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DESIGN OF A PELTON WHEEL TURBINE FOR A MICRO HYDRO POWER PLANT

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ABSTRACT

In Pelton wheel the energy gained by water and it is converted into kinetic energy by producing nozzle at the end of penstock. Pelton wheel was performed in low flow rate and high head. To perform pelton in establishment of micro hydro power plant various operating conditions, turbine parameters must be required in the design procedure. In this paper all the design parameters were calculated. These parameters included turbine power, runner diameter, runner speed, bucket dimensions, number of buckets, turbine specific speed.

Key Words : Pelton Wheel, Micro Hydro Power Plant, Design Parameters

I INTRODUCTION

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. 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. In reaction turbines water enters all around the periphery of runner finally water is discharged to the tail race through the draft tube.

Fig 1. Pelton Runner Model

The best example for impulse turbine is pelton turbine. 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.

1.1 Principal Components Required and Their Uses

Mechanical section

The various mechanical components required for the project include

a) Pelton wheel: For converting water potential energy to Mechanical (Rotational) energy.

b) Shaft: To link the rotational energy of the Pelton wheel to the alternator for generating power.

c) Bearings: For easy movement of the shaft in the frame and rotor.

d) Stable frame: To hold whole of the project firmly and rigidly so that there is no breakdown or vibrations or Less movement.

e) Screws, nuts, bolts, hammer etc: To be used for tighten various parts of the machine which include Linking the shaft with the Pelton Wheel.

f) Pump: To provide the water flow and to create artificial Head.

g) Nozzle: To provide the water jet coming out of the pump for high velocity jet.

h) Other various mechanical parts as per the requirements basis.

Electrical section:

The various electrical components required for our project includes

a)Alternator: To be used for current generating purpose

b) Cables: to connect and test the generated electricity.

c) 12v battery: To charge the electro magnet inside the stator of the alternator.

d) Other devices and materials as per the requirements.

Measuring instruments:

The various measuring instruments include

a) Multimeter: To measure current, voltage generated.

b) Tachometer: To measure the RPM of the shaft.

c) Marked bucket: To measure the rate of flow of the water from the pump.

d) Venire caliper, screw gauges etc: For measuring various dimensions.

II STEPS INVOLVED IN DESIGN OF PELTON WHEEL

The complete procedure of the pelton wheel which is used for micro hydro power plant as follows

1) Collecting the site data of power plant

This includes measuring head and water flow rate calculations

i). Calculation of the net head (H)

$$H=H_g-h_f \tag{1}$$

Where H_g = the gross head which is the vertical distance between water surface level at the intake and at the turbin(m)

h_f = total head losses due to the open channel, trash rack, intake, penstock and gate or valve. These losses approximately equal to 6% of gross head. (m)

ii) Calculation of the water flow rate (Q_t):

The water flow rate can be calculated by measuring the river or stream flow velocity (V_r) in ($m.s^{-1}$) and its cross-sectional area (A_r) in (m^2)

$$Q_t=V_r*A_r \qquad (m^3.s^{-1}) \tag{2}$$

iii) Calculation of the turbine input power (P_{ti})

The electrical input power to the turbine in (*Watt*) can be calculated as

$$P_i=\delta_w *g*C_v^2*H*Q_t \qquad \text{watts} \tag{3}$$

Where, δ_w = density of water ($kg.m^{-3}$)

c_v= Nozzle (jet) discharge coefficient (0.98)

g= Gravity acceleration constant ($9.81\ m.s^{-2}$)

iv) Calculation of the turbine speed (*N*)

The correlation between the specific speed (N_s) and the net head (*H*) is given for the Pelton turbine as

$$N_s=85.49 * \sqrt{n}/H^{0.243} \tag{4}$$

$$n=\frac{Q_t}{Q_n}$$

Then the turbine speed (in *r.p.m*) can be calculated as

$$N=N_s*\frac{H^{\frac{5}{4}}}{\sqrt{P_i}} \qquad (r.p.m) \tag{5}$$

Where,

Q_t = water flow capacity of each nozzle ($m^3.s^{-1}$).

Q_n=Nozzle flow rate ($m^3.s^{-1}$).

v) Calculation of the runner circle diameter (*D*)

The water jet through nozzle has a velocity (V_1) in ($m.s^{-1}$) can be calculated as

$$V_1=C_v*\sqrt{2*g*H} \quad (ms^{-1}) \qquad (6)$$

The runner tangential velocity (U) in ($m.s^{-1}$) can be calculated as

$$U=\frac{\pi*D*N}{60} \quad (ms^{-1}) \qquad (7)$$

Also the runner tangential velocity can be given as

$$U=k*V_1 \quad (ms^{-1}) \qquad (8)$$

Where, k = ratio of runner tangential velocity to nozzle or jet velocity

$$D=\frac{60*k}{\pi*N}*V_1 \quad (m) \qquad (9)$$

At maximum efficiency the value of k is in between 0.46 to 0.47.

Then the runner diameter at maximum efficiency can be calculated from equations (6) and (9)

$$D=38.6*\frac{\sqrt{H}}{N} \quad (m) \qquad (10)$$

vi) Calculation of nozzle dimensions

The water flow rate through each nozzle (Q_n) can be calculated as:

$$Q_n=V_1*a \quad (m^3.s^{-1}) \qquad (11)$$

The nozzle area (a) can be calculated as

$$a=\pi*\frac{d^2}{4} \quad (m^2) \qquad (12)$$

vii) Calculation of bucket dimensions

The bucket axial width can be calculated as

$$B_w=3.4*d \quad (m) \qquad (13)$$

The bucket radial length can be calculated as

$$B_l=3*d \quad (m) \quad (14)$$

The bucket depth can be calculated as

$$B_l=1.2*d \quad (m) \quad (15)$$

The number of buckets in each runner must be determined so that no water particle was lost while minimizing the risks of detrimental interactions between the out flowing water particles and adjacent buckets. It can be calculated as

$$Z=15+\frac{D}{(2*d)} \quad (16)$$

The runner size was determined by its diameter, and its shaper was determined by the number of buckets. The runner shaft was sized to mount directly on the generator shaft. The flinger seal was also necessary to seal the whole through which the generator shaft enters the turbine box. The radius of bucket center of mass to center of runner was given as

$$B_r=0.47*D \quad (m) \quad (17)$$

The bucket volume was given as

$$V_b=0.0063*D^3 \quad (m^3) \quad (18)$$

viii) Calculation of maximum turbine efficiency

i.) Hydraulic losses or power losses those occur due to flow irregularity within the bucket.

ii.) Windage losses which occur because of resistance in the air to the moving bucket.

iii) Mechanical losses in the system used to transmit the power from the turbine to the generator. If the turbine was mounted directly to the generator, there were no mechanical losses in the turbine

The input power to the turbine can be calculated as

$$Pi=\frac{\rho_w*Q_t*V_1^2}{2} \quad (watts) \quad (19)$$

The power output developed by the turbine was given as

$$P_o= \rho_w*U*[(vj-U)*(1+\psi*\cos(\varphi))] \quad (watts) \quad (20)$$

Then the turbine hydraulic efficiency can be calculated as

$$\acute{\eta}_{th}=\frac{P_i}{P_o} \quad (21)$$

$\varphi=180^0-\theta$

$\theta=160^0$ to 170^0

For maximum hydraulic turbine efficiency

$$U=0.5*V_1 \quad (m\ s^{-1}) \quad (22)$$

Then the maximum hydraulic efficiency was given as

$$\acute{\eta}_{max}=\frac{[1+\psi*\cos(\varphi)]}{2} \quad (23)$$

Then the total turbine efficiency was given as

$$\acute{\eta}_t=\acute{\eta}_{th}*\acute{\eta}_{tm} \quad (24)$$

If the turbine was mounted directly to the generator the mechanical losses can be neglected and the mechanical efficiency (η_{tm}) equal to unity.

III RESULTS AND DISCUSSIONS

The design calculations of the Pelton turbine were implemented by a Matlab Simulink computer program. From the table, it shows all the design parameters of a pelton turbine for maximum efficiency and with constant flow rate ($Q = 0.1\ m^3.s^{-1}$) for different gross head. Figure 2 shows variation of runner to nozzle diameter ratio with specific speed at different value of water flow rate, while figure shows the variation of the same ratio with nozzle length. The turbine maximum efficiency was found to be 96% constant.

Merits

a) This turbine can strictly extract energy as of any fast moving fluid

b) They can prepared out of metal, plastic, while metal is generally preferred.

c) Simple in construction and easy to maintenance

Demerits

a) This is not best turbine for low pressure streams by high flow rate

b) A lot of head loss occurs when the discharge is low

Applications

a) Pelton wheels are preferred turbine for hydropower when the available water source has relatively high head and low flow rate.

b) Pelton wheels are made in all sizes for maximum power and efficiency.

Table 1. Design parameters of the pelton wheel at maximum efficiency with a constant flow rate Q_t=0.1m^3.s^{-1}

H_g (m)	Po in (kw)	$\acute{\eta}_t$ in (%)	N in (r.p.m)	N_s	D in (m)	d in (m)	U (m.s^{-1})	V_1 (m.s^{-1})	Z
25	21.75	96.8	470	35.65	0.42	0.0575	12.28	23.05	20
30	26	96.8	500	35.22	0.42	0.059	12.6	24.4	20
35	30.25	96.8	530	34.79	0.42	0.061	12.93	25.75	20
40	34.5	96.8	560	34.36	0.42	0.062	13.25	27.1	20
45	38.75	96.8	590	33.93	0.42	0.064	13.58	28.45	20
50	43	96.8	620	33.5	0.42	0.065	13.9	29.8	20
55	47.25	96.8	650	33.07	0.42	0.066	14.23	31.15	20
60	51.5	96.8	680	32.64	0.42	0.068	14.55	32.5	20
65	55.75	96.8	710	32.21	0.42	0.069	14.88	33.85	20
70	60	96.8	740	31.78	0.42	0.071	15.2	35.2	20
75	64.25	96.8	770	31.35	0.42	0.073	15.53	36.54	20

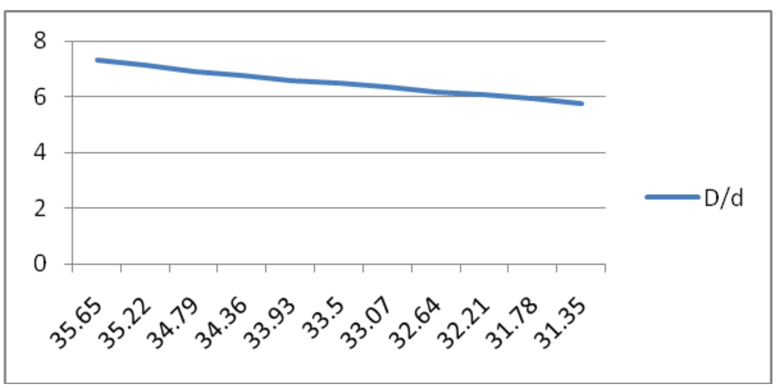

Fig.2 Variation of runner to nozzle diameter with a specific speed

IV CONCLUSION

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

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complete design of such turbine for maximum efficiency. The maximum efficiency was found to be 96% constant for different value of head.

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