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Flow Simulation And Static Structural Analysis on Pelton Turbine

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Abstract: ***Pelton turbine is used for high- head packages in the range 500-2000 meters. The output it produces about 10-three hundred MW. It includes 1 to six nozzles that may carry out based upon one or more nozzles. The energy available at inlet of rotary engine is most powerful kinetic power. In this paper 3 one of a kind pelton turbine designs are fascinated about distinct buckets. Design part is performed via using CATIA software program. After layout part completes evaluation is carried out by using ANSYS fluent. In ANSYS FLUENT the analysis is accomplished on three exceptional pelton turbine designs. After evaluation part is finished evaluating the solution in the ANSYS FLUENT undergoing static structural analysis based on the efficient pelton turbine bucket model and changing the material properties for the efficient pelton turbine by undergoing analysis using three different types of materials and finally concluding about which material is best to model pelton turbine.***

***Index Terms*: pelton turbine, Ansys fluent, buckets, CATIA, static structural analysis**

I. INTRODUCTION

The pelton wheel is one of the impulse turbines which produces power by converting the pressure energy into kinetic energy. This process is done with the help of jet nozzle assembly and runner is used to generate power from kinetic energy. Runner of Pelton turbine consists buckets that are mounted on the disc. Immediately after the jet strikes the angular rotation of the bucket takes place. The wheel will come into motion when the water jet strikes the buckets of the pelton wheel. Pelton turbine is a high head turbine. It is used in various applications. Advantages of pelton turbine over other turbines are many. It is having high overall efficiency and can operate at low discharge. The added benefits of this is it can be operated in salt water. Compared to other turbines it can be easily assembled. When it comes to disadvantages, the efficiency of it reduces with time. The generator, powerhouse required is large. Pelton turbine is mostly chosen when the flow rate is low. It is used at relatively high hydraulic heads.

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The water which is stored at high heads comes through the penstock and reaches the nozzle. Kinetic energy is increased and directs the water in the form of jet by the nozzle. This jet strikes the vanes of pelton wheel. Because of this the runner moves at very high speed and the spear which is at nozzle controls the amount of water striking the buckets. Then comes the generator which is attached to the shaft of runner which converts the mechanical energy into electrical energy. Buckets are located on the circumference with same spacing. The nozzles are tangential to the wheel circumference. Number of nozzles depend upon the water head and the running requirement. The nozzles present across the wheel varies. There are splitters at the center of the bucket. The water jets are divided into same watercourses which are also called streams. The water flows together with the internal curve of the bucket. The water leaves from the other side of the incoming jet. A small nozzle which directs the jet of water on back of buckets is provided to stop the runner for some time. This jet is called the breaking jet. Casing is provided to overcome the splashing of water. Moreover, it discharges water to tailrace. Using the high pace water turbine, the pelton wheel should be labored. It receives the excessive strain water jet from the water frame which is located on the excessive level to push the water downwards. Impulse on the blade of the pelton wheel turbine is produced by the stream water because of alternate inside the momentum. The rotation and torque within the shaft of the pelton wheel is generated using this impulse. To gain the optimal output the impulsive should pass backwards by way of the blades must be severe. Alternate in the momentum provides the maximum water movement. So, it's far located as quickly as the water circulation is bounced inside the opposite course to which it strikes the buckets with similar pace relative to the buckets.

II. DESIGN

Pelton wheel along with bucket was modeled in NX-CAD software based on the design calculations done using formulae.

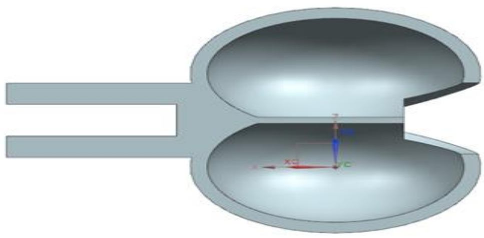

Fig 1 shows front view of pelton bucket

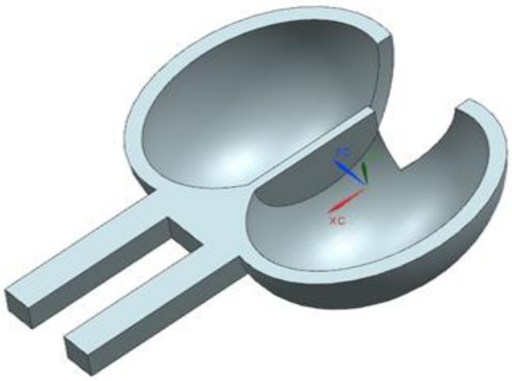

Fig 2 shows isometric view of pelton bucket

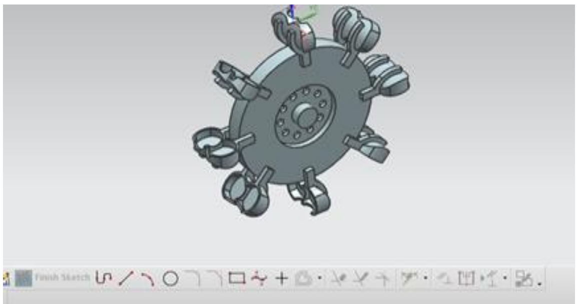

Fig 3 shows 3D model of 8 turbine bucket

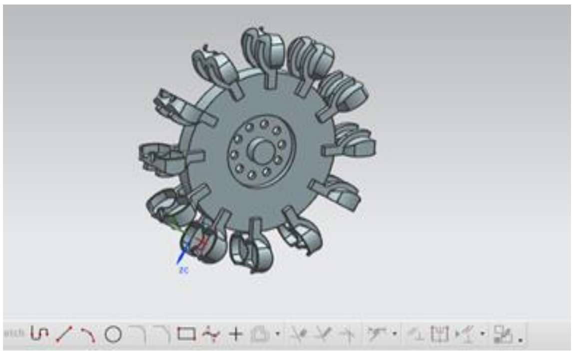

Fig 4 shows 3D model of 12 turbine bucket

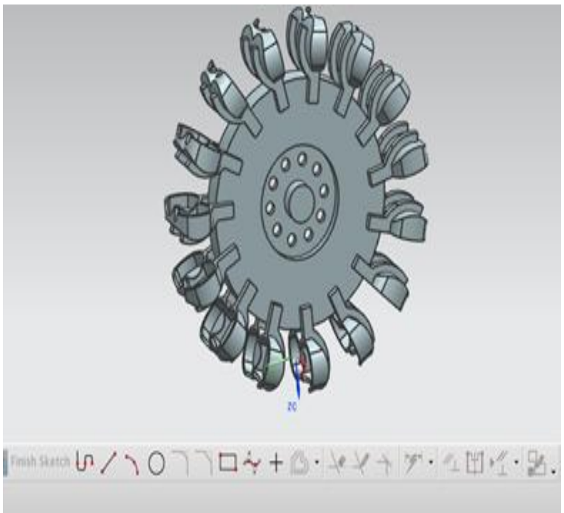

Fig 5 shows 3D model of 15 turbine bucket

III. CFD ANALYSIS

PROCEDURE FOR ANALYSIS PELTON WHEEL TURBINE WITH 8, 12 AND 15 BUCKETS

- Imported pelton wheel turbine in Ansys
- Creating water layer along pelton wheel
- Created mesh on pelton wheel turbine along with water boundary
- Created water inlet
- Created water outlet
- Created turbine wall
- Water inlet condition (density= 998.2 kg/m^3, cp (specific heat (j/kg-k)= 4182, thermal conductivity (w/m-k)= 0.6, viscosity (kg/m-s) =0.001003).
- Water inlet mass flow rate (mass flow rate kg/s=10), turbulence intensity (%)= 5, turbulence viscosity ratio= 10.

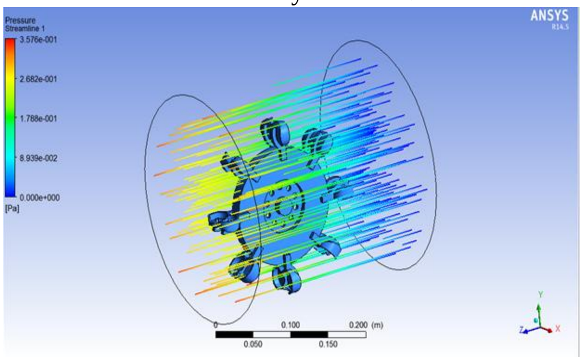

Fig 6 stream pressure for 8 buckets pelton turbine

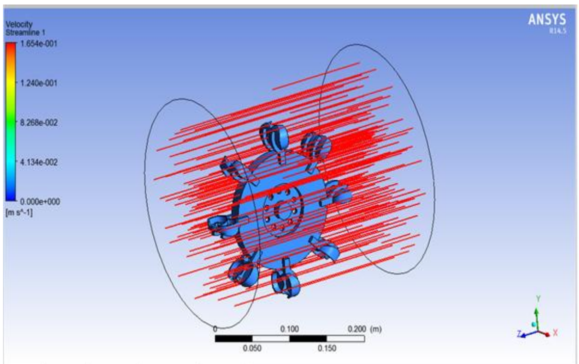

Fig 7 stream velocity for 8 buckets pelton turbine

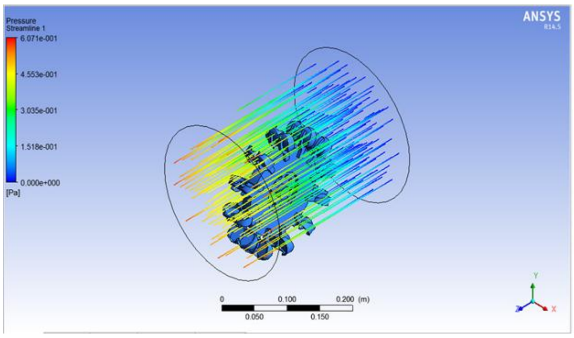

Fig 8 stream pressure for 12 buckets pelton turbine

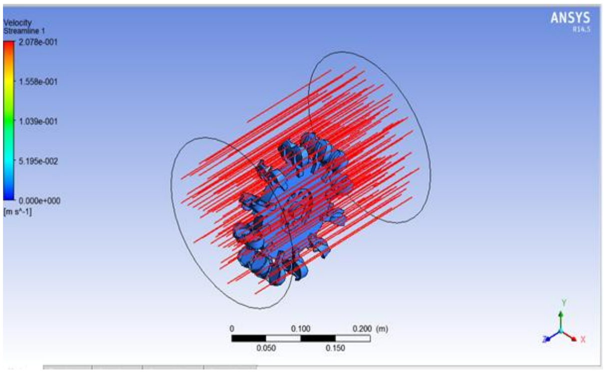

Fig 9 stream velocity for 12 buckets

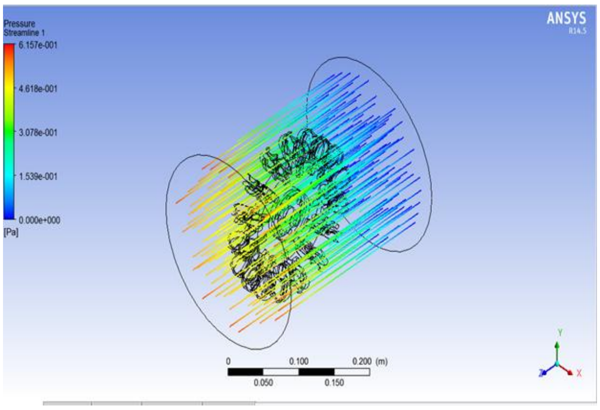

Fig 10 stream pressure for 15 buckets pelton turbine

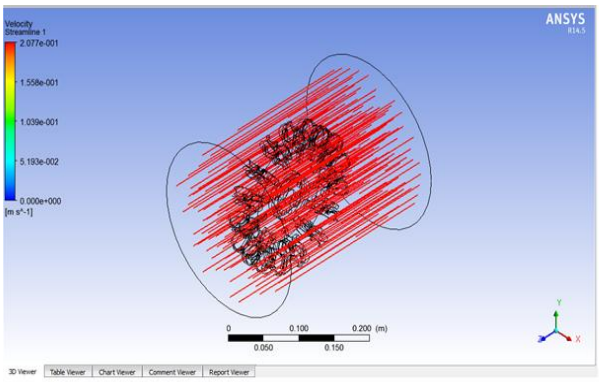

Fig 11 stream velocity for 15 buckets pelton turbine

From CFD analysis results, concluded that pelton wheel turbine with 15 buckets undergoes to high water pressure during working condition. It means that when fluid pressure is more, the turbine rotate with high velocity. This situation is goes to produce more electric power.Now the best material proposed for manufacturing of pelton wheel turbine by analysis process.

IV. MATH

1. Calculation of the net head (H):

$H = H_g - H_t$ m

Where, assume $H_g = 45$m

$H_t = 0.06 * H_g = 0.06*45 = 2.7$ m

$H = H_g - H_t = 45 - 2.7 = 42.3$ m

Net head (H) = 43m.

2. Calculation of the turbine speed (N) :

The turbine Speed Can be Calculated as:

$$N = N_s * \frac{H^{\frac{5}{4}}}{\sqrt{P}}$$

Where, assume N_s = 1900 rpm,

Power (P) = 45 kW

$$N = 1900 * \frac{43^{\frac{5}{4}}}{\sqrt{45000}}$$

N = 990 rpm

The Speed of the turbine = 990 rpm.

3. Calculation of the jet velocity (V_j) =

$V_j = 0.98* \sqrt{2 * g * H}$

Where g =9.8 m/sec

H = 43 m

$V_j = 0.98* \sqrt{2 * 9.81 * 43}$

V_j = 28.46 m/sec

The velocity of jet (V_j) = 28.46 m/sec

4. Calculation of the Bucket Speed (U_1) =

$U_1 = 0.46 * V_j$

Where V_j = 28.46 m/sec

$U_1 = 0.46 * 28.46$

U_1 = 13.09 m/sec

Calculation of drum diameter (Dr) =

$$U_1 = \frac{\pi * D_r * N}{60}$$

Where U_1 = 13.09 m/sec, N =990 rpm

$$13.09 = \frac{3.14 * D_r * 990}{60}$$

Dr = 0.252m

Diameter of drum = 0.252 m

6. Calculation of jet diameter (D_j) =

D_j = Dr /10

Where Dr =0.252 m

D_j = 0.252 /10 = 0.0252 m

Diameter of jet = 0.0252m

7. Calculation of area of jet or Nozzle (A_j) =

$$A_j = \frac{\pi}{4} D_j^{\,2}$$

Where D_j = 0.0252 m

$A_j = \frac{\pi}{4} * 0.0252^2$ = 0.4 $*10^{-3}$ m^2

Area of jet or Nozzle = 0.4 $*10^{-3}$ m^2

8. The water flow rate through each nozzle (Q_n) =

$Q_n = A_j * V_j$ m3/sec

$Q_n = 0.4 *10^{-3} * 28.46 = 0.011\ m^3/sec$

The water flow rate through each nozzle = 0.011 m^3/sec.

9. Calculations of force acting on the bucket due to impact of jet =

$F = \rho_w * Q_n * V_j$

Where Q_n = The water flow rate through each nozzle = 0.011 m^3/sec,

V_j = The velocity of jet = 28.46 m/sec,

ρ_w = density of water = 1000 kg/m^3

F = 1000* 0.011 * 28.46 = 313.06 N

Force acting on the bucket due to impact of jet = 313.06 N

V. STRUCTURAL ANALYSIS

Structural analysis comprises the set of physical legal guidelines and arithmetic required to observe and predicts the conduct of systems. The topics of structural evaluation are engineering artifacts whose credibility is judged in various applications depending upon their capability to withstand masses. Structural evaluation is the combination of both mechanics and dynamics in addition to the many failure theories. One main use of structural evaluation is the computation of deformations, internal forces, and stresses. Structural analysis is so important because it decides whether a design will withstand external and internal stresses acting on it.To perform an accurate analysis a structural engineer needs to decide such records as structural loads, geometry assist situations, and material homes. The outcomes of such assessment generally include manual reactions, stresses and displacements. This record is then in contrast to requirements that indicate the situations of failure. Superior structural assessment may additionally check dynamic reaction, stability and non- linear behavior.

A. *Structural analysis of pelton wheel turbine with 15 buckets using steel*

Material Properties of Stainless Steel Alloy material:

Density = 7850 Kg/m^3
Young's modulus = 200 GPa
Yield strength = 300 MPa
Poison's ratio = 0.3

Boundary conditions:

- A force of 313.06 N is applied on bucket of the pelton wheel.
- The centre of pelton is constrained in all dof.

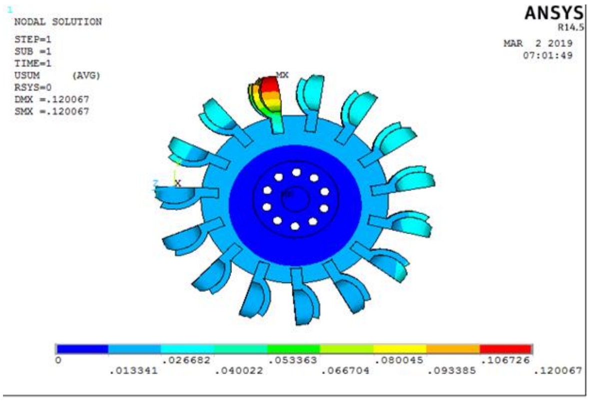

Fig 12 deformation results of pelton model

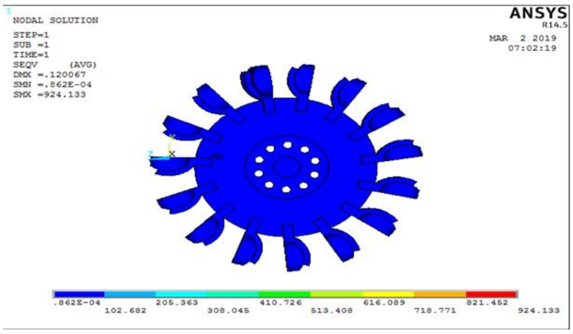

Fig 13 stress results of pelton model

B.STRUCTURAL ANALYSIS OF PELTON WHEEL TURBINE WITH 15 BUCKETS USING ALUMINIUM

Material Properties

1. Aluminum Alloy A413.0

Standard material properties of Aluminum Alloy are used for all the parts in the cylinder head.

Young's modulus = 71 GPa

Poisson's Ratio = 0.33

Density = 2660 Kg/m3

Yield Strength = 130 MPa

Boundary conditions:

- A force of 313.06 N is applied on bucket of the pelton wheel.
- The centre of pelton is constrained in all dof.

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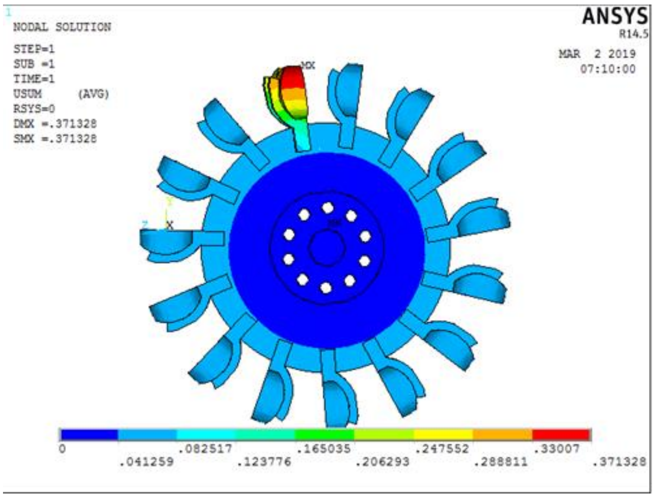

Fig 14 deformation results of pelton model

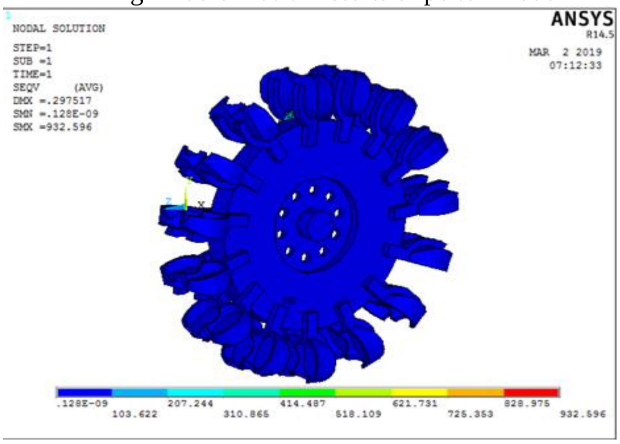

Fig 15 stress results of pelton model

C. STRUCTURAL ANALYSIS ON PELTON WHEEL TURBINE WITH 15 BUCKETS USING CAST IRON

Material Properties

1. Cast iron Alloy

Standard material properties of Cast iron Alloy are used for all the parts in the cylinder head.

Young's modulus = 150 GPa

Poisson's Ratio = 0.33

Density = 7810 Kg/m3

Boundary conditions:

- A force of 313.06 N is applied on bucket of the pelton wheel.
- The centre of pelton is constrained in all dof.

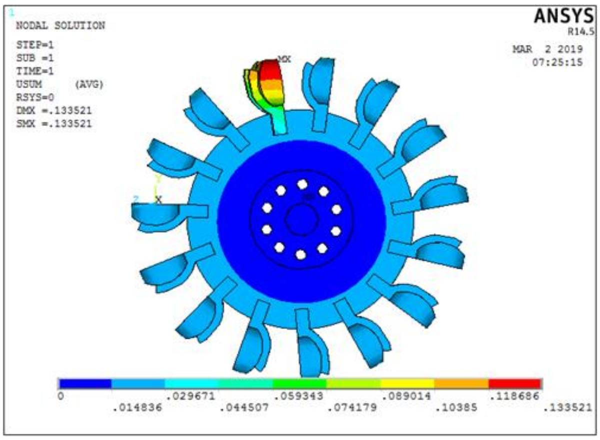

Fig 16 deformation results on pelton model

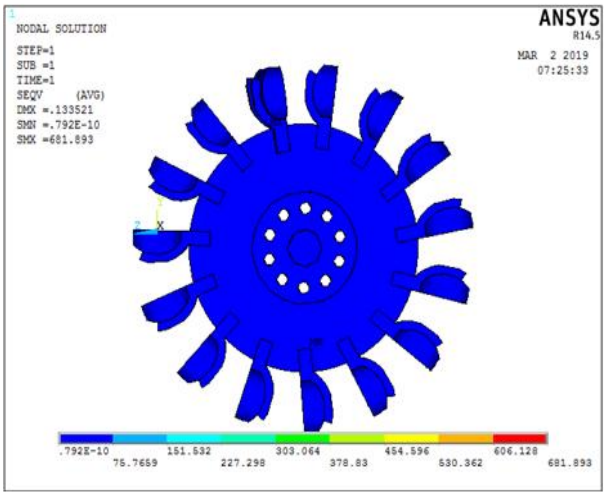

Fig 17 stress results on pelton model

VI. RESULTS AND CONCLUSIONS

Results of pelton wheel:

In this project, Pelton wheel is studied briefely under CFD and structural analysis. The following observations are observed from structural analysis.

There are Two different cases to study the Pelton wheel for structural behavior:

- CFD analysis
- Static analysis

From CFD analysis results

Pelton wheel turbine type	**Stream pressure values**
Pelton wheel turbine with 8 buckets	$3.57e^{-1}$
Pelton wheel turbine with 12 buckets	$6.07e^{-1}$
Pelton wheel turbine with 15 buckets	$6.157e^{-1}$

Table 1 CFD analysis results

From CFD analysis results, concluded that pelton wheel turbine with 15 buckets undergoes to high water pressure during working condition. It means that when fluid pressure is more, the turbine rotate with high velocity. This situation is goes to produce more electric power.

From structural analysis results

15 bucket pelton wheel turbine material types	Stress value (Mpa)
Using stainless steel	924.13
using aluminum	932.69
Using cast iron	681.89

Table 2 structural analysis results

From structural analysis results, Pelton wheel turbine with 15 buckets using Cast iron material released less stress compared with remaining. So finally concluded that Pelton wheel turbine with 15 buckets using Cast iron material is a best one.

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