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Design and Analysis of Pelton Wheel Bucket

K.Chandra Sekhar
Department of Mechanical Engineering,
SISTAM College, JNTUK, India.

P.Venu Babu
Department of Mechanical Engineering,
SISTAM College, JNTUK, India.

ABSTRACT

Pelton turbines are hydraulic turbines which are widely used for large scale power generation. A micro hydelpelton 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 Fiber; 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.

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.

Fig 1.1 Pelton wheel impulse type water turbine

1.1Points to remember for Pelton Turbine:

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

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

Where C_v = 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 ϕ = 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 165° if no angle of deflection is given.

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

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

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(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.

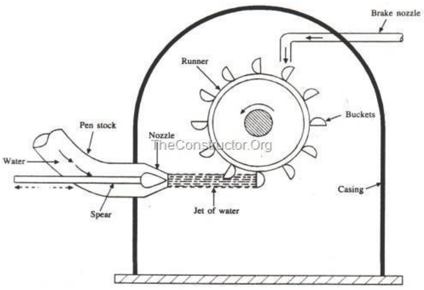

Fig 1.2 Construction of pelton turbine

2. Literature Survey

Nikhil Jacob George et.al. [1]In his paper they analyzed analysis ofthePelton wheel bucket modelled using CATIA V5 software.

AlexandrePerrig et.al. [2] In their research paper theypresent the results of investigations conducted on the freesurface flow in a Pelton turbine model bucket. Unsteady numerical simulations, based onthe two-phase homogeneous model, are performed together with wall pressure measurementsand flow visualizations.

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

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

Hong Han-Chi et.al. [5] 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.

TanerGocmez et.al.[6] 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.

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

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

MohdSajid Ahmed et.al. [9] In his research paper theyhad applied CFD methods to identify the optimum exhaust manifold for a 4-stroke 4-cylinder SI engine.

I.P. Kandylas et.al. [10] In this paper theyhad developed an exhaust system heat transfer model that included the steady state and transient heat conduction as well as convection and radiation.

Bin Zou et al. [11] 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.

P.L.S.Muthaiah et.al. [12] He has analyzed the exhaust manifold in order to reduce the backpressure and also to increase the particulate matter filtration.

K.S. Umesh et.al. [13] In their research paper they worked on eight different models of exhaust manifold were designed and analyzed to improve the fuel efficiency by lowering the backpressure and also by changing the position of the outlet of the exhaust manifold and varying the bend length.

Vivekananda Navadagi et.al. [14] In their research paper they analyzed the flow of exhaust gas from two different modified exhaust manifold with the help of Computational fluid dynamics.

Kulalet.al. [15]In their research work they comprehensively analyzes eight different models of exhaust manifold and concluded the best possible design for least fuel consumption.

Simon Martinez-Martinezet.al. [16] 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).

Gopaal et.al [17] in his paper he note that the exhaust pulse, created due to the release of high pressure exhaust gas from the cylinder to the exhaust manifold, would have three pressure heads – high, medium and low.

K.H. Park et.al. [18] in their paper"Modeling and Design of Exhaust Manifold Under Thermo mechanical Loading ", had proposed a thermal stress index (TSI) for designing the exhaust manifold.

J.DavidRathnaraj et.al [19] in his work "Thermo mechanical fatigue analysis of stainless steel exhaust manifolds" had proposed a model based on Isothermal data.

S.N.Ch.Dattu.Vet.al. [20] In his paper heperformed thermal analysis for the tubular type ICEngine exhaust manifold for various operating conditions.

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.

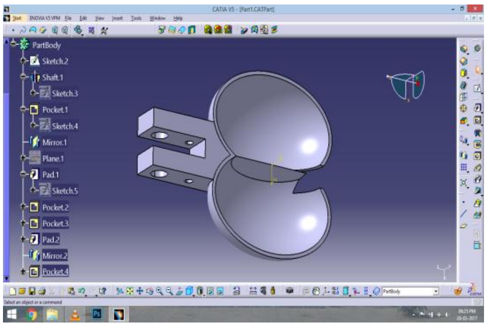

Fig 3.1 CATIA model of notable industries

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.

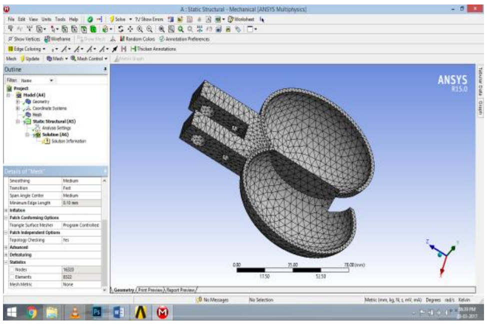

Fig 4.1Fine Mesh of Turbine Blade

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

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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

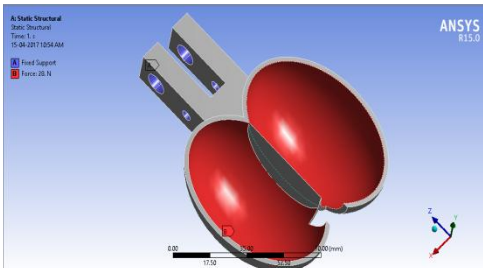

Figure 5.1 Pelton Wheel's Bucket Showing Fixed Supports

Case -1: Structural Analysis on Pelton Wheel's Bucket with Various Materials using Coarse Mesh

Material: Grey Cast Iron

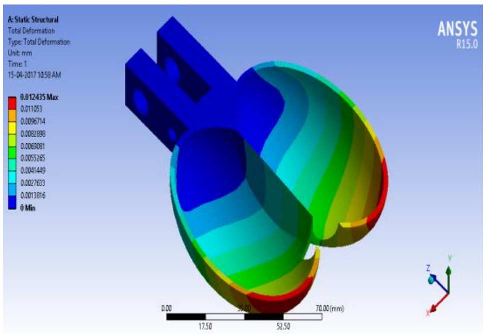

Figure 5.2 Total deformations in Grey Cast Iron Bucket

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

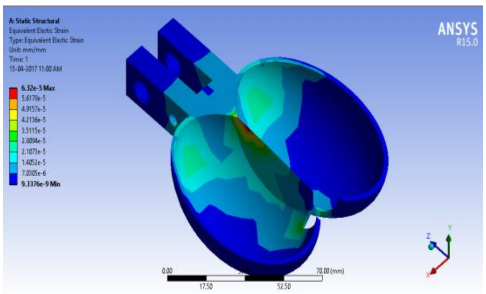

Figure 5.3 Equivalent Elastic Strain in bucket

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.

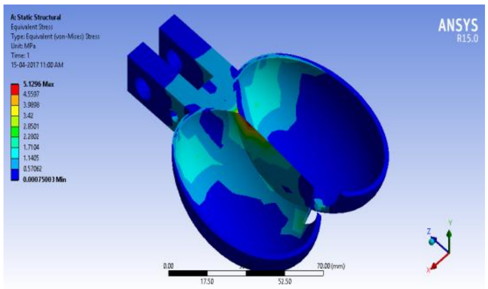

Figure 5.4 Equivalent Von-Mises stress in bucket

maximum stress of about 5.126 MPa and a minimum of 0.00075 MPa

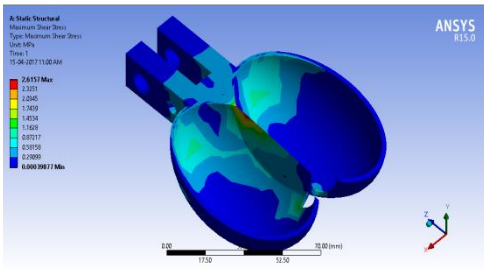

Figure 5.5 Maximum shear stress

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

Material: E-Glass Fiber

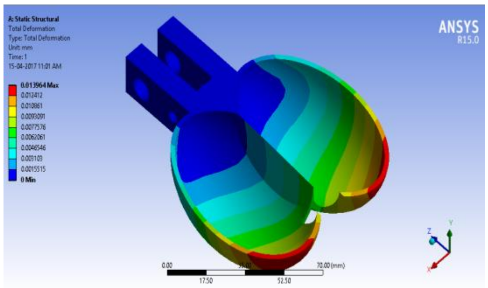

Figure 5.6 Total Deformation in E-Glass Bucket

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

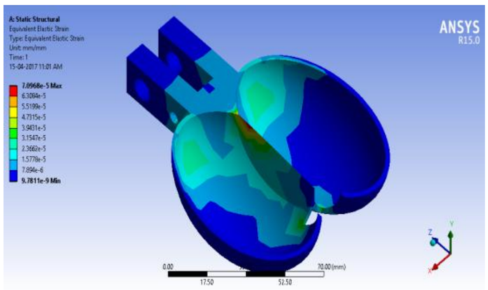

Figure 5.7 Equivalent Elastic Strain

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

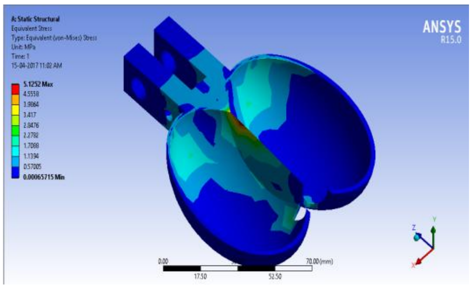

Figure 5.8 Equivalent von-mises stress

maximum stress of about 5.126 MPa and a minimum of 0.00065 MPa

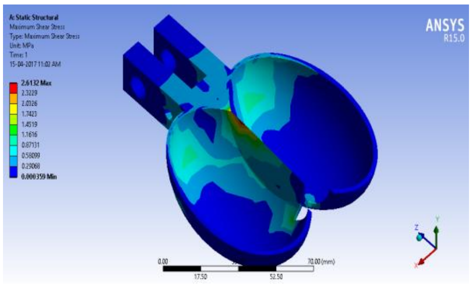

Figure 5.9 Maximum shear stress

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

Material:AISI 1018 Steel

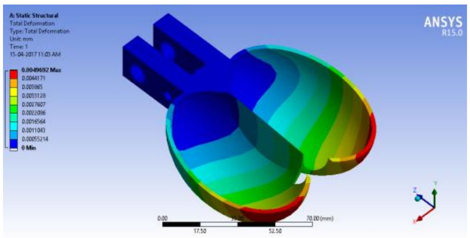

Figure 5.10 Total deformation in AISI 1018 Steel Bucket

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

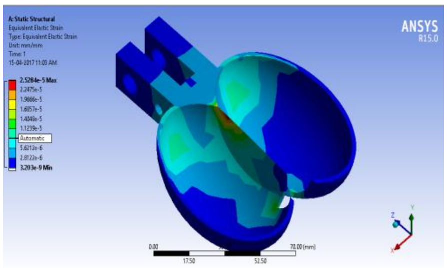

Figure 5.11 Equivalent elastic strain

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

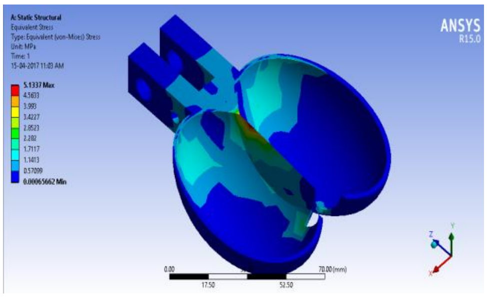

Figure 5.12 Equivalent von-mises stress

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

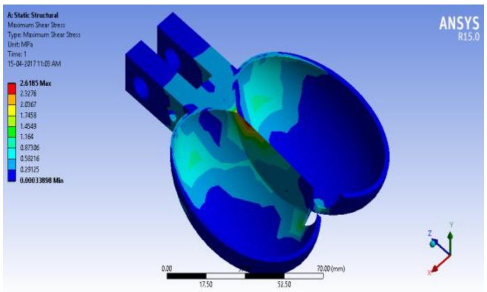

Figure 5.13 Maximum shear stress

Material:CA6NM Steel

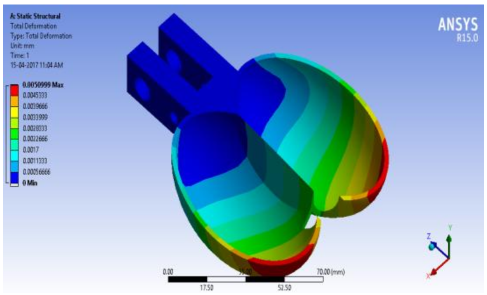

Figure 5.14 Total deformation of CA^NM Steel bucket

The maximum deformation got during the analysis in the pelton wheel’s bucket is 0.005099 mm and a minimum deformation of about 0 mm

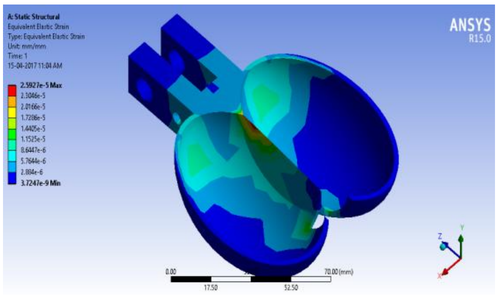

Figure 5.15 Equivalent elastic strain

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

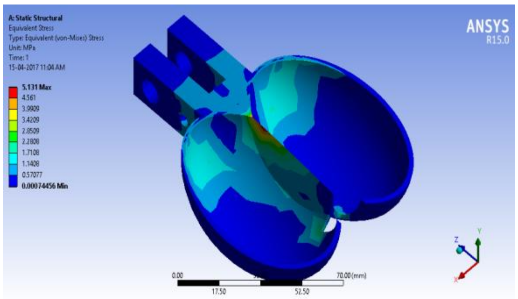

Figure 5.16 Equivalent von-mises stress

maximum stress of about 5.131 MPa and a minimum of 0.00074 MPa

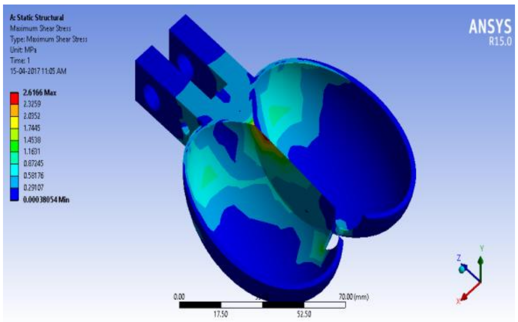

Figure 5.17 Maximum shear stress

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

Material:AL Alloy

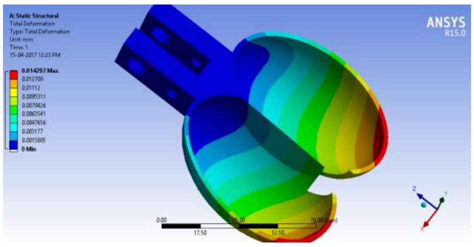

Figure 5.18 Total deformation in Al Alloy bucket

The maximum deformation got during the analysis in the pelton wheel's bucket is 0.0142 mm and a minimum deformation of about 0 mm

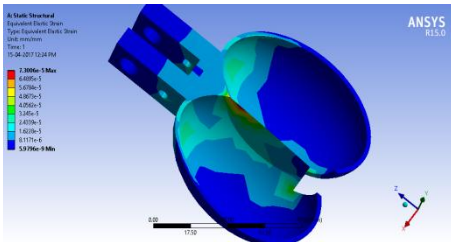

Figure 5.19 Equivalent elastic strain

maximum value of 6.32 e^-5 and minimum of about 9.337 e^-9.

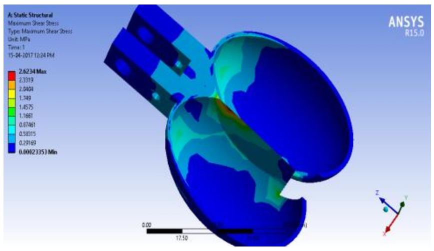

Figure 5.20 Maximum shear stress

maximum shear stress of about 2.62 MPa and a minimum of 0.00023 MPa

Material:TI6AL

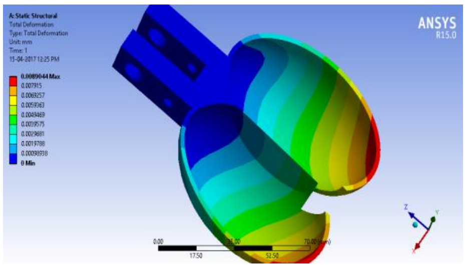

Figure 5.21 Total deformation in TI6Al bucket

The maximum deformation got during the analysis in the pelton wheel's bucket is 0.00890 mm and a minimum deformation of about 0 mm

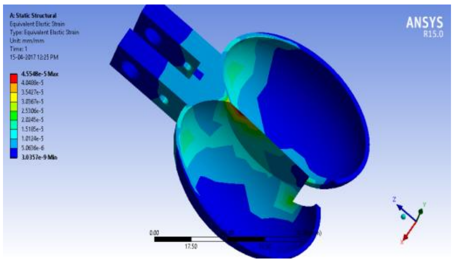

Figure 5.22 Equivalent elastic strain

maximum value of 4.554 e^-5 and minimum of about 3.035 e^-9.

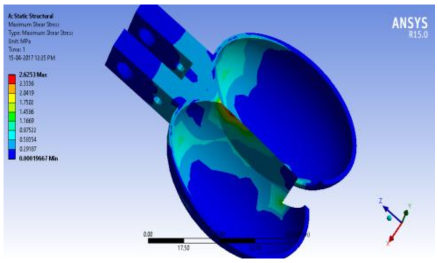

Figure 5.23 Maximum shear stress

maximum shear stress of about 2.62 MPa and a minimum of 0.000198 MPa

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Case -2: Structural Analysis on Pelton Wheel's Bucket with Various Materials using Fine Mesh

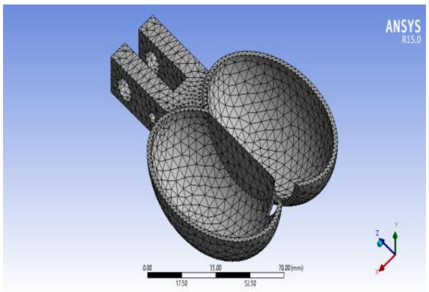

Figure 5.24 Fine meshed model of Pelton Wheel bucket

Material: Grey Cast Iron

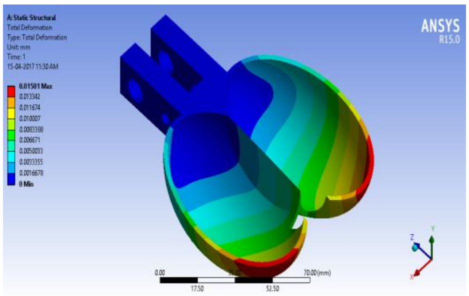

Figure 5.25 Total deformation in Grey Cast Iron bucket

The maximum deformation got during the analysis in the pelton wheel's bucket is 0.0150 mm and a minimum deformation of about 0 mm

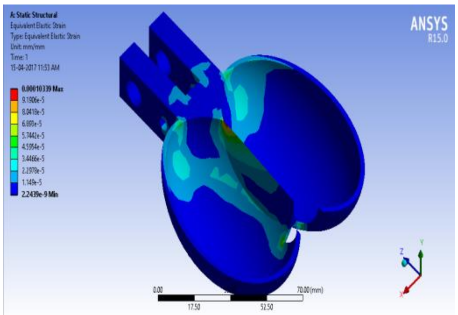

Figure 5.26 Equivalent elastic strain

maximum value of 0.000103 and minimum of about 2.243 e^-9.

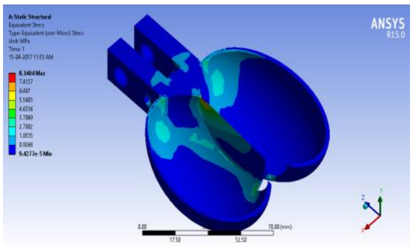

Figure 5.27 Equivalent von-mises stress

maximum stress of about 8.34 MPa and a minimum of 9.427 e^-5 MPa

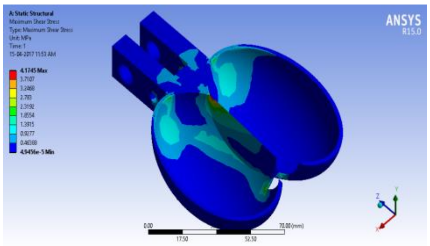

Figure 5.28 Maximum shear stress

maximum shear stress of about 4.17 MPa and a minimum of 4.9456 e^-5 MPa

Material: E-Glass Fiber

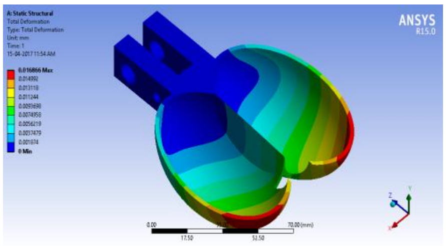

Figure 5.29 Total deformation in E-Glass bucket

The maximum deformation got during the analysis in the pelton wheel's bucket is 0.0168 mm and a minimum deformation of about 0 mm

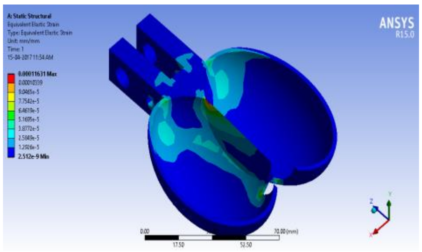

Figure 5.30 Equivalent elastic strain

maximum value of 0.000161 and minimum of about 2.51 e^-9.

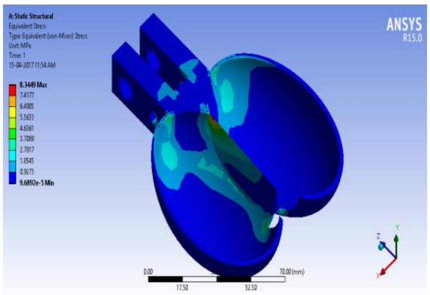

Figure 5.31 Equivalent von-mises stress

maximum stress of about 8.344 MPa and a minimum of 9.68 e^-5 MPa

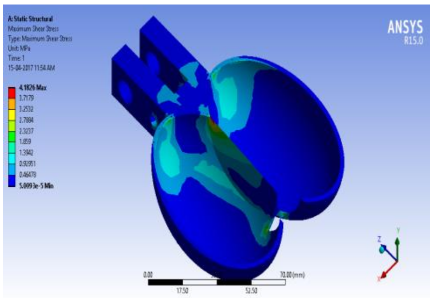

Figure 5.32 Maximum shear stress

maximum shear stress of about 4.18 MPa and a minimum of 5.0093 e^-5 MPa

Material:AISI1018

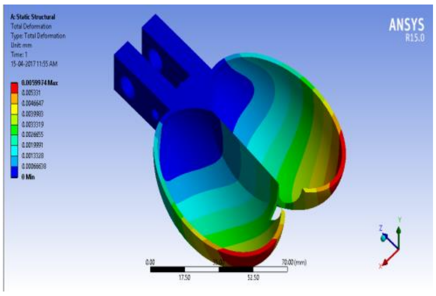

Figure 5.33 Total deformation in AISI 1018 bucket

The maximum deformation got during the analysis in the pelton wheel's bucket is 0.00599 mm and a minimum deformation of about 0 mm

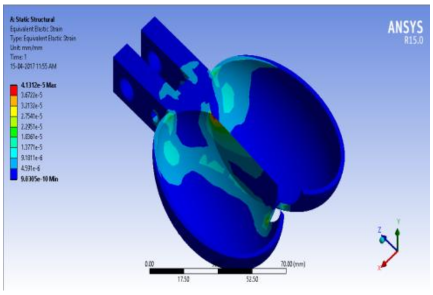

Figure 5.34 Equivalent elastic strain

maximum value of 4.131 e^-5 and minimum of about 9.03 e^-9.

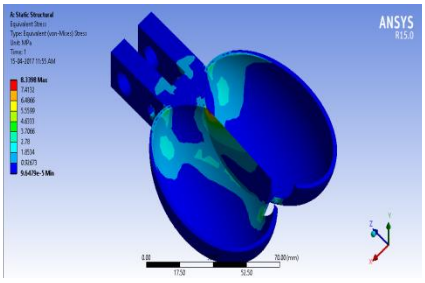

Figure 5.35 Equivalent von-mises stress

maximum stress of about 8.339 MPa and a minimum of 9.64 e^-5 MPa

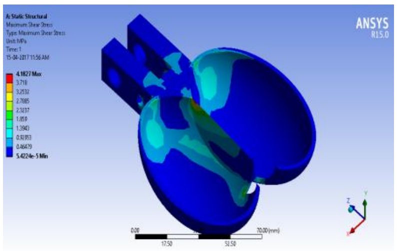

Figure 5.36 Maximum shear stress

maximum shear stress of about 4.18 MPa and a minimum of 5.42 e^-5 MPa

Material:CA6NM

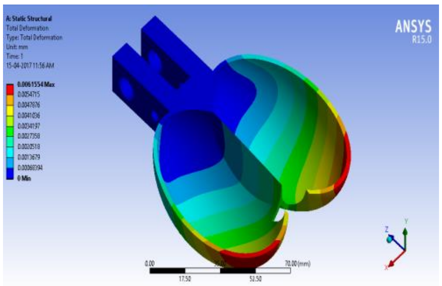

Figure 5.37 Total deformation in CA6NM bucket

The maximum deformation got during the analysis in the pelton wheel's bucket is 0.0061 mm and a minimum deformation of about 0mm.

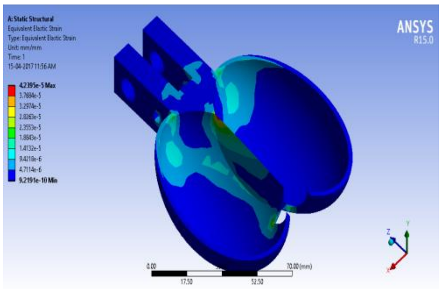

Figure 5.38 Equivalent elastic strain

maximum value of 4.23 e^-5 and minimum of about 9.21 e^-10.

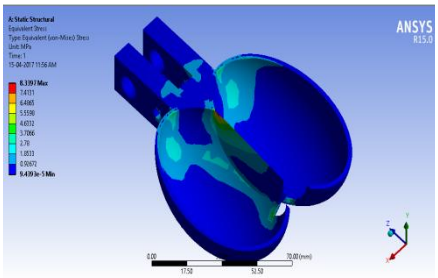

Figure 5.39 Equivalent von-mises stress

maximum stress of about 8.33 MPa and a minimum of 9.43 e^-5 MPa

Material:TI6AL

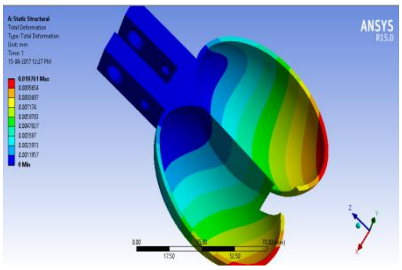

Figure 5.40 Total deformation in TI6Al bucket

The maximum deformation got during the analysis in the pelton wheel's bucket is 0.0107mm and a minimum deformation of about 0 mm.

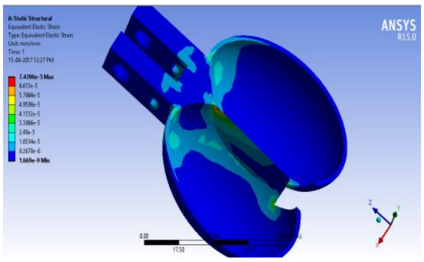

Figure 5.41 Equivalent elastic strain

maximum value of 7.43 e^-5 and minimum of about 1.669 e^-9.

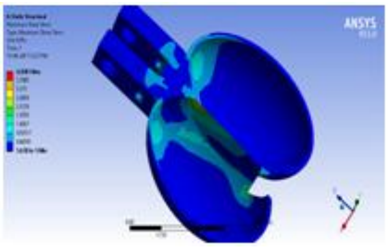

Figure 5.42 Maximum shear stress

maximum shear stress of about 4.2081 MPa and a minimum of 5.67 e^-5 MPa

Material: Al Alloy

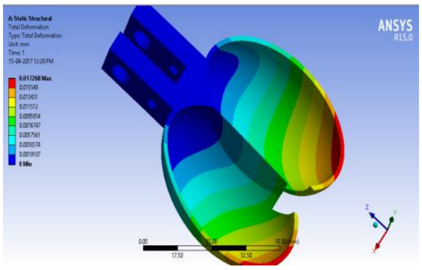

Figure 5.43 Total deformation in Al alloy bucket

The maximum deformation got during the analysis in the pelton wheel's bucket is 0.0172 mm and a minimum deformation of about 0 mm.

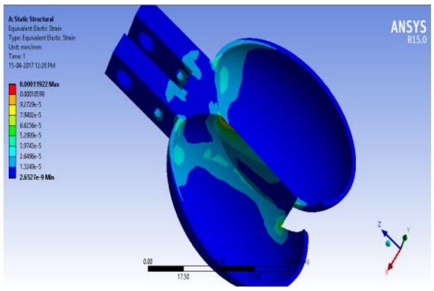

Figure 5.44 Equivalent elastic strain

maximum value of 0.00011 and minimum of about 2.65 e^-9.

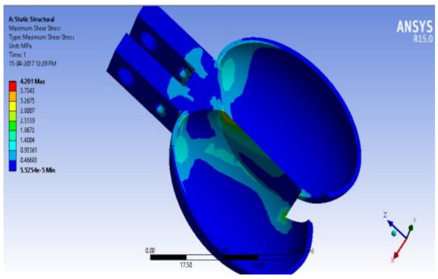

Figure 5.45 Maximum shear stress

maximum shear stress of about 4.201 MPa and a minimum of 5.525 e^-5 MPa

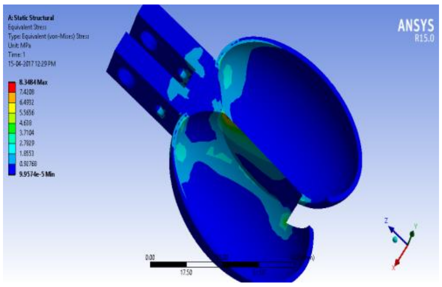

Figure 5.46 Equivalent von-mises stress

maximum stress of about 8.34 MPa and a minimum of 9.95 e^-5 MPa

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 MULTI-CYLINDER 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 Determine Optimal 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.

[12] Rajesh Bisane, Dhananjaykatpatal, "EXPERIMENTAL INVESTIGATION & CFD ANALYSIS OF AN SINGLE CYLINDER FOUR STROKE C.I. ENGINE EXHAUST SYSTEM",IJRET, eISSN: 2319-1163.

[13] Dr. K Ashok Reddy, "Exhaust Manifold Developmental Activates in Compression Ignition Engine", IJETCAS ISSN-2279-0047.

[14]Gopaal, MMM kumara varma, Dr L sureshkumar ,"Exhaust manifold design-FEA approach", IJETT–Volume17 Number 10–Nov2014 ISSN:2231-5381.

[15] Atul A. Patil,L.G. Navale,V.S. Patil, "Simulative Analysis of Single Cylinder Four Stroke C.I. Engine Exhaust System", INTERNATIONAL JOURNAL OF SCIENCE, SPIRITUALITY, BUSINESS AND TECHNOLOGY(IJSSBT),Vol. 2, No.1,November2013ISSN 2277—7261.