Design and Analysis of Pelton Wheel Bucket

M Hema Sundara Rao
Department of Mechanical Engineering,
SISTAM Engineering College,
Ampolu, A.P - 532401, India.

P. Dilip Kumar
Department of Mechanical Engineering,
SISTAM Engineering College,
Ampolu, A.P - 532401, India.

ABSTRACT

Pelton turbines are hydraulic turbines which are widely used for large scale power generation. A micro hydel pelton turbine is miniature model of actual pelton turbine which can be used for small scale power generation. This type of turbines converts potential energy of water at height into kinetic energy by allowing the water to fall freely on the pelton runner. This water impact provides necessary torque required for the rotation the runner by overcoming its inertia forces. The rotation of runner develops a mechanical energy which is coupled to the alternator which converts it into electrical energy. The project shows the analysis of the Pelton wheel bucket modelled using CATIA V5 software. The material used in the manufacture of pelton wheel buckets is studied in detail and these properties are used for analysis. The bucket is analyzed using ANSYS Workbench 15.0 .The bucket geometry is analyzed by considering the force and also by considering the pressure exerted on different points of the bucket. Structural analysis was carried out with two different meshes and also six different materials such as Grey Cast Iron; E-glass Fibre; AISI 1018 Steel; CA6nm Steel; Al Alloy; Ti6Al . The best combination of parameters like Von misses Stress and Equivalent shear stress, Deformation, shear stress and weight reduction for turbine bucket were done in ANSYS software. Grey cast iron has more factor of safety, reduce the weight, increase the stiffness and reduce the stress and stiffer than other material. With this analysis we can determine the lifetime and the strength of pelton turbine.

Key words: Pelton turbine, power generation, bucket, stiffer, strength.

1. INTRODUCTION

The Pelton wheel is an impulse type water turbine. It was invented by Lester Allan Pelton in the 1870s. The Pelton wheel extracts energy from the impulse of moving water, as opposed to water's dead weight like the traditional overshot water wheel. Many variations of impulse turbines existed prior to Pelton's design, but they were less efficient than Pelton's design. Water leaving those wheels typically still had high speed, carrying away much of the dynamic energy brought to the wheels. Pelton's paddle geometry was designed so that when the rim ran at half 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.

1.1 Points to remember for Pelton Turbine:

(i) The velocity of the jet at inlet is given by

$$V_1 = C_v \sqrt{2gH}$$

Fig 1.1 Pelton wheel impulse type water turbine

Where = co-efficient of velocity =0.98 or 0.99.
H= Net head on turbine

(ii) The velocity of when (u) is given by

$$u = \phi \sqrt{2gH}$$

Where = speed ratio. The value of speed ratio varies from 0.43 to 0.48

(iii) The angle of deflection of the jet through the buckets is taken at 165o if no angle of deflection is given.

(iv) The mean diameter or the pitch diameter D of the pelton turbine is given by

$$u = \frac{\pi DN}{60} .or. D = \frac{60u}{\pi N}$$

(v) Jet Ratio: it is defined as the ratio of the pitch diameter (D) of the pelton turbine to the diameter of the jet (d). It is denoted by m and is given as m = D/d (=12 for most cases).

(vi) Number of bucket on a runner is given by

$$Z = 15 + \frac{D}{2d} = 15 + 0.5m$$

Where m = jet ratio

(vii) Number of jets: it is obtained by dividing total rate of flow through the turbine by the rate of flow of water through a single jet.
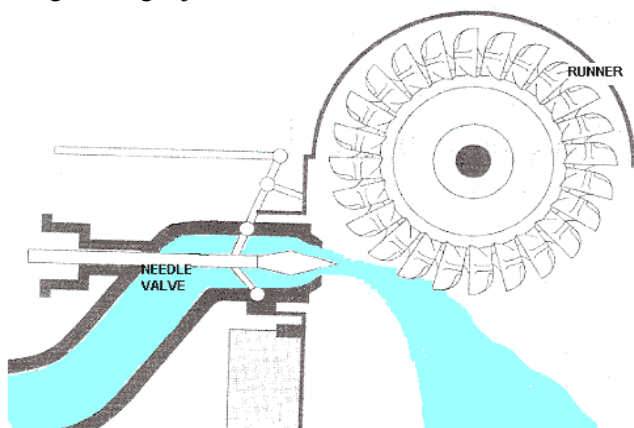

Fig 1.2 Construction of pelton turbine

2. Literature Survey

In his paper they analyzed analysis of the Pelton wheel bucket modelled using CATIA V5 software. [1]

In their research paper they present the results of investigations conducted on the free surface flow in a Pelton turbine model bucket Unsteady numerical simulations, based on the two-phase homogeneous model, are performed together with wall pressure measurements and flow visualizations. [2]

In their research they had employed numerical simulations (CFD methods) for estimating the flow loss coefficient in manifolds. [3]

In their research paper they have developed a multi-objective optimization method for the exhaust manifold by using Divided Range Multi objective Genetic Algorithm. [4]

In their research paper they used GT-Power, 1-dimensional software, for estimating the engine performance of a single cylinder IC engine. The power output predicted from the software was compared against the experimental data. [5]

In their —Designing Exhaust Manifolds Using Integral Engineering Solutions focused on the development of a reliable approach to predict failure of exhaust manifolds and on the removal of structural weaknesses through the optimization of design. [6]

In their paper they had performed CFD analysis to estimate the performance of the exhaust manifold while placing the catalytic converter near to it (Close-Coupled Catalytic Converter). [7]

In this research paper he conducted CFD simulations on manifold of direct injection diesel engine. [8]

In his research paper they had applied CFD methods to identify the optimum exhaust manifold for a 4-stroke 4-cylinder SI engine. [9]

In this paper they had developed an exhaust system heat transfer model that included the steady state and transient heat conduction as well as convection and radiation. [10]

In their research paper they have discussed the impact of temperature effect on exhaust manifold modal analysis by mapping temperature field from the CFD software and then heat conduction process is analyzed in FEM software with the temperature field boundary conditions.[11]

He has analyzed the exhaust manifold in order to reduce the backpressure and also to increase the particulate matter filtration. [12]

3. METHOLDOLOGIES

CATIA (Computer Aided Three-dimensional Interactive Application)is a multi-platform CAD/CAM/CAE commercial software suite developed by the French company Assault Systems. Written in the C++ programming language, CATIA is the cornerstone of the Assault Systems product lifecycle management software suite.
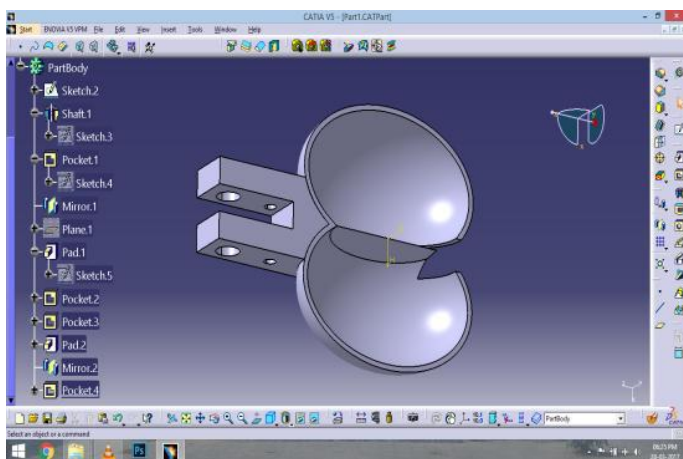
Fig 3.1 CATIA model of notable industries

4. INTRODUCTON OF ANSYS WORKBENCH

The ANSYS Workbench represents more than a general purpose engineering tool. It provides a highly integrated engineering simulation platform. Supports multi-physics engineering solutions. Provides bi-directional parametric

associatively with most available CAD systems. ANSYS represents an application that Provides access to a range of ANSYS Engineering Simulation solutions.
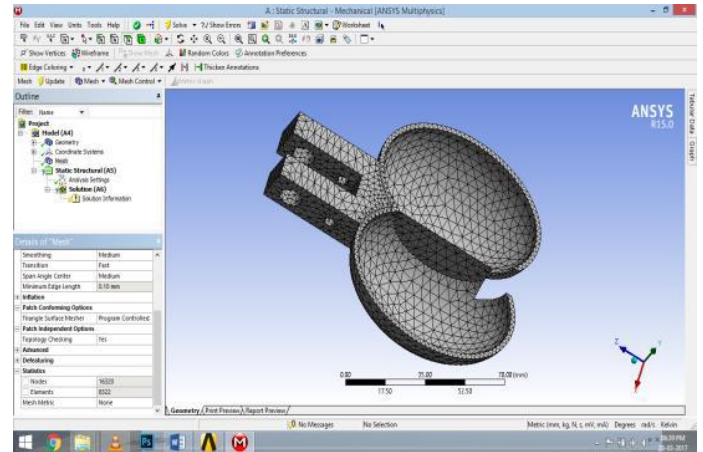

Fig 4.1Fine Mesh of Turbine Blade

5. RESULTS AND DISCUSSIONS

Here in this investigation structural analysis of pelton wheel's bucket is carried out by varying meshes and keeping remaining parameters same. In this research pelton wheel's bucket undergo Coarse and Fine mesh in order to get results. For every mesh 6 different types of materials were considered and their material properties were clearly shown in before chapter.

Even though the materials used for analysis are same due to variation in meshing the results varied and clearly shown in the results and in figures. Materials used to perform analysis were Grey Cast Iron; E-glass Fiber; AISI 1018 Steel; CA6nm Steel; Al Alloy; Ti6Al.
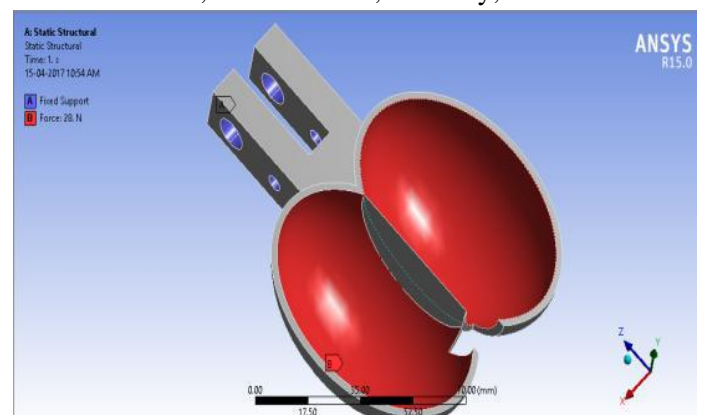

Figure 5.1 Pelton Wheel's Bucket Showing Fixed Supports

Case -1: Structural Analysis on Pelton Wheel's Bucket with Various Materials using Coarse Mesh
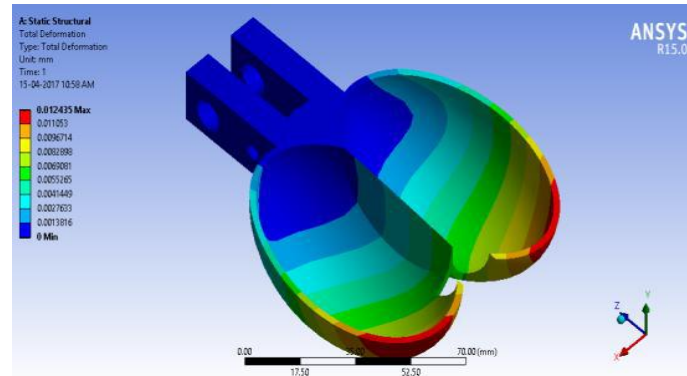## Material: Grey Cast Iron

Figure 5.2 Total deformations in Grey Cast Iron Bucket

The maximum deformation got during the analysis in the pelton wheel's bucket is 0.0124mm and a minimum deformation of about 0.0013mm.
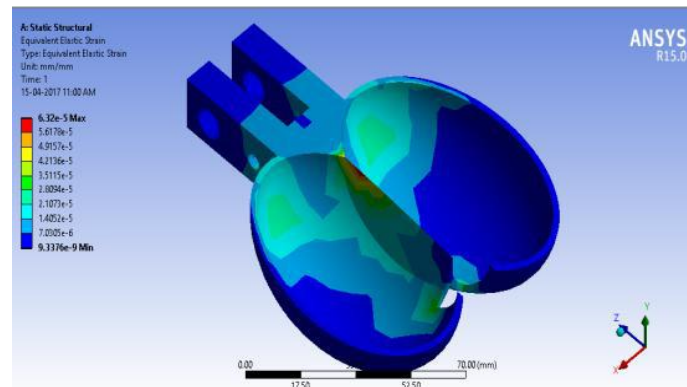

Figure 5.3 Equivalent Elastic Strain in bucket

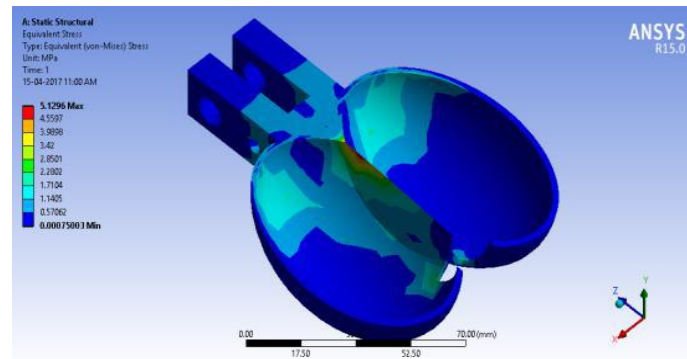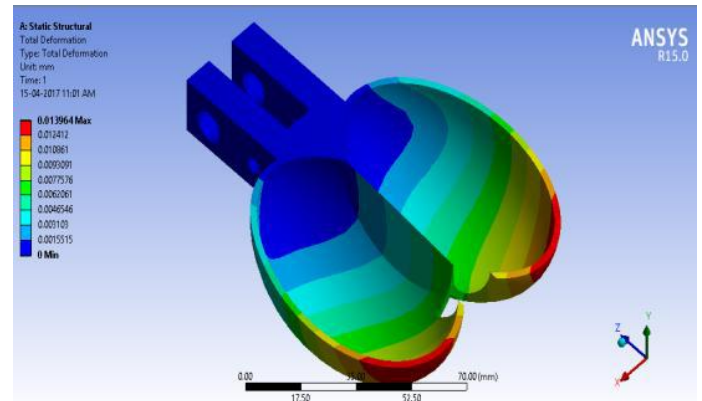Here in this analysis too coarse mesh is used and got strain about maximum value of 6.32 e^-5 and minimum of about 9.337 e^-9.

Figure 5.4 Equivalent Von-Mises stress in bucket

Maximum stress of about 5.126 MPa and a minimum of 0.00075 MPa.
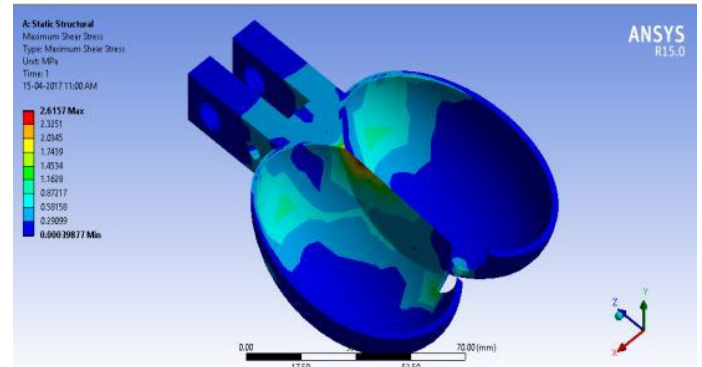
Figure 5.5 Maximum shear stress

maximum shear stress of about 2.615 MPa and a minimum of 0.000398 MPa.

Material: E-Glass Fibre

Figure 5.6 Total Deformation in E-Glass Bucket

The maximum deformation got during the analysis in the pelton wheel's bucket is 0.0139 mm and a minimum deformation of about 0 mm
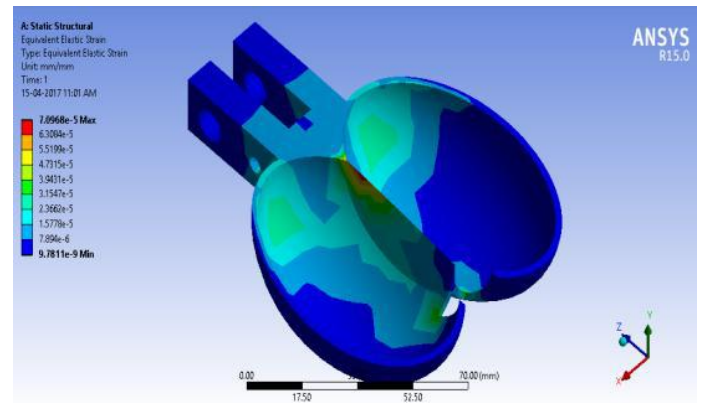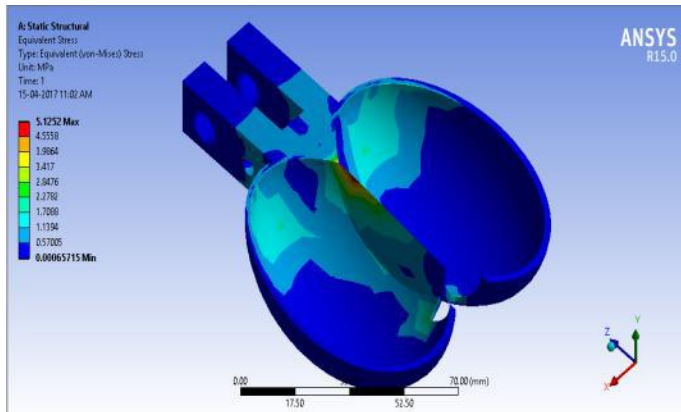

Figure 5.7 Equivalent Elastic Strain

Maximum value of 7.09 e^-5 and minimum of about 9.7811 e^-9.

Figure 5.8 Equivalent von-mises stress

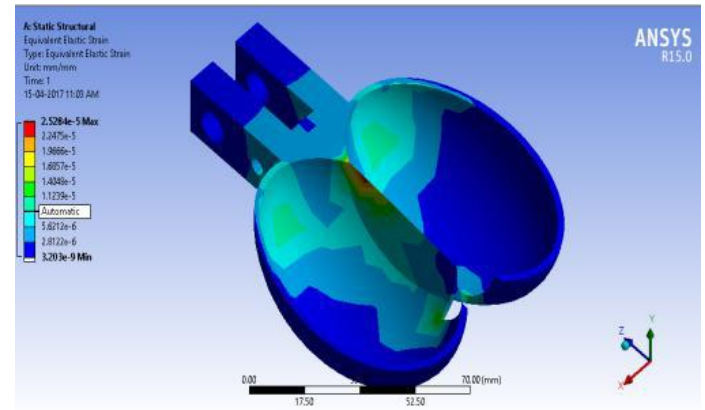Maximum stress of about 5.126 MPa and a minimum of 0.00065 MPa.

Figure 5.9 Maximum shear stress

maximum shear stress of about 2.613 MPa and a minimum of 0.000359 MPa

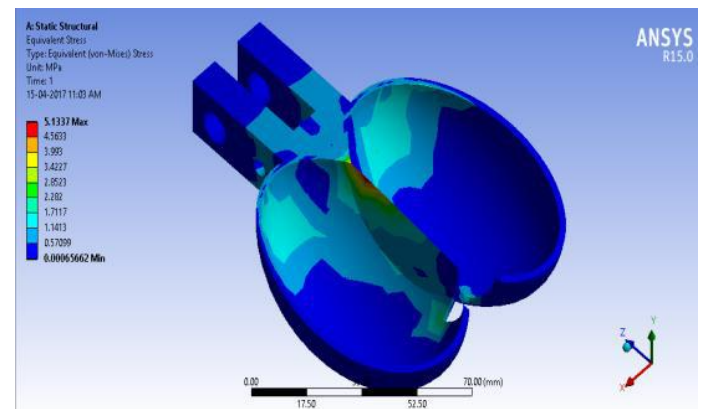**Material: AISI 1018 Steel**
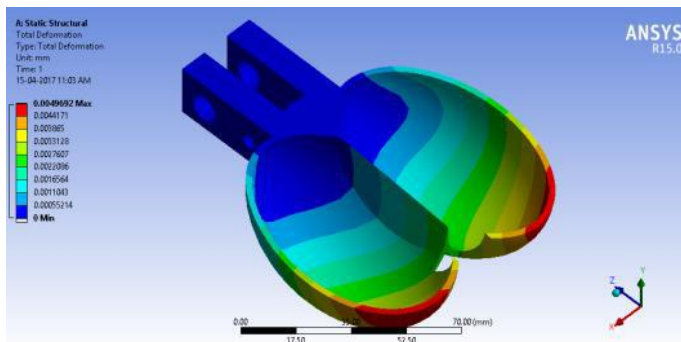
Figure 5.10 Total deformation in AISI 1018 Steel Bucket

The maximum deformation got during the analysis in the pelton wheel's bucket is 0.00496 mm and a minimum deformation of about 0 mm.

Figure 5.11 Equivalent elastic strain

maximum value of 2.528 e^-5 and minimum of about 3.203 e^-9.

Figure 5.12 Equivalent von-mises stress

maximum stress of about 5.133 MPa and a minimum of 0.00065 MPa

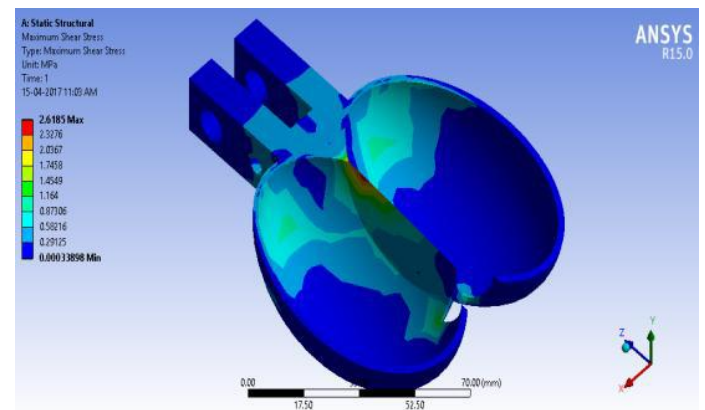**Figure 5.13 Maximum shear stress**

Material: CA6NM Steel
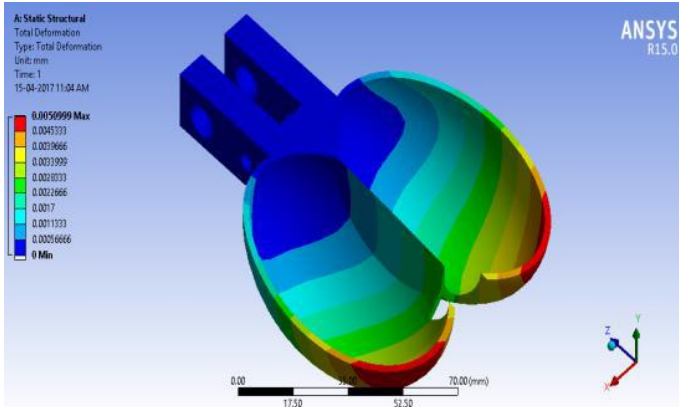
Figure 5.14 Total deformation of CA6NM Steel bucket

Figure 5.15 Equivalent elastic strain

maximum value of 2.59 e^-5 and minimum of about 3.72 e^-9.

Figure 5.16 Equivalent von-mises stress

Figure 5.17 Maximum shear stress

Maximum shear stress of about 2.615 MPa and a minimum of 0.00038 MPa

Material:AL Alloy

Figure 5.18 Total deformation in Al Alloy bucket
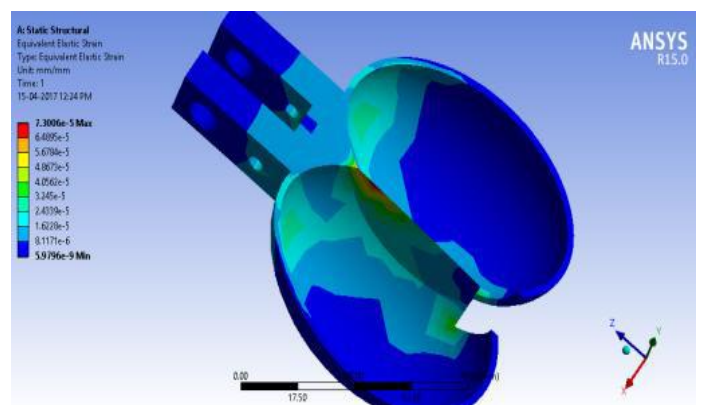

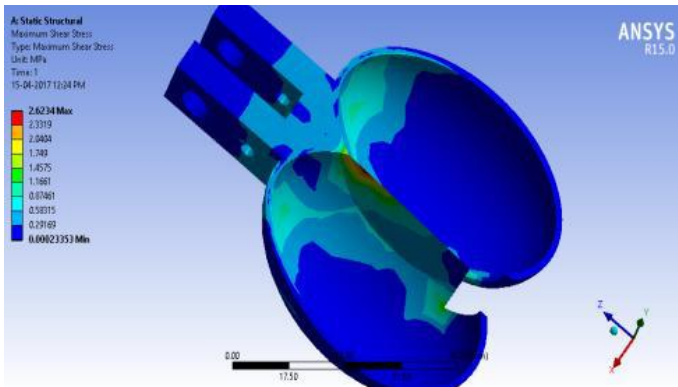**Figure 5.19 Equivalent elastic strain**

Figure 5.20 Maximum shear stress

6. CONCLUSION

Pelton turbines are hydraulic turbines which are widely used for large scale power generation. In this thesis we performed the investigation on structural analysis of pelton wheel bucket is carried out by varying meshes and keeping remaining parameters constant. In this research pelton wheel's bucket undergo Coarse and Fine mesh in order to get results.

For every mesh 6 different types of materials were considered and the outputs total deformation, Equivalent Elastic Strain in bucket, Equivalent Von-Misses stress and Maximum shear stress are calculated.

Even though the materials used for analysis are same due to variation in meshing the results varied. Materials used to perform analysis were Grey Cast Iron; E-glass Fiber; AISI 1018 Steel; CA6nm Steel; Al Alloy; Ti6Al. Among the above materials E-glass Fiber have the best performance with fine mesh than other materials.

7. References

[1] Nikhil Jacob George, SebinSabu, Kevin Raju Joseph, ―Static Analysis On Pelton Wheel Bucket‖,International Journal of Engineering Research & Technology (IJERT)IJERTIJERT,ISSN: 2278-0181, Vol. 3 Issue 3, March – 2014.

[2] AlexandrePerrig, François Avellan,Jean-Louis Kueny,MohamedFarhat, ―Flow in a Pelton Turbine Bucket Numerical and Experimental Investigations‖, 350 / Vol. 128, MARCH 2006 , Transactions of the ASME.

[3]MohdSajid Ahmed, Kailash B A, Gowreesh, ―DESIGN AND ANALYSIS OF A MULTICYLINDER FOUR STROKE SI ENGINE EXHAUST MANIFOLD USING CFD TECHNIQUE‖, International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056.

[4]Kanupriya Bajpai, Akash Chandrakar, Akshay Agrawal, Shiena Shekhar, ―CFD Analysis of Exhaust Manifold of SI Engine and Comparison of Back Pressure using Alternative Fuels‖, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE),Volume 14, Issue1Ver. I (Jan.-Feb. 2017).

[5]K. Nanthagopal, B. Ashok,R. ThundilKaruppa Raj, ―Design considerations and overview of an engine exhaust manifold gasket‖, Journal of Chemical and Pharmaceutical SciencesISSN: 0974-2115.

[6]VivekanandNavadagi, SiddaveerSangamad, ―CFD Analysis of Exhaust Manifold of Multi- Cylinder Petrol Engine for Optimal Geometry to Reduce Back Pressure‖, International Journal of Engineering Research & Technology Vol. 3 - Issue 3 (March - 2014).

[7] K.S.Umesh ,V.K. Pravin and K. Rajagopal , ―Experimental Investigation of Various Exhaust Manifold Designs and Comparison of Engine Performance Parameters for These to DetermineOptimal Exhaust Manifold Design for Various Applications‖, Proc. of Int. Conf. on Advances in Mechanical Engineering, AETAME

[8] gopaal, m mm kumara varma, dr. L suresh kumar, ―thermal and structural analysis of an exhaust manifold of a multi cylinder engine‖, international journal of mechanical engineering andtechnology (ijmet)issn 0976 – 6340.

[9] k. S. Umesh, v. K. Pravin& k. Rajagopal, ―cfd analysis of exhaust manifold of multi-cylinder si engine todetermine optimal geometry for reducing emissions,international journal of automobile engineering issn 2277-4785vol. 3, issue 4, oct 2013, 45-56.

[10] Jae Ung Cho, ―A Study on Flow Analysis of theExhaust Manifold for Automobile‖, International Journal ofApplied Engineering Research ISSN 0973-4562 Volume 11, Number 2(2016).

[11] MarupillaAkhilTeja, KatariAyyappa, Sunny Katam and PangaAnusha, **"**Analysis of Exhaust Manifold using Computational Fluid Dynamics**",** July 28, 2016.