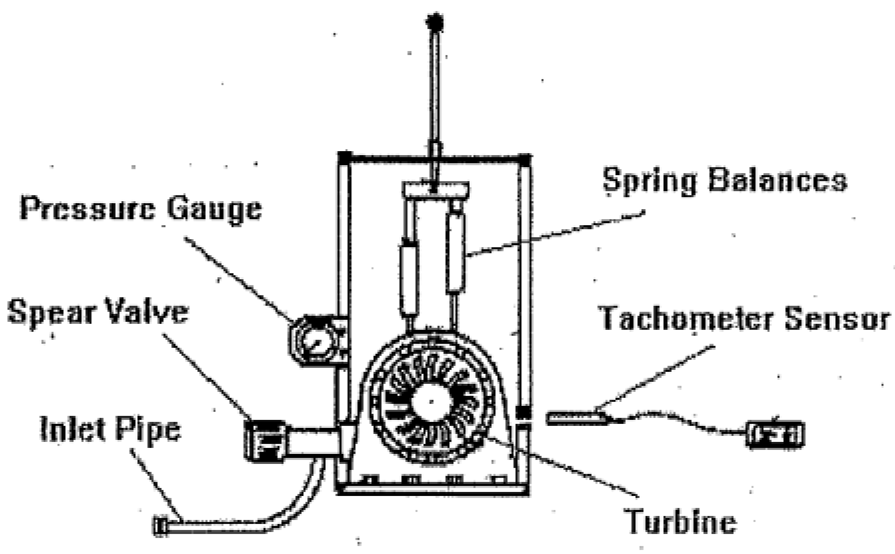

Figure 2. Schematic of the Pelton Turbine

Figure 2

<u>Experimental Set-Up and Procedures</u>

<u>Equipment set-up:</u>

We first positioned the apparatus above the working channel of the hydraulic bench. We then connected the flexible tube of the turbine apparatus at the hydraulic bench supply connector. The tachometer will be used to find the speed of the turbine. We then set up a band brake assembly which will be used to apply force on the turbine and change the operating speed of the turbine. Then add the band brake assembly and lower it until the brake is clear of the brake drum.

Procedure:

First, we closed the bench flow control valve and kept the spear valve closed but did not force it shut. We then turned the switch of the bench pump and opened the bench control valve fully. We then gradually opened the spear valve. We had the band brake assembly around the brake drum and tension in both the spring balances is at 0 mark. With 0 mark applied the turbine operates at maximum speed. We then found the maximum speed of the turbine using the tachometer. We placed the tachometer horizontally to read the readings in the tachometer. A stabilized number in the tachometer is the correct motor speed. When the turbine was operating at a maximum speed, we found the flow rate through the turbine using a stopwatch and collecting 4L and 5L of water in the hydraulic bench. We then recorded the inlet pressure gauge readings. Next, we applied tension in the band brake slightly to slow the rotor speed slightly. Using the tachometer to find the speed of the turbine. We then recorded the spring balance readings, pressure gauge readings, and flow rate using a stopwatch. We then increased the tension in the brake and repeated steps 8-10 and collected at least a total of 6 sets of data. Our last data set was the highest speed at which the rotor has 0 speed. After 6 sets of data are collected with the spear valve completely open, we reduce the flow rate slightly by closing the spear valve and repeat the experiment from steps 1 through 11. Then repeated steps 6 through 12 for different flow rates.

Discussion

Table 1. Spear Valve Completely Open

Rotor Speed	Force 1	Force 2	Inlet Head	Brake Force	Torque	Brake Power	Volume Flow Rate	Hydraulic Power	Turbine E
N	w_1	w_2	H_i	F_b	T	P_b	Q_v	P_h	E_t
(Hz)	(N)	(N)	(mH_20)	(N)	(N-m)	(W)	(m^3/s)	(W)	(%)
1.617	4.20	2.00	1.75	2.20	0.0660	0.670	$2.58e^{-4}$	4.429	15.14
5.450	4.10	1.90	1.75	2.20	0.066	2.260	$2.98e^{-4}$	4.961	45.55
7.767	4.10	1.90	2.00	2.20	0.066	3.221	$3.09e^{-4}$	6.063	53.13
11.100	4.10	1.90	2.50	2.20	0.066	4.603	$3.47e^{-4}$	8.510	54.09
12.583	4.10	1.90	3.00	2.20	0.066	5.218	$3.65e^{-4}$	10.742	48.58
13.700	4.10	1.90	3.00	2.20	0.066	5.681	$3.80e^{-4}$	11.183	50.80
14.733	4.10	1.90	3.50	2.20	0.066	6.110	$3.92e^{-4}$	13.459	45.39
16.367	4.10	1.90	4.00	2.20	0.066	6.787	$4.16e^{-4}$	16.324	41.58

Sample Calculations:

$n = 97 \text{ rpm} = \frac{97}{60} = 1.617 \text{ Hz}$

$w_1 = 4.20$ N

$w_2 = 2.00$ N

$H_i = 1.75$ m H_20

$F_b = w_2 - w_1 = |2.00 - 4.20| = 2.20$ N

$T = F_b \times r = 2.20 \text{ N} \times 0.03 \text{ m} = 0.0660$ N-m

$P_b = 2 \times \pi \times n \times T = 2 \times \pi \times 1.617$ Hz $\times$ 0.0660 N-m = 0.670 W

$Q_v = 0.258$ L/s = 0.000258 m^3/s

$P_h = \rho \times g \times H_i \times Q_v$ = 997 kg/s^2 ×1.75 m H_20 × 0.000258 m^3/s = 4.429 $kg \times m^2/s^3$ = 4.429 W

$E_t = \eta t = P_b / P_h \times 100\%$ = (0.670/4.429) × 100 % = 15.14 % efficiency

Conclusion

Turbines are used universally in clean energy, and in this lab we utilized one and aimed to determine the power and efficiency of the turbine. We also determined how the brake power changes at different speeds.The greatest efficiency occurred at 11.100 HZ with an efficiency of 54.09%.

References

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