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Research paper

OPTIMIZATION OF PELTON TURBINE BLADE

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Abstract

Due to an inefficient electric infrastructure, electricity is often scarce in rural areas. To address this issue, researchers have focused on a novel idea called the "MICRO HYDRO TURBINE," and their efforts are yielding promising results. When water comes down from higher elevations, a micro turbine may be placed in the stream and the potential energy of the water head used to power the turbine's rotor. In this research, a Pelton turbine is being studied and optimised since its efficiency is higher than that of other reaction turbines.SOLID WORKS is used to create a blade model, which is then sent to ANSYS for analysis.Three distinct materials have been subjected to both static and dynamic examination. Blade material geometry has been determined for three distinct jet sizes. Static and dynamic load optimisation of the blade material has been completed.

Key Words: Pelton Wheel, Jet Diameter, Blade Geometry, Natural Modes

1. INTRODUCTION

Hydroelectricity is widely utilised since it is a sustainable energy source. In 250 BC, hydropower was discovered being used to power a clock. In 1882, a water wheel was used to harness hydropower for the first time to generate electricity [1].

There has been a greater energy issue during the last decade. The necessity of alternate energy production methods in the face of this challenge cannot be overstated. Renewable sources of electricity including wind, tidal, solar, and hydro are essential in this case.[2]

A hydraulic turbine is a rotational component that transforms linear motion into rotary motion that is then linked to a generator to generate power.Potential energy is transformed into kinetic energy when water flows over the penstock from a dam and into the turbine blades. The turbine turns the generator which converts mechanical energy to electrical energy.It's possible to get up to 100 kW of power [4].

The efficiency of the pelton wheel and cross flow turbine in micro hydro power plants has been the focus of a case study by Loice Gudukea and Ignatio Madanhire[7]. A high-efficiency pelton turbine for a micro-hydro power plant was designed by Bilal Abdullah Nasir[8]. Sabin Sabu et al.[9] have created a 3D model and design documentation of a pelton wheel bucket.A pelton wheel for steels was developed and studied by Vinod et al. [10]. Static study of the pelton wheel bucket has been taken up by Nikhil Jacob et al. [11]. Bucket pelton wheel design and static analysis have been heavily emphasised in previous publications. In this study, we choose three materials and their geometries for three distinct jet diameters in an effort to find the optimal material for the pelton turbine bucket.

Second, think about the design.

The strains imposed on a turbine blade determine its final size. The pressures are:

1. Thermodynamic Pressures
2. Centripetal forces, secondly
3. tensions in bending
4. Pressures caused by one's own body mass.

Ratios based on jet diameters are used to establish the blade's dimensions.[12]

Here are some measurements for the buckets:

Bucket width, b=3.2d

Bucket height, h=2.7d

Cavity length, h_1=0.35d

Length to impact point, h_2=1.5d

Bucket depth, t=1.01d

Cavity width, a=1.2d

d=Diameter of jet

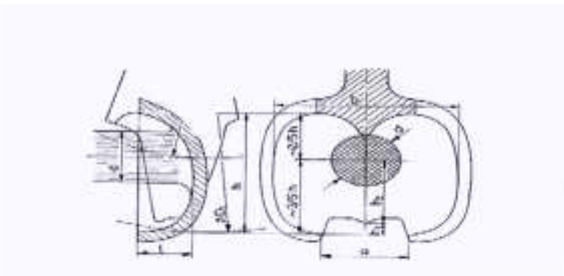

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Fig 2.1 Pelton turbine blade cross-section, front and side

Table 2.1: Dimensions for the blades:

Blade dimensions for three different jet diameters are shown in Table 2.1. These are determined by using the aforementioned ratios in terms of jet diameters.

Bucket Dimension(mm)	Jet Diameter(mm)		
	10	20	25
B	32	64	80
H	27	54	67.5
h_1	3.5	7	87.5
h_2	15	30	37.5
T	10.1	20.2	25.5
A	12	24	30

3. Modelling and Analysis

For various sized jets, solid works is used to simulate turbine blades. The simulated turbine blades with a 10, 20, and 30 mm jet diameter are shown in Figures 1, 2, and 3, respectively.

Fig.1- Blade for 10mm jet diameter.

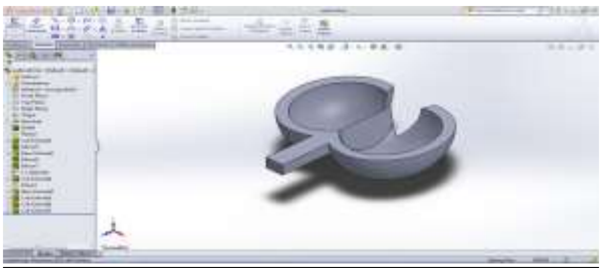

Fig.2- Blade for 20mm jet diameter.

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Fig.3-Blade for 25mm jet diameter.

Analysis:

Applying a jet's thrust to the blade:

Speed, Cv=0.98; Height, H=10m; Gravitational Acceleration, g=9.81m/s2

Velocity of jet, $V_{jet}=C_{v*}\sqrt{(2*g*H)}$

$=0.98*\sqrt{(2*9.81*10)}$

$=13.72$ m/s

To obtain consistent power output irrespective of blade utilised the rpm is maintained constant as N=1200rpm.

Force for 10mm jet dia:

Speed ratio, φ=0.43

$D_{run}=60*u/(\pi*N)$

u,bucket speed= $\varphi*\sqrt{(2*g*H)}$

$=0.43*\sqrt{(2*9.81*10)}$

$=6.023$ m/s

Consequently, Diameter of runner, $D_{run}=60*6.023/(\pi*1200)$

$=0.0959$ m $=96$ mm

Force of jet $F=2*\rho*Q_{act}*V_{jet}$ [8]

Coefficient of discharge, $C_d=0.54$

$C_d=\frac{Qact}{Qth}$

$Q_{act}=C_d$*Area of jet*velocity of jet

$=0.54*(\frac{\pi}{4})*d^2*V_{jet}$

$=5.818*10^{-4}$ m^3/s

Therefore, $F=2*1000*5.818*10^{-4}*13.72$

$=15.97$ N

Force for 20mm jet dia:

Speed ratio, φ=0.45

$D_{run}=60*u/(\pi*N)$

u,bucket speed= $\varphi*\sqrt{(2*g*H)}$

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$=0.45*\sqrt{(2*9.81*10)}$

$=6.303$ m/s

Therefore, Diameter of runner, $D_{run}=60*6.303/(\pi*1200)$

$=0.10036$ m $=100$ mm

Force of jet $F=2*\rho*Q_{act}*V_{jet}$

Coefficient of discharge, $C_d=0.54$

$C_d=\frac{Qact}{Qth}$

$Q_{act}=C_d$*Area of jet*velocity of jet

$=0.54*(\frac{\pi}{4})*d^2*V_{jet}$

$=2.327*10^{-3}$ m3/s

Therefore, $F=2*1000*2.327*10^{-3}*13.72$

$= 63.88$ N

Force for 25mm jet dia:

Speed ratio, $\varphi=0.46$

$D_{run}=60*u/(\pi*N)$

u,bucket speed= $\varphi*\sqrt{(2*g*H)}$

$=0.46*\sqrt{(2*9.81*10)}$

$=6.443$m/s

Therefore, Diameter of runner, $D_{run}=60*6.443/(\pi*1200)$

$=0.103$ m $=103$ mm

Force of jet $F=2*\rho*Q_{act}*V_{jet}$

Coefficient of discharge, $C_d=0.54$

$C_d=\frac{Qact}{Qth}$

$Q_{act}=C_d$*Area of jet*velocity of jet

$=0.54*(\frac{\pi}{4})*d^2*V_{jet}$

$=3.63*10^{-3}$ m^3/s

Therefore, $F=2*1000*3.63*10^{-3}*13.72$

$=99.83$ N

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Blade arm = 0.5 * Drun, where Drun is the runner's diameter, is used to simulate the blade's length.

The ANSYS 14.5 software performs the analysis using bronze, structural steel, and cast iron as potential materials.

Bronze, structural steel, and cast iron have all been subjected to dynamic analysis. The chosen materials also provide natural modes in a similar fashion.

Table. 4.1 Natural Modes

Jet diameter(mm)	Natural modes	Material		
		Cast Iron Frequency(Hz)	Bronze Frequency(Hz)	Structural Steel Frequency(Hz)
10	1	2088.2	1726	2356.7
	2	2832.1	2314.4	3179.8
	3	4326.1	3517.8	4844.7
	4	8878.5	7228.5	9952.2
	5	10101	8174.8	11287
	6	11898	9789.4	13405
	7	18540	15008	20723
	8	21143	17320	23775
	9	24187	19706	27119
	10	27543	22538	30953
20	1	1110.3	915.2	1251.4
	2	1159	947.72	1301.8
	3	1840.5	1494.5	2059.8
	4	3967.3	3227.8	4445.7
	5	4329.1	3493.4	4831
	6	5155.2	4229.8	5800.9
	7	8136.2	6571.6	9084.7
	8	10406	8516.61	11696
	9	11098	9035.6	12440
	10	13404	10934	15041
25	1	918.2	752.28	1032.2
	2	977.79	803.74	1100.9
	3	1569.2	1271.6	1754.6
	4	3324.8	2707	3727.2
	5	3662.7	2965.5	4093.9

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	6	4313.5	3542.8	4855.9
	7	6569.4	5313.9	7340.4
	8	7988.2	6534	8976.8
	9	9001.4	7319.9	10084
	10	10254	8369.7	11511

Table. 4.2 Stresses and Deformations

Jet diameter Mm	Parameter	Material		
		Cast Iron	Bronze	Structural Steel
10	Stress(Mpa)	8.47	8.28	9.949
	Deformation(microns)	5.018	6.039	3.96
20	Stress(Mpa)	10.874	10.795	10.795
	Deformation(microns)	11.0902	13.338	8.0285
25	Stress(Mpa)	11.33	11.195	11.195
	Deformation(microns)	9.0816	10.985	6.591

Tables 4.1 and 4.2 show that Cast iron has a greater natural frequency for a jet diameter of 10mm, whereas structural Steel has a higher natural frequency for jet diameters of 20mm and 25mm. More so, for a given jet diameter of 10mm, Structural Steel has a better load bearing capability and lower deformation. Cast Iron can take higher pressure while deforming less than stainless steel for a 20mm jet diameter. Cast Iron has more stress bearing capability for a jet diameter of 25mm, but structural Steel has less deformation. These results suggest that, for a given blade geometry and jet diameter, structural steel is the optimal material, with cast iron and bronze coming in a distant second and third, respectively. The choice is generalizable to the production of blades for Pelton wheels of turbines.

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5. Conclusions

The goal of this study was to determine the best blade material for a tiny Pelton wheel turbine. Standard proportions in terms of jet diameter for three distinct materials were used to arrive at the resulting blade geometry. The study and modelling are complete. The best material for making turbine blades, it has been determined, is structural steel.

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