OPTIMIZATION OF TURBINE DISTRIBUTOR SYSTEM BY SELECTION LESS THICKNESS MATERIAL

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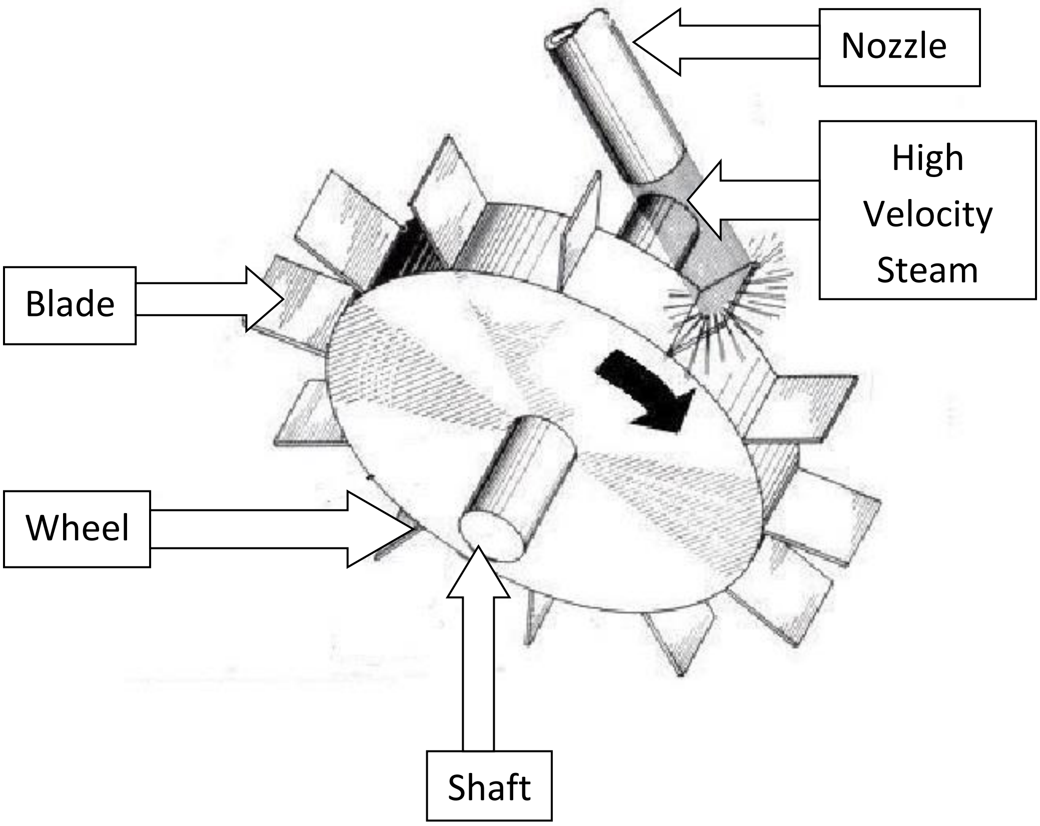
ABSTRACT:
A survey has been carried out in the development of Pelton turbine. It has been observed that hydro power generation is of great importance. The efficiency of Pelton Turbine in effected by improving the material characteristics of the distributor. Design optimization has been persued in the light of smarter materials in the light of smarter materials and capital cost saving.

Recent effort is dedicated to optimization of Distributor/Manifold for the Pelton Turbine which is used to maintain pressure on turbine. Most of Distributor/Manifold is heavy and not reliable. Also cost of distributer is high due to bad selection of material for manufacturing which create overhead to the Pelton Turbine making it inefficient. Thus, for the optimization of the turbine it is requires optimization of Distributer/ Manifold where selection of material become very important and ply vital role. A material selection procedure has been obtained, thereby formulating the problem as 'Optimization of turbine distributor using less thickness material selection'.

1.INTRODUCTION:

A turbine is a rotary engine that extracts energy from a fluid flow and converts this into handy work. A turbine is a turbo machine with at least one moving part called a rotor assembly, which is a shaft or drum with blades attached. Moving fluid acts on the blades so that they move and impart rotational energy to the rotor. Early turbine examples are windmills and waterwheels. The name turbine is a Greek word which is come from turbulence. In fluid dynamics, turbulence or turbulent flow is a flow regime characterized by chaotic property changes.

There are so many turbines available in the literature, however here we only focused on optimization of pelton wheel turbine. The pelton wheel turbine is an impulse turbine which is very easy to understand. In this A nozzle transforms water under a high head into a powerful jet. The momentum of this jet is destroyed by striking the runner, which absorbs the resulting force. If the velocity of the water leaving the runner is nearly zero, all of the kinetic energy of the jet has been transformed into mechanical energy, so the efficiency is high. A practical impulse turbine was invented by Lester A. Pelton in California around 1870. There were high-pressure jets there used in placer mining, and a primitive turbine called the hurdy-gurdy, a mere rotating platform with vanes, had been used since the '60's, driven by such jets. Pelton also invented the split bucket, now universally used. Pelton is a trade name for the products of the company he originated, but the term is now used generically for all similar impulse



turbines. A general diagram of a Pelton wheel turbine is shown in following figure 1.1

There are two types of turbines, reaction and the impulse, the difference being the manner of head conversion. In the reaction turbine, the fluid fills the blade passages, and the head change or pressure drop occurs within the runner. An impulse turbine first converts the water head through a nozzle into a high-velocity jet, which then strikes the buckets at one position as they pass by. The runner passages are not fully filled, and the jet flow past the buckets is essentially at constant pressure. Impulse turbines are ideally suited for high head and relatively low power. The Pelton turbine used in this experiment is an impulse turbine.

Figure 1.1 Basic diagram of turbine

The Pelton turbine consists of three basic components a stationary inlet nozzle, a runner and a casing. The runner consists of multiple buckets mounted on a rotating wheel. The jet strikes the buckets and imparts momentum. The buckets are shaped in a manner to divide the flow in half and turn its relative velocity vector nearly 180°.

The primary feature of the impulse turbine is the power production as the jet is deflected by the moving buckets. Assuming that the speed of the exiting jet is zero (all of the kinetic energy of the jet is expended in driving the buckets), negligible head loss at the nozzle and at the impact with the buckets (assuming that the entire available head is converted into jet velocity), the energy equation applied to the control volume shown in Figure 1.2 provides the power extracted from the available head by the turbine is shown in equation 1.1.

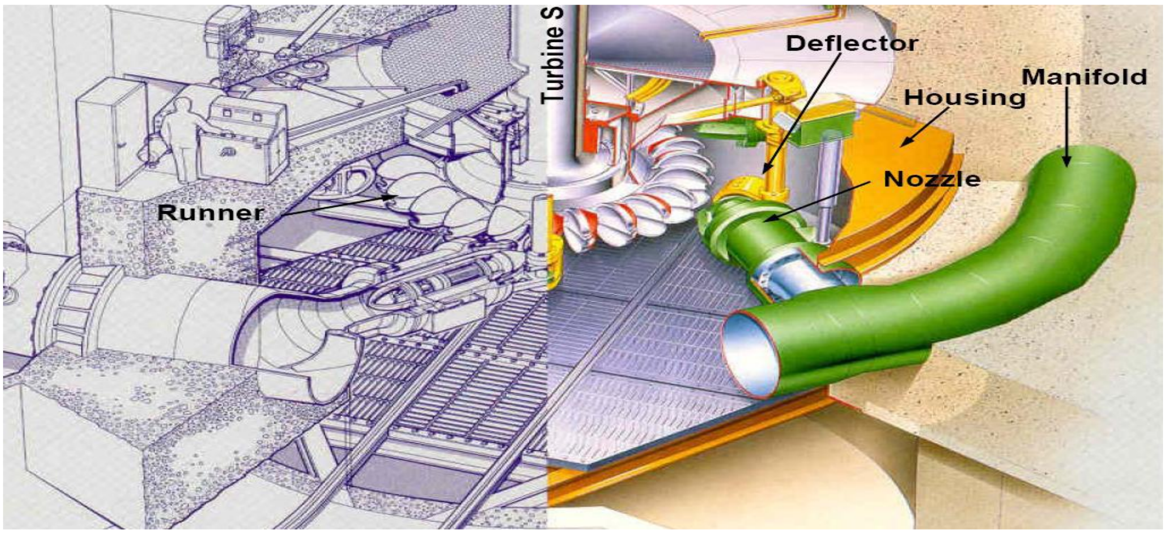
$$P_{available} = QH_{available} \qquad x \qquad z \qquad 1.1$$

Where Q is the discharge of the incoming jet, and $H_{available}$ is the available pressure head on the nozzle.

1.1 Pelton Turbine Components

- **Housing:** The function of the housing is to form a rigid unit with passages for the needle servomotor piping, feedback mechanisms, and the deflector shafts. The shape of the wetted side of the housing is important for directing the exit water effectively away from the runner.
- **Needle Valve/Nozzle:** The function of the needle jet (or nozzle) is to regulate the flow of water to the runner in an impulse turbine runner. The needle jet is regulated by the governor via mechanical-hydraulic or electro-hydraulic controls. The shape is designed for rapid acceleration at the exit end and for assuring a uniform water jet shape at all openings. The needle valve/nozzle assembly is placed close to the runner as possible to avoid jet dispersion due to air friction.
- **Runner:** The runner consists of a set of specially shaped buckets mounted on the periphery of a circular disc. It is turned by forced jets of water which are discharged from one or more nozzles. The resulting impulse spins the turbine runner, imparting energy to the turbine shaft. The buckets are split into two halves so that the central area does not act as a dead spot (no axial thrust) incapable of deflecting water away from the oncoming jet.
- **Discharge Chamber**: The function of the discharge chamber is to enable water existing the runner to fall freely toward the drainage. It also functions as a shield for the concrete work and avoids concrete deteriorations due to the action of the water jets. Correct water level regulation (surge chambers) inside this chamber is critical for maximum efficiency.

- **Deflectors:** The deflectors have the function to bend the jet away from the runner at load rejections to avoid too high of a speed increase. Moreover it protects the jet against exit water spray from the runner. The deflector arc is bolted to the deflector support structure frame with the control valve of the needle servomotors. A seal ring around the deflector shaft bearing housing prevents water and moisture from penetrating into the bearing.
- **Turbine Shaft**: The function of the turbine shaft is to transfer the torque from the turbine runner to the generator shaft and rotor. The shaft typically has a bearing journal for oil lubricated hydrodynamic guide bearings on the turbine runner end. Shafts are usually manufactured from forged steel, but some of the larger shafts can be fabricated.
- **Guide Bearing**: The function of the turbine guide bearing is to resist the mechanical imbalance and hydraulic side loads from the turbine runner, thereby maintaining the turbine runner in its centered position in the runner seals. It is typically mounted as close as practical to the turbine runner and supported by the head cover. Turbine guide bearings are usually oil lubricated hydrodynamic (babbitted) bearings.
- **Distributor/Manifold**: The function of the distributor (or manifold) is to provoke an acceleration of the water flow towards each of the main injectors. The advantage of this design is to keep a uniform velocity profile of the flow.



Multi-nozzle vertical Pelton turbine

1.2 Function and Design Rules of Pelton Wheel Turbine:

Pelton's paddle geometry was designed so that when the rim ran at ½ the speed of the water jet, the water left the wheel with very little speed; thus his design extracted almost all of the water's impulse energy—which allowed for a very efficient turbine.

In this turbine Nozzles direct forceful, high-speed streams of water against a rotary series of spoon-shaped buckets, also known as impulse blades, which are mounted around the circumferential rim of a drive wheel — also called, a runner. As the water jet impinges upon the contoured bucket-blades, the direction of water velocity is changed to follow the contours of the bucket. Water impulse energy exerts torque on the bucket-and-wheel system, spinning the wheel; the water stream itself does a "u-turn" and exits at the outer sides of the bucket, completely decelerated to a low velocity. In the process, the water jet's momentum is transferred to the wheel and thence to a turbine. Thus, "impulse" energy does work on the turbine. For maximum power and efficiency, the wheel and turbine system is designed such that the water jet velocity is twice the velocity of the rotating buckets. A very small percentage of the water jet's original kinetic energy will remain in the water, which causes the bucket to be emptied at the same rate it is filled and thereby allows the high-pressure input flow to continue uninterrupted and without waste of energy. Typically two buckets are mounted side-by-side on the wheel, which permits splitting the water jet into two equal streams. This balances the side-load forces on the wheel and helps to ensure smooth, efficient transfer of momentum of the fluid jet of water to the turbine wheel.

The specific speed n_s of a turbine dictate the turbine's shape in a way that is not related to its size. This allows a new turbine design to be scaled from an existing design of known performance. The specific speed is also the main criterion for matching a specific hydro-electric site with the correct turbine type.

$n_s = n\sqrt{P} / \sqrt{\rho}(gH)^{5/4}$

(dimensioned parameter), n= rpm

Where;

P= Power (W)
H= Water head (m)
ρ = Density (kg/m^3)
The formula implies that the Pelton turbine is most suitable for applications with relatively high hydraulic head H, due to the 5/4 exponent being greater than unity, and given the characteristically low specific speed of the Pelton.

2.METHODOLOGY :

The recent work is carried out after a training period of four weeks at B.H.E.L, Bhopal. It has been observed that the distributor/manifold for Pelton turbine under study is five jet types. The distributor/manifold is made up of different sections, the section being made up of cylinders and cones (frustum and truncated types) different sections are joined together. The cylindrical sections are 21 nos. and cone sections are 27 nos. joined together. The diameter at each joining section is obtained from the plant. Formulae used for calculating the thickness of different sections, namely:

a) Cone Segments.
b) Cylindrical Segments.

The data obtained from the plant has been summarised below:

Table 2.1 Dimensions of the cylindrical and cone segments (obtained from the plant)

Segment Type Cylinder / Cone	Diameter(mm)		Length of Cone Segment(mm)
	Initial (mm)	Final (mm)	
Cylinder (1-2)	2000	2000	
Cone (2-3)	2000	2090	762.93
Cone (3-4)	2090	2284.1	1706.85
Cone (4-5)	2284.1	2485	1665.47
Cone (5-6)	2485	1204.2	1585.44
Cone (6-7)	1204.2	955.8	710.18
Cylinder (7-8)	955.8	955.8	
Cone (5-9)	2485	2231.3	1969.13
Cone (9-10)	2231.3	2083.7	1753.64
Cylinder (10-11)	2083.7	2083.7	1707.83
Cone (11-12)	2083.7	2268.5	1943.94
Cone (12-13)	2268.5	1099.2	1268.04
Cone (13-14)	1099.2	955.8	736.16
Cylinder (14-15)	955.8	955.8	
Cone (12-16)	2268.5	2027.6	1873.58
Cone (16-17)	2027.6	1863.7	1706.98
Cylinder (17-18)	1863.7	1863.7	

Cone (18-19)	1863.7	2029	1593.31
Cone (19-20)	2029	1080	1244.76
Cone (20-21)	1080	955.8	660.14
Cylinder (21-22)	955.8	955.8	
Cone (19-23)	2029	1741.5	1719.35
Cone (23-24)	1741.5	1614	1178.33
Cylinder (24-25)	1614	1614	
Cylinder (25-26)	1614	1614	
Cone (26-27)	1614	1757.2	1439.69
Cone (27-28)	1757.2	1060.9	1370.37
Cone (28-29)	1060.9	955.8	698.16
Cylinder (29-30)	955.8	955.8	
Cone (27-31)	1757.2	1478.3	1709.67
Cone (31-32)	1478.3	1317.9	1268.51
Cylinder (32-33)	1317.9	1317.9	
Cylinder (33-34)	1317.9	1317.9	
Cone (34-35)	1317.9	1434.7	1215.49
Cone (35-36)	1434.7	1060.9	1092.06
Cone (36-37)	1060.9	955.8	1143.44
Cylinder (37-38)	955.8	955.8	
Cone (35-39)	1434.7	1012.6	1531.68
Cone (39-40)	1012.6	955.8	994.78
Cylinder (40-41)	955.8	955.8	
Cylinder (41-42)	955.8	955.8	
Cylinder (42-43)	955.8	955.8	
Cylinder (43-44)	955.8	955.8	

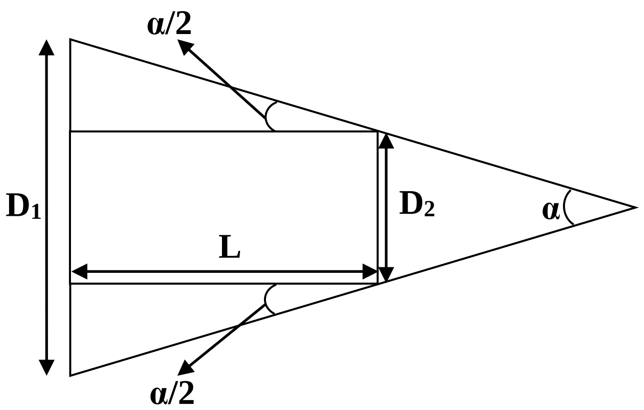
Cylinder (44-45)	955.8	955.8	
Cylinder (45-46)	955.8	955.8	
Cylinder (46-47)	955.8	955.8	
Cylinder (47-48)	955.8	955.8	
Cylinder (48-49)	955.8	955.8	

Material	Stress	Pressure	
ASTM A516	86 MPa	P_1 = 8.5 MPa	P_2 = 12.75 MPa
ASTM A537	105 MPa	P_1 = 8.5 MPa	P_2 = 12.75 MPa
EN 10028	127 MPa	P_1 = 8.5 MPa	P_2 = 12.75 MPa

Table 2.2 Properties of material and operating pressures.

3.FORMULAE USED:

3.1 Cone Segments



$$\sigma = \frac{P \times D}{2t\cos\alpha/2} + \frac{P}{2}$$

where,

σ= stress in MPa

P=pressure in MPa

D=diameter in mm

L=length in mm

t=thickness in mm

Further

$$\tan \alpha/2 = \frac{D_2 - D_1}{2L}$$

where, D_1=Initial diameter in mm.

D_2= Final diameter in mm.

3.2 Cylindrical Segments.

$$\sigma = \frac{P \text{ x } D}{2t} + \frac{P}{2}$$

where,

σ= stress in MPa

P=pressure in MPa

D=diameter in mm

t=thickness in mm

4.RESULTS & DISCUSSION:

The results are obtained for each segment namely Cone segments and Cylinder segments (frustum and transacted type).

4.1 Case A (Cone Segments)

The calculation of different materials for the shape of cones with different parameters i.e. pressure, stress, diameters, angle and thickness etc. and the equation are as follows:

Table 4.1: Summary of thickness of different section of the distributor/manifold.

Material	Shape	Pressure	Stress	Diameter	Angle	Thickness
	CONE -1					

ASTM A516		8.5 MPa	86	d1=2000,d2=2090	3.31	t1=104.18
		12.75 MPa	86	”		t2=167.66
ASTM A537		8.5 MPa	105	”		t1=84.536
		12.75 MPa	105	”		t2=135.36
EN 10028		8.5 MPa	127	”		t1=69.38
		12.75 MPa	127	”		t2=110.67
	CONE -2					
ASTM A516		8.5 MPa	86	d1=2090.0,d2=2284.1	3.2	t1=108.87
		12.75 MPa	86	”		t2=183.23
ASTM A537		8.5 MPa	105	”		t1=88.34
		12.75 MPa	105	”		t2=147.93
EN 10028		8.5 MPa	127	”		t1=72.507
		12.75 MPa	127	”		t2=120.95
	CONE -3					
ASTM A516		8.5 MPa	86	d1=2284.1,d2=2485	3.43	t1=117.107
		12.75 MPa	86	”		t2=199.35
ASTM A537		8.5 MPa	105	”		t1=96.54
		12.75 MPa	105	”		t2=160.95
EN 10028		8.5 MPa	127	”		t1=79.25
		12.75 MPa	127	”		t2=131.59

4.2 Case B (Cylindrical Segments).

The calculation of different materials for the shape of cylinder with different parameters i.e. pressure, stress, diameters and thickness etc .and the equation are as follows:

Where the stress for the different materials are as follows:

ASTM A516 , σ =86

ASTM A537, σ =105

EN 10028 , σ=127

Material	Shape	Pressure	Stress	Diameter	Thickness
	Cylinder 1				
ASTM A516		8.5 MPa	86	d1=2000,d2=2000	t1=103.97
		12.75 MPa	86	”	t2=160.125
ASTM A537		8.5 MPa	105	”	t1=84.36
		12.75 MPa	105	”	t2=129.27
EN 10028		8.5 MPa	127	”	t1=69.24
		12.75 MPa	127	”	t2=105.69
	Cylinder 2				
ASTM A516		8.5 MPa	86	d1=955.8,d2=955.8	t1=49.68
		12.75 MPa	86	”	t2=76.52
ASTM A537		8.5 MPa	105	”	t1=40.32
		12.75MPa	105	”	t2=61.78
EN 10028		8.5MPa	127	”	t1=33.09
		12.75MPa	127	”	t2=50.51
	Cylinder 3				
ASTM 516		8.5MPa	86	d1=2083.7,d2=2083.7	t1=108.32
		12.75MPa	86	”	t2=166.82
ASTM 537		8.5MPa	105	”	t1=87.89
		12.75MPa	105	”	t2=134.68
EN 10028		8.5MPa	127	”	t1=72.14

		12.75MPa	127	”	t2=110.12

5. CONCLUSION:

In the present world, fossil fuels are getting exhausted at an alarming rate. Hydropower generation is of great significance. Pelton Turbine is prominent in its contribution towards the same. Distributer/ Manifold for the Pelton Turbine is used for maintaining pressure. BHEL, Bhopal manufactures Distributer/Manifold in the hydro turbine engineering division. The Distributer/Manifold under study is five jet type. The distributer/manifold is made up of different sections, the sections being made up of cylinders and cones (frustum and truncated type); cylindrical sections are 21 numbers and cone sections are 27 numbers joined together. The outside diameter of each joint is obtained from the plant. Three different materials have been selected for Distributer/Manifold. The materials are ASTM A516, ASTM A537 and EN 10028. The thickness of different section of distributer/manifold has been calculated at each joint using the requisite formulae. As per the objective of selecting material with less thickness for manufacturing distributer in light of reducing / optimizing the weight and cost thereby increasing efficiency ; it is concluded to select EN10028 with the values obtained for thickness.

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