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MATERIAL OPTIMIZATION OF PELTON WHEEL TURBINE BLADE FOR DIFFERENT JET DIAMETERS

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ABSTRACT
In rural parts, there exists power scarcity due to ineffective electric grid system. To overcome the problem, a new concept known as MICRO HYDRO TURBINE has been given emphasis and significant research is still in progress. In general the principle is when water flows from high terrains, a micro turbine is installed in the stream, where potential energy of water head is utilized to rotate the rotor of micro hydro turbine. Since the efficiency of Pelton turbine is relatively more compared to other reaction turbines, in this work a Pelton turbine has been considered for investigation for optimization. The turbine blade is modeled in SOLID WORKS and is imported to ANSYS. Both Static and dynamic analysis have been performed for three different materials. The geometry of blade material has been arrived at for three different jet diameters. At the end, the blade material has been optimized in terms of static and dynamic loads.

KEYWORDS: Pelton Wheel, Jet Diameter, Blade Geometry, Natural Modes

INTRODUCTION
Hydropower is a renewable vital source used in many parts of the world. The use of Hydro power was first found in 250 BC where it is utilized to run the clock. The first application of hydro power to produce electricity was in 1882 using a water wheel [1].

During the last 10 years, energy crisis is more. To face these problem alternative techniques of producing energy has got so much importance. In this scenario, renewable energy resources such as wind, tidal, solar and hydro power are required.[2]

Hydraulic turbine may be defined as a rotary component which converts the linear motion into rotary motion for which a generator is coupled to produce electricity.[3]The water flows along the penstock from a dam and hits the turbine blades in the process of conversion from potential energy to kinetic energy. The turbine rotates the generator which converts mechanical energy to electrical energy.[4] The power may be up to 100 KW[5].

Loice Gudukea and Ignatio Madanhire[6] have taken up a case study on efficiency improvement of Pelton wheel and cross flow turbine in micro hydro power plants. Bilal Abdullah Nasir[7] done work on design of high efficiency Pelton turbine for micro hydro power plant. Sabin Sabu etal[8] have designed and modeled a Pelton wheel bucket. Vinod etal[9] have designed and analyzed a Pelton wheel for steels in their work. Nikhil Jacob etal[10]have taken up static analysis of Pelton wheel bucket. The earlier works clearly reflects that emphasis has been laid mainly on design and static analysis of Pelton wheel bucket. In this work an attempt has been made to optimize the material for Pelton turbine bucket by selecting three different materials and their geometry for three specific jet diameters, both in static and dynamic conditions.

DESIGN CONSIDERATIONS
The dimensions of the turbine blade are decided based on the stresses acting on the blade. The stresses are:
1. Thermal stresses
2. Centrifugal stresses
3. Bending stresses
4. Stresses due to self weight.

The dimensions of the blade are determined by using ratios in terms of jet diameters.[11]
The dimensions of the buckets are as follows
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
The cut section of Pelton bucket in front and side
Views is shown in Fig 1.0

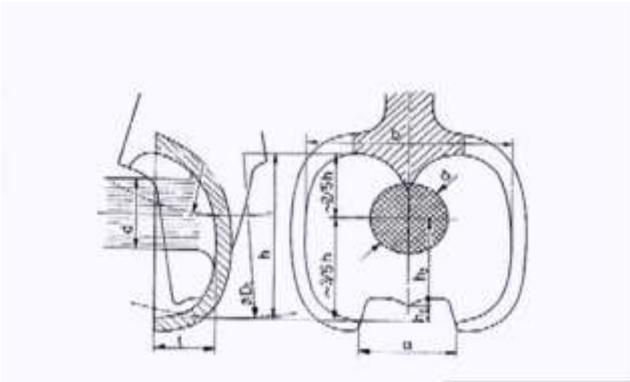

Fig 1.0 Cut-section of Pelton turbine blade in front and side views

Table 1.0 shows the dimensions for the blade corresponding to three jet diameters. These are calculated using the ratios in terms of jet diameters as mentioned above.

Table 1.0 Blade dimensions

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

MODELLING

Turbine blades are modelled using solid works for different jet diameters. Fig. 2.0, 3.0, 4.0 shows the modelled turbine blade for 10,20 and 25mm jet diameters respectively.

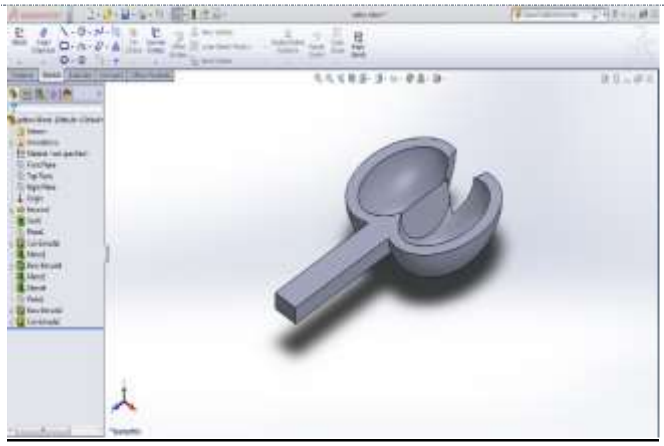

Fig.2.0 Blade for 10mm jet diameter.

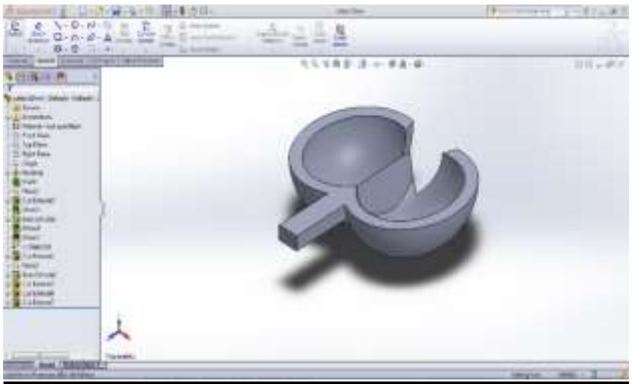

Fig.3.0 Blade for 20mm jet diameter.

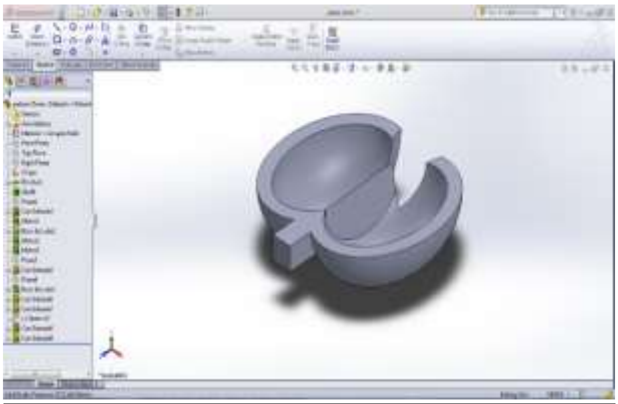

Fig.4.0 Blade for 25mm jet diameter.

ANALYSIS

Force applied by jet on the blade

Coefficient of velocity, $C_v = 0.98$, Head, $H=10$m, acceleration due to gravity, $g=9.81 m/s^2$

Velocity of jet, $V_{jet}=C_v * \sqrt{2*g*H}$

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

$=13.72$ m/s

To get constant power output independent of blade used, the rpm is kept constant as 1200.

Force calculation for 10mm jet dia.

Speed ratio, φ=0.43

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

u,bucket speed= φ *$\sqrt{2 * g * H}$

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

=6.023 m/s

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

=0.0959 m =96 mm

Force of jet F=2 *ρ*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 calculation for 20mm jet dia.

Speed ratio, φ=0.45

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

u,bucket speed= φ*$\sqrt{2 * g * H}$

=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 *ρ*Q_{act}*V_{jet}

Coefficient of discharge, C_d=0.54

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

$Q_{ac\,t}$= C_d*Area of jet*velocity of jet

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

=2.327*10^{-3} m^3/s

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

= 63.88 N

Force calculation for 25mm jet dia.

Speed ratio, φ=0.46

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

u, bucket speed = φ *$\sqrt{2 * g * H}$

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

= 6.443m/s

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

=0.103 m =103 mm

Force of jet F=2 *ρ*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

The diameter of runner is used in modeling the blade arm where blade arm=0.5*D_{run}

Analysis is done in ANSYS 14.5 considering three different materials Bronze, Structural steel and Cast iron and results are shown in Table 2.0.

Table 2.0 Stresses and Deformations

Jet dia. 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

RESULTS AND DISCUSSIONS

Dynamic analysis has been taken up for bronze, structural steel and cast iron. Similarly natural modes are obtained for the selected materials and are presented in Table 3.0.

Table. 3.0 Natural Modes

Jet dia. (mm)		**Material and corresponding natural frequency (Hz)**		
	Natural modes	**Cast Iron**	**Bronze**	**Structural Steel**
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
	1	1110.3	915.2	1251.4

20	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
	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

From the above Tables 2.0 and 3.0 it is evident that for a jet diameter of 10mm, Cast iron is having higher natural frequency and structural Steel is possessing higher natural frequency for jet diameters of 20mm and 25mm. Further, Structural Steel is having higher load bearing capacity for a jet diameter of 10mm and also its deformation is less. For a jet diameter of 20mm, Cast Iron is able to withstand more stress whereas deformation is less. For a jet diameter of 25mm, Cast Iron is having more stress bearing capacity whereas structural Steel is having less deformation. In view of these findings it can be concluded that structural Steel is more Optimum material over cast Iron and Bronze for a specific blade geometry in relation to particular jet diameter. The selection can be generalized for the fabrication of Pelton wheel turbine blade.

CONCLUSION

In this paper, an attempt has been made to optimize the blade material for a micro Pelton wheel turbine. The blade geometry has been arrived at using standard proportions in terms of jet diameter for three different materials. Modeling and analysis has been done. Finally it has been concluded that structural steel is the most effective material for fabrication of turbine blade.

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