DESIGN AND THERMAL ANALYSIS OF PELTON WHEEL

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Abstract: A Pelton-wheel impulse turbine is a hydro mechanical energy conversion device which converts gravitational energy of elevated water into mechanical work. This mechanical work is converted into electrical energy by means of running an electrical generator. The kinetic energy of the Water-jet is directed tangentially at the buckets of a Pelton-wheel. The Water-jet strikes on each bucket’s convex profile splitter and get split into two halves. Each half is turned backwards, almost through 180° relative to the bucket on a horizontal plane. Practically this angle may vary between 165° to 170°. Normally all the jet energy is used in propelling the rim of the bucket wheel. Invariably some jet water misses the bucket and passes onto the tail race without doing any useful work. This hydro device is a good source of hydro-electrical energy conversion for a high water head. The present work in this research paper deals with some advanced modifications in the conventional Pelton-wheel so that it can be used for low-head and heavy-discharge applications. Both kinetic and potential energy of the water source is consumed by the runner wheel. Considerable gravitational effect of the water jet is exploited by means of some modifications in a conventional Peltonwheel. A comparatively heavy generator can be run by this modified Pelton-wheel turbine under lowhead and heavy-discharge conditions. The modified features provide enough promising opportunities to use this turbine for Mini and Micro hydro power plants.

1. INTRODUCTION

Hydro-power is an ancient resource of green electricity. Water from the rivers, lakes, ponds and plants evaporates due to sunlight heating. This results in the rise of water vapour against the gravitational pull of the earth. In the atmosphere, it cools and condenses into drops of rain and snow, which falls on hills and mountains. A considerable amount of solar energy is still retained in the water in the form of gravitational potential energy. Therefore, solar energy is the ultimate source of hydro energy which basically represents stored gravitational energy. It is understood that water continuously flows on the earth surface to reach the sea. This happens because of the spherical shape of the earth that tends to exert natural gravitational pull on surface water. The amount of stored hydro energy is directly proportional to the height and amount of the water above sea level. A turbine is the mechanical device which consumes the hydro energy of an elevated water level by means of pressure energy (in the case of a reaction turbine) or by means of kinetic energy (in the case of an impulse turbine). The hydro energy consumed by a turbine is passed onto the electrical generator shaft in the form of mechanical energy. A Pelton-wheel is a tangential flow free-jet impulse turbine named after an American engineer, Lesser Pelton. It is simple, robust and the only hydraulic turbine which operates efficiently on high heads in excess of 450 m. The working pressure in this turbine remains atmospheric only. It possesses simple construction and smooth running features with good performance characters.

The Pelton wheel extracts energy from the impulse of moving water, as opposed to its weight like traditional overshot water wheel. Although many variations of impulse turbines existed prior to Pelton's design, they were less efficient than Pelton's design; the water leaving these wheels typically still had high speed, and carried away much of the energy. Pelton's paddle geometry was designed so that when the rim runs at 1/2 the speed of the water jet, the water leaves the wheel with very little speed, extracting almost all of its energy, and allowing for a very efficient turbine.

FUNCTION- The water flows along the tangent to the path of the runner. Nozzles direct forceful streams of water against a series of spoon-shaped buckets mounted around the edge of a wheel. As water flows into the bucket, the direction of the water velocity changes to follow the contour of the bucket. When the water-jet contacts the bucket, it exerts pressure on the bucket and the water is decelerated as it does a "U-turn" and flows out the other side of the bucket at low velocity. In the process, the water's momentum is transferred to the turbine. This "impulse" does work on the turbine. For maximum power and efficiency, the turbine system is designed such that the water-jet velocity is twice the velocity of the bucket. A very small percentage of the water's original kinetic energy will still remain in the water; however, this allows the bucket to be emptied at the same rate it is filled, (see conservation of mass), thus allowing the water flow to continue uninterrupted. Often two buckets are mounted side-by-side, thus splitting the water jet in half (see photo). This balances the side-load forces on the wheel, and helps to ensure smooth, efficient momentum transfer of the fluid jet to the turbine wheel.
Because water and most liquids are nearly incompressible, almost all of the available energy is extracted in the first stage of the hydraulic turbine. Therefore, Pelton wheels have only one turbine stage, unlike gas turbines that operate with compressible fluid.

Applications:

Pelton wheels are the preferred turbine for hydro-power, when the available water source has relatively high hydraulic head at low flow rates, where the Pelton wheel is most efficient. Thus, more power can be extracted from a water source with high-pressure and low-flow than from a source with low-pressure and high-flow, even when the two flows theoretically contain the same power. Also a comparable amount of pipe material is required for each of the two sources, one requiring a long thin pipe, and the other a short wide pipe. Pelton wheels are made in all sizes. There exist multi-ton Pelton wheels mounted on vertical oil pad bearings in hydroelectric plants. The largest units can be up to 200 megawatts. The smallest Pelton wheels are only a few inches across, and can be used to tap power from mountain streams having flows of a few gallons per minute. Some of these systems utilize household plumbing fixtures for water delivery. These small units are recommended for use with thirty meters or more of head, in order to generate significant power levels. Depending on water flow and design, Pelton wheels operate best with heads from 15 meters to 1,800 meters, although there is no theoretical limit.

Design Rules:

The specific speed $\eta_s$ of a turbine dictates 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.

$$\eta_s = n \sqrt{\frac{P}{H^{5/4}}}$$

where:

- $P$ = Power (kW)
- $H$ = Water head (m)

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.

Energy and initial jet velocity

In the ideal (frictionless) case, all of the hydraulic potential energy ($E_p = mgh$) is converted into kinetic energy ($E_k = mv^2/2$) (see Bernoulli's principle). Equating these two equations and solving for the initial jet velocity ($V_i$) indicates that the theoretical (maximum) jet velocity is $V_i = \sqrt{2gh}$. For simplicity, assume that all of the velocity vectors are parallel to each other. Defining the velocity of the wheel runner as: $u$, then as the jet approaches the runner, the initial jet velocity relative to the runner is: $(V_i - u)$.
Final jet velocity

Assuming that the jet velocity is higher than the runner velocity, if the water is not to become backed-up in runner, then due to conservation of mass, the mass entering the runner must equal the mass leaving the runner. The fluid is assumed to be incompressible (an accurate assumption for most liquids). Also it is assumed that the cross-sectional area of the jet is constant. The jet speed remains constant relative to the runner. So as the jet recedes from the runner, the jet velocity relative to the runner is: \( -(V_i - u) = -V_i + u \). In the standard reference frame (relative to the earth), the final velocity is then: \( V_f = (-V_i + u) + u = -V_i + 2u \).

Turbine physics and derivation

Optimal wheel speed

We know that the ideal runner speed will cause all of the kinetic energy in the jet to be transferred to the wheel. In this case the final jet velocity must be zero. If we let \( -V_i + 2u = 0 \), then the optimal runner speed will be \( u = V_i / 2 \), or half the initial jet velocity.

Torque

By newton’s second and third laws, the force \( F \) imposed by the jet on the runner is equal but opposite to the rate of momentum change of the fluid, so:

\[
F = -m(V_f - V_i) = -pQ((-V_i + 2u) - V_i) = -pQ(-2V_i + 2u) = 2pQ(V_i - u)
\]

where \( (p) \) is the density and \( (Q) \) is the volume rate of flow of fluid. If \( (D) \) is the wheel diameter, the torque on the runner is: \( T = F(D/2) = pQD(V_i - u) \). The torque is at a maximum when the runner is stopped (i.e. when \( u = 0 \), \( T = pQDV_i \)). When the speed of the runner is equal to the initial jet velocity, the torque is zero (i.e. when \( u = V_i \), then \( T = 0 \)). On a plot of torque versus runner speed, the torque curve is straight between these two points, \((0, pQDV_i)\) and \((V_i, 0)\).

II. RELATED WORK

Mounting the Runners on the Wheel

After the runners were cut, it was clear that with the smaller diameter wheel and its resulting high speed of rotation, any unbalance in the wheel would cause vibrations that might result in damage. As a result, extra care was taken to ensure that the wheel was as balanced as possible. This meant that the original plan of using the acrylics discs to sandwich the runners was considered too inaccurate and a new procedure that could place each runner accurately was conceived.

Precision Mounting of the Runners in the Radial Plain:

Though the acrylic disc would not be used for structure, it was used to act as a mount for the runners. The hole in the disc would act as a marker for the centre of rotation, while the machine screw attached through the hole would mark the axis perpendicular to the plane of rotation. Before each of the runners was cut, a line was drawn on their flanges to indicate the radial centre line.
A stack of washers was then added to the center of the wheel. Unlike the acrylic disc and machine screw, these washers would be glued permanently inside the wheel. The washers served two purposes: to preserve the axis of rotation after the acrylic disc and the machine screw were removed, and to act as a spacer to ensure that each runner was positioned the same distance from the center of rotation, i.e. the diameter of the washer.

Wax was then added between the radial lines so that they could temporarily hold the runners without covering up the guide lines. Each of the runners was then stuck onto the wax. The first step was to line up the runner’s center line with the radial lines on the acrylic disc. Because the disc is transparent, this was accomplished by looking through the disc and sliding the runner until its center line completely matched the radial line scratch on the opposite side of the disc. This ensured that each runner was exactly spaced in the radial plane.

The second step was to make sure that the ends of each runner was pushed tightly against the washers. This ensured that each runner was exactly the same distance from the shaft.

**Precision Mounting of the Runners in the Vertical Axis:**

At this stage, steps had been taken to ensure that the wheel was radially spaced, but for the wheel to act correctly as a Pelton Wheel, the centre ridge of each of the runners must be able to split the water jet. This means that each runner’s ridge must be placed exactly parallel with the plane of rotation. To accomplish this, the acrylic disc holding the runners was held in a drill-press by the machine screw. This setup enabled the disc to be turned through the axis of rotation. A laser level was then clamped in place at the level of the water jet.

The angle of each runner was then adjusted so that its center ridge came in contact with the laser line. The angle of each runner was then adjusted so that its center ridge came in contact with the laser line.

**Gluing the Runners into the Wheel:**

Once each of the runners was properly positioned in the horizontal, vertical, and radial directions, they were held in place with a layer of epoxy resin. This was accomplished by simply applying a thin layer while the wheel was still held in the drill-press. After the runners were held in place, wax formwork was added to the sides of the acrylic disc, and a structural layer of epoxy resin was pored on the top surface.

Once

**Cleaning and Painting the Wheel**

At this point, the structure of the wheel had been pored, and 24 hours had passed giving the epoxy resin time to cure. As with the initial molds, a knife was used to remove large imperfections or drip marks, and a buffing wheel was used to clean up the surface for painting. After the wheel had been cleaned and polished, a primer coat was added. Once dry, any drip marks were sanded away.

The shaft coupling was then temporarily attached to the wheel by the machine screw. The coupling was oriented so that its center ridge came in contact with the laser line. The angle of each runner was then adjusted so that its center ridge came in contact with the laser line.

**III. IMPLEMENTATION**

**Working principal and hydraulic efficiency of a conventional Pelton-wheel turbine**

The water from the reservoir flows through a penstock which contains a nozzle at the outlet. The nozzle increases the kinetic energy of the penstock water. At the outlet this nozzle produces a Water-jet. This Water-jet strikes on the buckets (Vanes) of therunner and transfers its kinetic energy to the bucket’s wheel. The general formula of any hydro system is

\[ P = \sigma g Q H \]

Where:

- \( P \) is the mechanical power produced at the turbine shaft (in Watts)
- \( N \) is the hydraulic efficiency of the turbine, is the density of water in \((1000 \text{ kg/m}^3)\)
- \( g \) is the acceleration due to gravity in \((9.81 \text{ m/s}^2)\)
- \( Q \) is the volume flow rate passing through the turbine in \((\text{m}^3/\text{s})\)
- \( H \) is the effective pressure head of water across the turbine in \((\text{m})\)

For an impulse turbine of a Pelton-wheel type, the mechanical power can be changed by means of changing \(\sigma, Q, \) and \( H \) inputs because \(\sigma, g \) and \( g \) are constant. The force exerted by the water jet on buckets (vanes) of the runner in the direction of motion is given as:

\[ F_x = a \left(V_1(V_{w1} + V_{w2})\right) \]

Here,

- \( a = \text{Cross section area of water-jet in } m^2 = \frac{\pi d^2}{4} \)
- \( d = \text{diameter of jet in } m \)
- \( V_1 = \text{Velocity of the jet at the inlet of bucket splitter,} \)
- \( V_{w1} = \text{Velocity of the whirl at inlet in } m/s, \)
- \( H = \text{Net head acting on the Pelton-wheel in } m, \)
- \( g = \text{Acceleration due to gravitation in } m/s^2, \)
- \( V_{w2} = \text{Velocity of the whirl at outlet in } m/s \)

The work done by the jet on the runner per second is as:

\[ W_j = F_x \times u = a \left(V_1(V_{w1} + V_{w2})\right) \times u \text{ Nm/s} \]

Here,

- \( u = \text{Tangential linear velocity of the bucket wheel at pitch circle in } m/s \)

The energy supplied to the jet is in the form of kinetic energy which is given as \(\frac{1}{2} mv^2\).

Now,
Kinetic Energy (K.E.) of the jet per second is given as:

\[ \text{K.E.} = \frac{1}{2} a V_1 \times V_1^2 \] (*3*)

Hydraulic Efficiency \( h = \) Work done by jet per second

\[ \div \text{K.E. of jet per second.} \]

**Basic Working Values**

To provide power to the water turbine, our calculations will be based on residential water pressure to act as the prime mover. Residential pressure can vary depending on several factors, including: distance and elevation difference from the water reservoir, age of the pipes, leakage in the municipal water network, level of impurities present, etc. For a North American home, the average water pressure will be between 45 to 80 psi, with some extreme cases reaching from 30 to 115 psi. For calculation purposes, we will assume the low end of acceptable pressure and use 45 psi.

The flow rate will be determined experimentally, but based on the North American residential standard, a ½ inch copper pipe.

**Hydraulic Head**

In hydroelectric projects, calculations are based on the available hydraulic head. This is a measurement of the difference in elevation between the water source and the turbine. For this project, we will calculate the theoretical hydraulic head based on the available water pressure.

Residential Water Pressure 45 psi

1 psi = 6894.757 Pascal

Therefore 45 psi = \(3.1 \times 10^5\) N/m

In order to calculate the hydraulic head, we use the simplified Bernoulli’s equation of incompressible fluids and assume that the pressure at the surface of the water supply is negligible.

\[ \text{Head (m)} = [\text{Final Pressure (N/m)}^2 - \text{Initial Pressure (N/m)}^2] / \text{Specific Weight of Water} \]

Specific Weight of Water = \(10000 \text{ kg/m}^3\)

\(H = 3.1 \times 10^5 \text{ N/m}^2 - (0) / 9810 \text{ N/m}^3\)

\[ H = 31.62 \text{ m} \]

**Flow Rate** \( q \):

The second fundamental value to be derived is the amount of water available through the pipe, known as the flow rate. To measure the flow rate, the water supply was opened, and the amount that flowed out in 10 seconds was collected in a large bucket. Once the experimental time had elapsed, the contents of the bucket were measured by pouring it into a measuring cup. The following is a summery of the calculations

3.75 L in 10 seconds

0.375 L/s

**Basic Calculation of Available Power**

Once the hydraulic head and flow rate have been established for our theoretical micro-hydro project, a ballpark value of power is calculated in order to derive the requirements of the generator. The following formula was used

\[ P(kW) = q(m^3/s) \times H(m) \times g(ms^{-2}) \times \rho(kgm^{-3}) \times \eta(\%) \times [1/1000] \]

Or

\[ P(kW) = 0.735 \times 10^{-3} [m^3/s] \times 31.62(m) \times 9.81(ms^{-2}) \times 1000(kgm^{-3}) \times [1/1000] \]

As this calculation is just designed to give us our upper limit, we will assume an efficiency of 100%

\[ P(kW) = 0.116 \text{ kW} \]

Or 116 Watts

**Choice of Generator**

Three main factors where used in choosing a generator for the project: cost, rate of rotation, and available power. The maximum available power was calculated above to be 116 watts. This means that for safety reasons, the generator should be rated for at least a minimum load of 116 watts, or we run the risk of overheating. With the minimum power set as a limiting factor, the following choices were considered.

**AC Motor repurposed to work as a generator**

AC induction motors are by fare the most common midsized (1/5 HP) to large (5 HP) electric motors available. Finding an inexpensive second hand unite available for the project would be simple. But induction motors do not use permanent magnets, as such, a large capacitor is often required to “jump start” the induction process if the motor is to work as a generator. Because any information other than what is printed on the motor is almost impossible to find on second hand motors, repurposing a second hand AC motor with a starter capacitor was considered too difficult, and outside the scope of the project.

**Designing the Water Turbine**

In a very basic sense, water turbines can be separated into two broad categories: reaction turbines that act on a change in pressure in the flow of a fluid, and impulse turbines that are put in motion by the impact of a water jet against a paddle or runner. The precise nature of the application is used to judge which of the many turbine designs is ultimately used. In general, reaction turbines require a very high level of precision between the impeller and its housing, as any gap between the two will result in a much lower efficiency. This requirement for a high precision housing makes the construction of a reaction turbine impractical for this project. The result is that an impulse turbine, specifically a Pelton Wheel was chosen for the turbine design.
The Pelton Wheel

A Pelton wheel is constructed of double cup runners that receive the impact from a high pressure water jet and convert it into rotational movement. The runners are contoured to split the water flow into two halves and reflect both halves backwards, thus maximizing the efficiency of the transfer of energy. Unlike other turbine designs once common in pre-industrial applications, the runners are not meant to hold fluid, rather to expel it, as gravity plays no real part in the collision and subsequent transfer of energy.

The design and dimensions of an ideal Pelton wheel can be calculated from the basic specifications already calculated above. The following is a summery of the pertinent information.

**Hydraulic Head:** \( H = 31.62 \text{m} \)

**Flow Rate:** \( q = 3.75 \times 10^{-3} \text{m}^3 \text{s}^{-1} \)

**Rotation:** 2000 to 3000 RPMs

**Design of the Pelton Wheel**

The design of the ideal Pelton Wheel can be separated into three categories: calculating the ideal water jet width, calculating the ideal diameter of the wheel, and calculating the dimensions of the runners. In the first two cases, the calculations will be based on the initial characteristics summarized above, while the shape and dimensions of the runners will be determined primarily by the calculated width of the water jet.

The calculations used to generate the shape and dimensions of our Pelton Wheel were all based on those found in: MHPG Series, Harnessing Water Power on a Small Scale, Volume 9 Micro Pelton Turbines; published by SKAT, Swiss Centre for Appropriate Technology, 1991.

**The Ideal Width of the Water Jet**

The width of the water jet used is an important factor that will help to establish the physical shape of the Pelton Wheel runners. The width of the water jet determines the speed of the fluid impacting the runners and is based on the available Hydraulic Head. The following calculations are used to design the water jet width.

**Calculation 1.1: Absolute Velocity of the Water Jet \( c \) (m \text{s}^{-1})**

\[
\begin{align*}
c &= k \left( 2 \frac{g H}{c} \right)^{\frac{1}{2}} \\
&= 0.96 \left( 2 \times 9.81 \times 31.62 \right)^{\frac{1}{2}} \\
&= 23.67 \text{m/s}
\end{align*}
\]

**Calculation 1.2: Optimal Jet Diameter: \( d \) (m)**

\[
\begin{align*}
d &= \left( \frac{4q}{\pi c} \right)^{\frac{1}{2}} \\
&= \left[ \frac{4 \times 3.75 \times 10^{-3}}{\pi \times 23.67} \right]^{\frac{1}{2}} \\
&= 4.5 \text{mm}
\end{align*}
\]

**The Ideal Diameter of the Pelton Wheel**

The Ideal Diameter or Pitch Circle Diameter is the width of a circle calculated from the point of impact of the water jet. The water jet impacts the runners towards the back of the scoops, so the real diameter or Outside Diameter will be slightly larger. The Pitch Circle Diameter along with the width of the water jet will determine the speed of rotation and the torque on the wheel. The reason for this is that the jet width determines the speed at which the water strikes the wheel, while the larger the wheel, the larger the moment arm, but the slower its rotation. Based on the chosen generator and the expected load, the Pitch Circle Diameter will be designed to produce 2500 RPMs.

**Calculation 2.1: Optimal Peripheral Velocity: \( u \) (m \text{s}^{-1})**

\[
\begin{align*}
u &= k \left( 2 \frac{g H}{u} \right)^{\frac{1}{2}} \\
&= 0.45 \left( 2 \times 9.81 \times 31.62 \right)^{\frac{1}{2}} \\
&= 11.097 \text{m/s}
\end{align*}
\]

**Calculation**

**Pitch Circle Diameter: \( D \) (m)**

\[
\begin{align*}
D &= \left( 60 \frac{u}{n} \right) / (\pi n) \\
&= \left( 60 \times 11.097 \times 1 \right) / (\pi \times 2500) \\
&= 0.0847 \text{m} \\
&= 8.5 \text{cm}
\end{align*}
\]

**The Physical Dimensions of the Runners**

The dimensions of the runners are calculated based off of the width of the water jet. The following formulas were used based on established standards. The meaning behind these measurements can be obtained from the following diagram.
Ideal Dimensions of a Pelton Wheel Runner

Calculation 3.1: Bucket Width: \( b \) (mm)

\[
b = (3.2)d \\
= (3.2)(4.5) \\
= 14.4 \text{ mm}
\]

Calculation 3.2: Bucket Height: \( h \) (mm)

\[
h = (2.7)d \\
= (2.7)(4.5) \\
= 12.15 \text{ mm}
\]

Calculation 3.3: Cavity Length: \( h_1 \) (mm)

\[
h_1 = (0.35)d \\
= (0.35)(4.5) \\
= 1.6 \text{ mm}
\]

Calculation 3.4: Length to Impact Point: \( h_2 \) (mm)

\[
h_2 = (1.5)d \\
= (1.5)(4.5) \\
= 6.75 \text{ mm}
\]

Calculation 3.5: Bucket Depth: \( t \) (mm)

\[
t = (0.9)d \\
= (0.9)(4.5) \\
= 4.05 \text{ mm}
\]

Calculation 3.6: Cavity Width: \( a \) (mm)

\[
a = (1.2)d \\
= (1.2)(4.5) \\
= 5.4 \text{ mm}
\]

Calculation 3.6: Offset of Bucket: \( k \) (mm)

\[
k = (0.17)d \\
= (0.17)(4.5) \\
= 3.4 \text{ mm}
\]

Once the ideal values had been calculated, a times two safety factor was used to produce the working values. The following table summaries the working values.

**Working Values for the Pelton Wheel**

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Value</th>
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<tbody>
<tr>
<td>( b )</td>
<td>28.8 mm</td>
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<tr>
<td>( h )</td>
<td>24.3 mm</td>
</tr>
<tr>
<td>( h_1 )</td>
<td>3.2 mm</td>
</tr>
<tr>
<td>( h_2 )</td>
<td>13.5 mm</td>
</tr>
<tr>
<td>( t )</td>
<td>8.1 mm</td>
</tr>
<tr>
<td>( a )</td>
<td>10.8 mm</td>
</tr>
<tr>
<td>( k )</td>
<td>6.8 mm</td>
</tr>
<tr>
<td>( D )</td>
<td>85 mm</td>
</tr>
<tr>
<td>( d )</td>
<td>4.5 mm</td>
</tr>
</tbody>
</table>

**Working Dimensions of a Pelton Wheel**

\[
b = 28.8 \text{ mm} \\
= 24.3 \text{ mm} \\
h = 3.2 \text{ mm} \\
h_2 = 13.5 \text{ mm} \\
t = 8.1 \text{ mm} \\
a = 10.8 \text{ mm} \\
k = 6.8 \text{ mm} \\
D = 85 \text{ mm} \\
d = 4.5 \text{ mm}
\]

**Redesigning the Pelton Wheel Runners**

As a result of the change in the diameter of the wheel, the flanges attached to the runners are much too large. A systematic method for accurately cutting the flanges was then developed. A wooden rig was constructed to hold the runners by their flange. Saw lines were cut into the rig, allowing each runner to be cut in exactly the same way. In this manner, a close uniformity was maintained among the runners.
### IV. EXPERIMENTAL RESULTS

**Model (C4) > Static Structural (C5) > Solution (C6) > Results**

<table>
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<tr>
<th>Object Name</th>
<th>Total Deformation</th>
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<th>Equivalent Stress</th>
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</table>

**Results**

| Minimum | 0. mm | 6.5372e-013 mm/mm | 4.9682e-008 MPa |
| Maximum | 2.6153e-003 mm | 6.6139e-005 mm/mm | 12.484 MPa |

**Information**

| Time    | 1. s   |
| Load Step | 1     |
| Substep  | 1     |
| Iteration Number | 1     |

**Integration Point Results**

| Display Option | Averaged |

---

**Model (C4) > Static Structural (C5) > Solution (C6) > Total Deformation > Figure**

**Model (C4) > Static Structural (C5) > Solution (C6) > Equivalent Elastic Strain > Figure**

**Model (C4) > Static Structural (C5) > Solution (C6) > Equivalent Stress > Figure**
V. CONCLUSION

This project is done by creating a three-dimensional model PELTON WHEEL and this model is generated by using design software CATIA. CATIA is useful for designing different numbers of models as per the dimensions, as it is a versatile application. The model should be analyzed and measured which is designed in proe. The obtained model is taken and geometric views are generated and following screenshots are shown. Analysis of the design is obtained by using ANSYS software and following results and tables are listed in this project.

REFERENCES:

[1] Handbook of Die Design by Ivana Suchy
[3] Pro/Engineer WildFire 2.0 by Steven G. Smith