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Structural Analysis of Pelton Turbine Blade with CATIA and ANSYS using Cast Iron, INCONEL 600 and 1020 Steel Alloy –A Case Study

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Abstract- The scope of this work is to generate a 3-dimensional model of the Pelton wheel bucket in CATIA workbench to perform structural analysis under the static load conditions and to compare the analysis among three different materials of Pelton turbine bucket. In this work some critical data like stress, strain and deformation developed are analyzed. The bucket has been analyzed in ANSYS WORKBENCH simulation tool by using three different materials namely Cast Iron, INCONEL 600, 1020 Steel Alloy under given loading conditions. INCONEL 600 material has produced least stress and stain values as compared to other materials. INCONEL 600 material has least maximum deformation as compared to other materials. After the analysis, among the three materials, it is concluded that the best material is INCONEL600 for Pelton Turbine Blade as the stress, strain and deformation developed in INCONEL are less under given loading conditions and INCONEL 600 retains strength over a wide range of temperatures. So INCONEL 600 is observed as a suitable material for Pelton wheel bucket in the present case study.

Key words - Cast Iron; INCONEL 600; 1020 Steel Alloy; Stress; Strain; Deformation.

1. INTRODUCTION

In any application, improper selection of material leads to the failure and damage due to excessive forces. At that time proper material is needed for replacement. Pelton wheel buckets generally get corrosion and cracks when made up of Steel and aluminum materials. Due to corrosion, the material loses its strength. So it is necessary to search for alternate materials which do not get corroded when in contact with water.

The INCONEL Material, Gray Cast Iron and 1020 Steel materials were taken in the present case study. The INCONEL material was considered because of its high stiffness, low stress and low deformation.

INCONEL belongs to the group of austenitic nickel-chromium-based super alloys. These alloys are oxidation- and corrosion-resistant materials and well suited for service in extreme environments subjected to pressure and heat. When heated, it forms a thick and stable oxide layer protecting the surface from further attack. This material retains strength over a wide temperature range and is attractive for high temperature applications.

The properties of the INCONEL 600 material are given in the table 1.

Table1, Inconel 600 Properties

Material	Inconel 600
Density	8.4 g/cc
Young’s modulus	207Gpa
Poisson’s ratio	0.33
Tensile strength ultimate	655Mpa
Tensile strength yield	310 MPa
Elongation break	45%

Gray iron, or Gray cast iron, is a type of cast iron that has a graphitic microstructure. It is named due to the gray color of the fracture it produces, which is due to the presence of graphite. It is the foremost common cast iron and therefore mostly used cast material based on weight.

is used for housings where the stiffness of the component is more important than its tensile strength, such as internal combustion engine cylinder blocks, pump housings, Turbines, valve bodies, electrical boxes, and decorative castings. Grey cast iron's properties of high thermal conductivity and specific heat capacity are generally beneficial to produce cast iron utensils and disc brake rotors.

Table 2, Gray cast iron properties

Material	Cast iron
Density	7.2 g/cc
Young's modulus	130 Gpa
Poisson's ratio	0.28
Tensile strength ultimate	700Mpa
Tensile strength yield	172Mpa
Elongation break	15%

Carbon Steel is the steel with carbon content up to 2.1% by weight. The definition of steel from the yank Iron and Steel Institute (AISI) states "Steel is taken into account to be steel when: No minimum content is such or needed for metal, cobalt, molybdenum, nickel, niobium, titanium, tungsten, vanadium or zirconium, or any other element to be added to obtain a desired alloying effect. The specified minimum for copper doesn't exceed zero.40 percent; or the maximum content specified for any of the following elements does not exceed the percentages noted: Manganese 1.65, Silicon 0.60, Copper 0.60 in percentage.

Table 1, 1020 Steel Properties

Material	1020 STEEL
Density	7.85 g/cc
Young's modulus	140Gpa
Poisson's ratio	0.29
Tensile strength ultimate	394.72Mpa
Tensile strength yield	294.74 MPa
Elongation break	0.365

1.1 Introduction to CATIA:

CATIA V5, is the product of Dasssault Systems, France, is a completely re-engineered, Next-generation family of CAD/CAM/CAE software solutions for Product Lifecycle Management. CATIA V5 delivers innovative technologies for max productivity and power, from the origination conception to the ultimate product. CATIA V5 reduces the training curve, because it permits the flexibleness of exploitation feature-based and constant styles CATIA V5 provides 3 basic platforms: P1, P2, and P3.P1 is for little and medium-sized process-oriented firms that want to grow toward the massive scale digitized product definition.P2 is for the advanced style engineering firms that need product, process, and resource modeling.P3 is for the high-end style applications and is largely for Automotive and region business, where high quality surfacing or Class-A surfacing is used. The subject of interpretability offered by CATIA V5 includes receiving gift information from the opposite CAD systems and even between its own product information management modules.

The real profit is that the links stay associative. Due to this, any change made to this external data gets notified and the model could be updated quickly CATIA V5 serves the essential style tasks by providing totally different workbenches. A work bench is outlined as such setting consisting of a collection of tools that permits the user to perform specific style tasks. The basic workbenches in CATIA V5 are Part Design, Wireframe and Surface Design, Assembly Design and drafting.

1.2. Introduction to ANSYS*:*

ANSYS may be a large-scale utile finite part program developed and maintained by ANSYS opposition to broadly analyze a wide spectrum of problems arises in engineering mechanics and other allied sciences. Program Organization:
The ANSYS program is categorized into two basic levels:

1.2.1. Beginning level:

The Beginning level acts as an entry into and out of the ANSYS program. It is conjointly used sure as shooting international program controls like dynamical the work name, clearing (zeroing out) the information, and repeating binary files. When one first enters the program, one is at the Beginning level.

1.2.2. Processor (or) Routine level:

At the Processor level, several processors are a particular analysis task. For example, the general pre-processor (PREP7) is where one prepares the available. Each processor may be a set of functions that perform model, the solution processor (SOLUTION) is where one apply loads and obtain the solution, and the general postprocessor (POST1) is where one evaluates the results of a solution. An additional postprocessor, POST26, enables one to evaluate solution results at specific points in the model as a function of time.

1.2.3Material models:

ANSYS allows several different material models. i.e Linear elastic material models (isotropic, orthotropic, and anisotropic) and Non-linear material models (hyper elastic, multi linear elastic, inflexible and Visco elastic), Heat transfer material models (isotropic and orthotropic), temperature dependent material properties and Creep material models.

1.2.4. Loads:

The word hundreds in ANSYS nomenclature includes boundary conditions and outwardly or internally applied forcing functions, as illustrated in Loads Examples of loads in different disciplines are:

- Structural: structural loads are displacements, force, pressures, temperatures (for thermal strain) and Gravity.

- Thermal: Thermal loads are internal heat generation, temperatures, heat flow rates, convections, and Infinite surface.

- Magnetic: Magnetic loads are magnetic current segments, magnetic potentials, magnetic flux, source current density and infinite surface.

- Electric: Electric loads are current, electrical charges, electrical potentials (voltage), charge Densities and infinite surface.

- Fluid: The fluid loads velocities and pressure Loads are divided into six categories: Degrees Of Freedom constraints, forces (concentrated loads), surface loads, body loads, inertia loads and coupled field loads.

1.2.5. Analysis types:

The following are analyses in ANSYS.

- Structural analysis types: Static Analysis, Modal Analysis, Harmonic Analysis, Transient Dynamic Analysis, Spectrum Analysis, Buckling Analysis, Explicit Dynamic Analysis, Fracture mechanics, and Beam Analysis.

- Thermal analysis types : Steady-state thermal analysis, transient thermal analysis.

- CFD (Computational Fluid Dynamics) Analysis types : Laminar and/or Turbulent, Thermal, Free surface, Compressible and/or incompressible, Newtonian and/or Non-Newtonian, Multiple species transport.

1.2.6 Post processing:

Post process means that reviewing the results. It is the most important step in the analysis, because one tries to understand how the applied loads effect design, how good finite element mesh is, and so on Two postprocessors are available to review results POST1, the general Postprocessor, and POST26, the time-history postprocessor. POST1 allows one to review the results over the entire model at specific load steps and sub steps (or at specific time points or frequencies).

POST26 allows one to review the variation of a particular result item at specific points in the model with respect to time, frequency, or some other result item. In a transient magnetic analysis, for instance, one can draw graph between the eddy current in a particular element versus time. Or, in a nonlinear structural analysis, one can draw graph between the forces at a particular node versus its deflection.

2. LITERATURE REVIEW:

Nikhil Jacob George et.al [1] analyzed analysis of the Pelton wheel bucket modeled using CATIA V5 software. Alexandre Perrig et.al [2] presented the results of investigations conducted on the free surface flow in a Pelton turbine model bucket. Unsteady numerical simulations based on two-phase homogeneous model are performed together with wall pressure measurements and flow visualizations. Mohd sajid Ahmed et.al [3] had applied CFD methods to identify the optimum exhaust manifold for a 4-stroke 4-cylinder spark ignition engine.

Masahiro Kanazaki[4] has developed a multi-objective optimization method for the exhaust manifold by using Divided Range Multi objective Genetic Algorithm. Vivekananda Navadagi et.al [5] analyzed the flow of exhaust gas from two varieties of improved exhaust manifold with the support of Computational fluid dynamics.

K.S.Umesh et.al[6] worked on eight different models of exhaust manifold were designed and analyzed to improve the fuel efficiency by lowering the back pressure and also by changing the position of the outlet of the exhaust manifold and varying the length of the bend. Martinez-Martinez et.al.[7] had 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] conducted CFD simulations on manifold of direct injection diesel engine. I.P. Kandylas et.al.[9] 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. [10] 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.[11] has analyzed the exhaust manifold in order to reduce the backpressure and also to increase the particulate matter filtration.

Kulalet.al.[12], made a comprehensively analyzed eight different models of exhaust manifold and concluded the best possible design for least fuel consumption.

3. STRUCTURAL ANALYSIS:

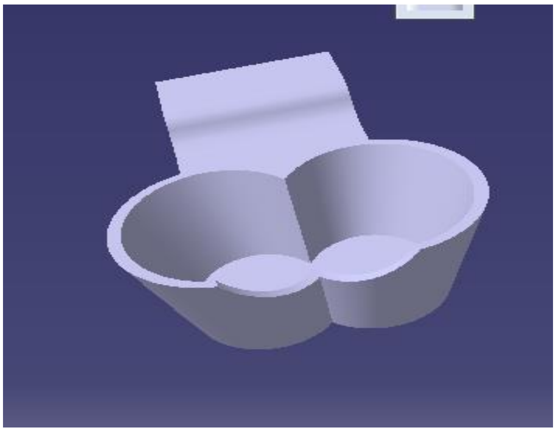

Fig.1. Pelton wheel bucket in CATIA

The fig.1. Shows the Pelton wheel bucket model in CATIA

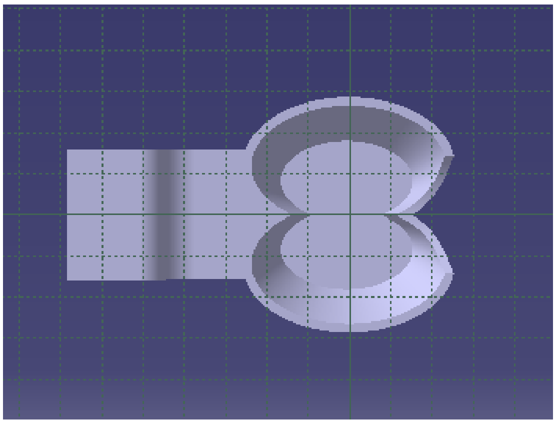

Fig.2. Pelton Bucket Top View

The fig.2. Shows the top view of the Pelton wheel bucket in CATIA.

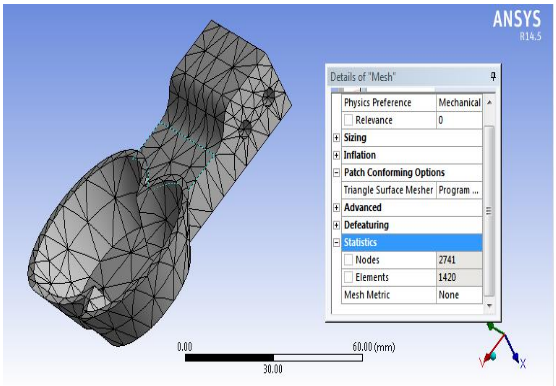

Figure.3.Meshing of Pelton Wheel Bucket

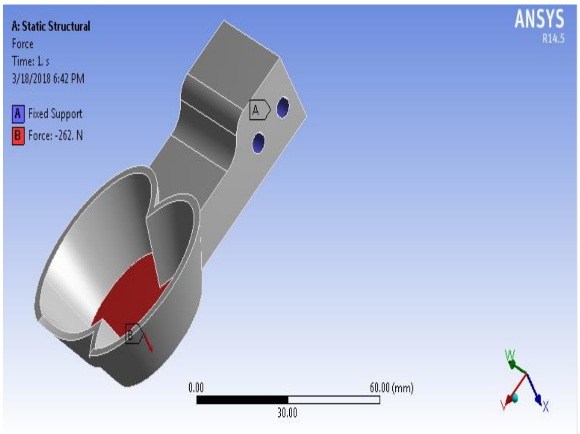

Fig. 1. Boundary Condition on Pelton Wheel Bucket with 262 N force.

The fig.4. Shows the loading conditions of the Pelton wheel bucket captured from ANSYS

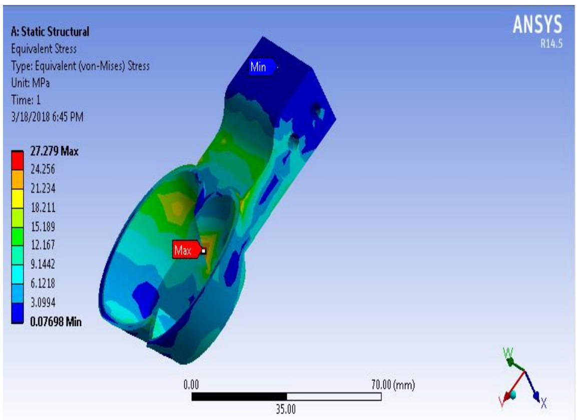

Fig.5. Stress on INCONEL 600 Material

The fig.5. Shows different values of the stress for the material INCONEL 600 captured from ANSYS. The maximum value of stress obtained is 27.279 Mpa . It is observed that the stress is minimum at the stem area and maximum at the area of the bucket, where water strikes.

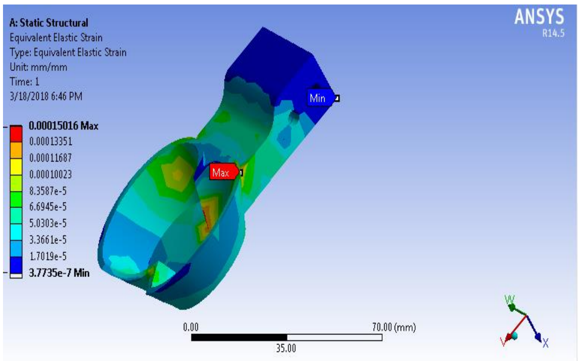

Fig.6. Strain on INCONEL 600 Material

The fig.6. Shows different values of strain for the material INCONEL 600 captured from ANSYS. The maximum value of strain obtained is 0.00015. It is observed that the strain is minimum at the stem area and maximum at the area of the bucket, where water strikes.

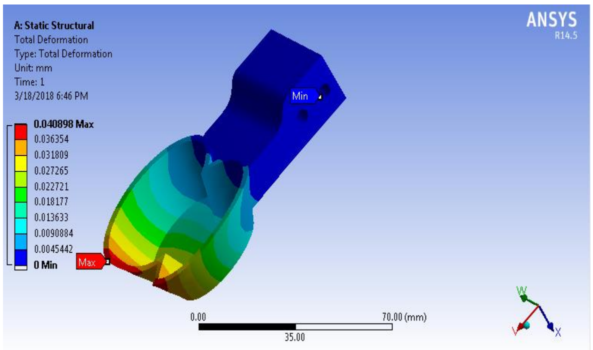

Fig.7. 2Total Deformation on INCONEL 600 Material

The fig.7. Shows the different deformation values for the material INCONEL 600 captured from ANSYS. The maximum value of deformation obtained is 0.036354 mm. It is observed that the deformation is minimum at the stem area and maximum at the bucket extreme tip.

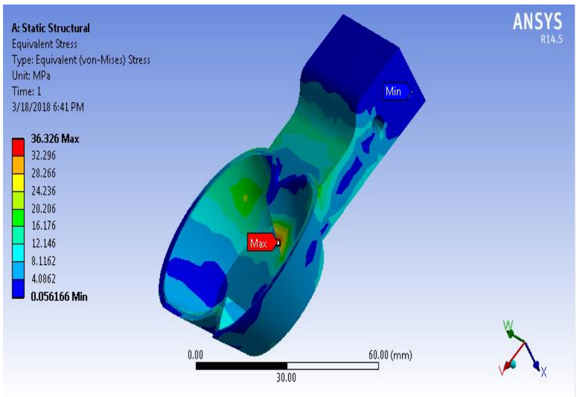

Fig.8. Stress on Cast Iron

The fig.8. Shows different values of stress for the material Cast Iron captured from ANSYS. The maximum value of stress obtained is 36.326 Mpa . It is observed that the stress is minimum at the stem area and maximum at the area of the bucket, where water strikes.

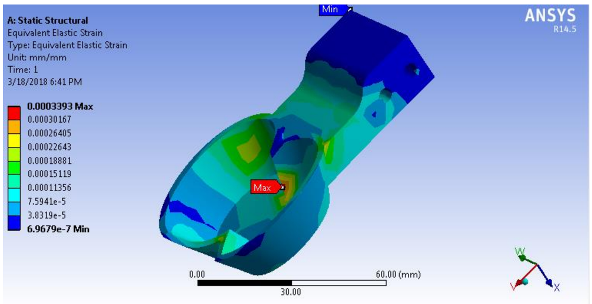

Fig.9. Strain on Cast Iron

The fig.9. Shows the different strain values for the material Cast Iron. The maximum value of strain obtained is 0.00033. It is observed that the strain is minimum at the stem area and maximum at the area of the bucket, where water strikes.

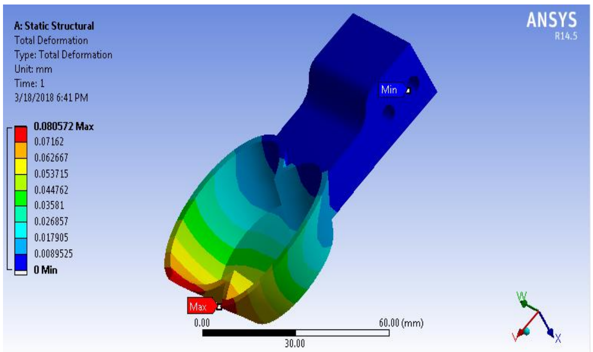

Fig.10. Total deformation on Cast Iron

The fig.10. Shows different values of deformation for the material Cast Iron captured from ANSYS. The maximum value obtained is 0.08057 mm. It is observed that the deformation is minimum at the stem area and maximum at the bucket extreme tip.

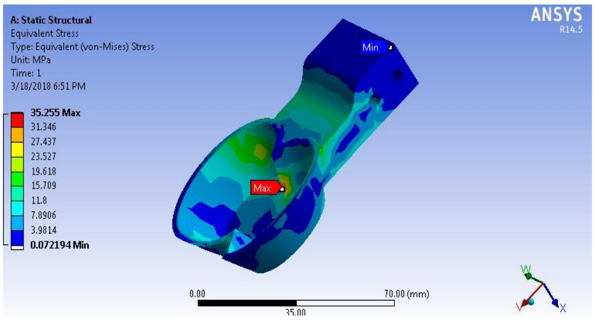

Fig.11. Stress on 1020 STEEL Alloy

The fig.11. Shows the different values of stress for the material 1020 STEEL captured from ANSYS. The maximum value of stress obtained is 35.255 Mpa. It is observed that the stress is minimum at the stem area and maximum at the area of the bucket, where water strikes.

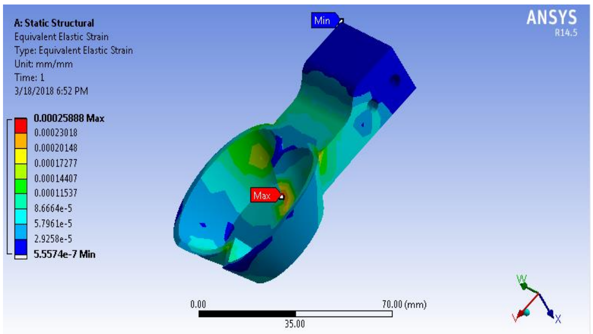

Fig.12. Strain on 1020 STEEL Alloy

The fig.12. Shows different values of strain for the material 1020 STEEL Alloy captured from ANSYS. The maximum value of strain obtained is 0.00023. It is observed that the strain is minimum at the stem area and maximum at the area of the bucket, where water strikes.

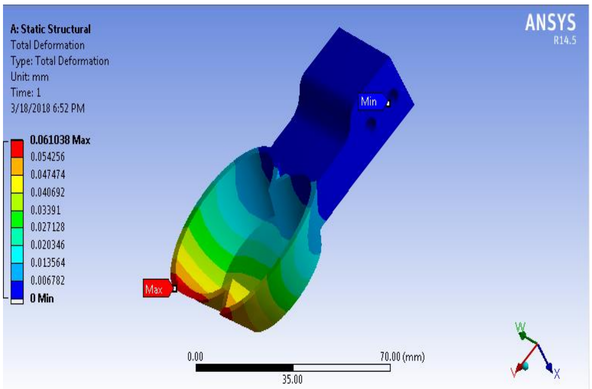

Fig.13. Total deformation on 1020 STEEL

The fig.13. shows different values of deformation for the material 1020 STEEL Alloy captured from ANSYS. The maximum value obtained is 0.061038 mm. It is observed that the deformation is minimum at the stem area and maximum at the bucket extreme tip.

4. RESULTS AND DISCUSSIONS:

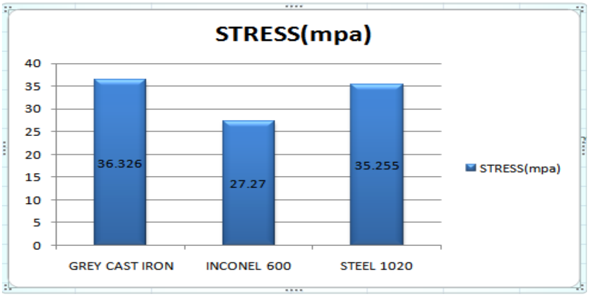

Fig.14. Graph showing stress for the materials

The fig.14. Shows different values of maximum stress in the materials. INCONEL 600 material has least stress value i.e 27.27 Mpa compared to other materials.

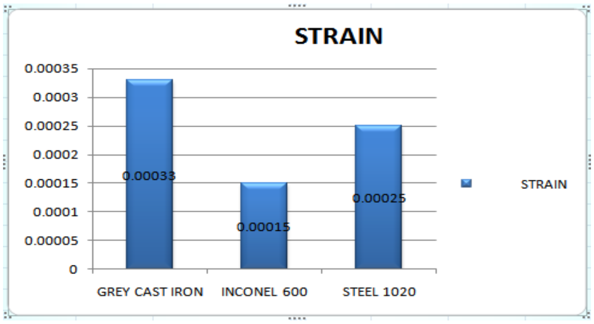

Fig.15. Graph Showing strain for the materials

The fig.15. shows values of maximum strain values for the materials. INCONEL 600material has least strain value i.e 0.00015 compared to other materials .

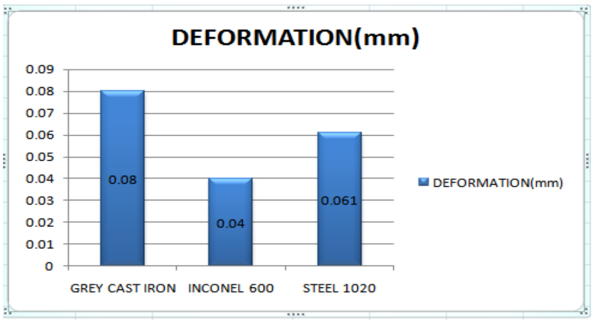

Fig .16. Graph Showing Total Deformation For The materials.

The fig.16. Shows values of deformation for the materials. INCONEL600 material has least maximum deformation value i.e 0.04 mm as compared to other materials.

5. CONCLUSION

Modeling of Pelton wheel bucket is done by using CATIAV5 Software and then the model is imported into ANSYS Software for Structural analysis on the Pelton wheel bucket to check the quality of materials such as, INCONEL 600,GREY CAST IRON, STEEL 1020. From the investigation, the obtained Von-misses stresses, strain, deformation for the materials, respectively compared to all these materials INCONEL 600 material has less stresses, deformations and strain. Finally structural analysis is done and concluded that INCONEL 600 as good material because, INCONEL alloys are oxidation-corrosion-resistant materials and well suitable for service in extreme environments subjected to pressure and heat. When heated, INCONEL forms a thick, stable, passivating oxide layer protecting the surface from further attack. INCONEL retains strength over a wide temperature range, and then INCONEL is suitable material for pelton wheel bucket.

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