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STRUCTURAL ANALYSIS OF PELTON BUCKET WITH AISI 1020 STEEL AND STRUCTURAL STEEL MATERIAL BY USING SOLID WORKS AND ANSYS

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Abstract

Pelton Turbine is the hydraulic turbine, a type of impulse turbine. An Impulse turbine is generally suitable for the low flow rate and high head. The discharge water from the nozzle impacts the bucket of the Pelton wheel to produce the hydropower. There are some reasons behind the failure of the Pelton bucket like as: silt erosion, cavitation, fatigue etc. The main reason behind the fatigue failure is the material property and stress concentrations. A high concentration of stresses occurs at the root of the bucket due to its cantilever structure each time a bucket experiences the impact of the water jet. In this work, there are two materials AISI 1020 Steel and Structural Steel have been considered for analyzing the Pelton bucket. For the 3D CAD model of the Pelton bucket Solid works 14.0 and for simulation work ANSYS 15.0 software has been used. In simulation work analysis types were static structural. This paper focuses on von-mises stress, total deformation of von-mises strain to analyze the suitable material for the Pelton bucket. From the obtained results it has been observed that among both materials Structural Steel is suitable for buckets due to low-stress concentration, total deformation and strain.

Keywords: ANSYS, AISI 1020, Structural Steel, Pelton Bucket, Solidworks.

I. Introduction

Energy is the main key to the development of any country. There are two main types of energy one is conventional and the other one is renewable. Hydropower is the type of renewable energy which is generated through the hydro turbine. Hydro turbine is the rotary mechanical device which converts kinetic energy of water into useful work [I]. The further classification of hydroturbine is given below:

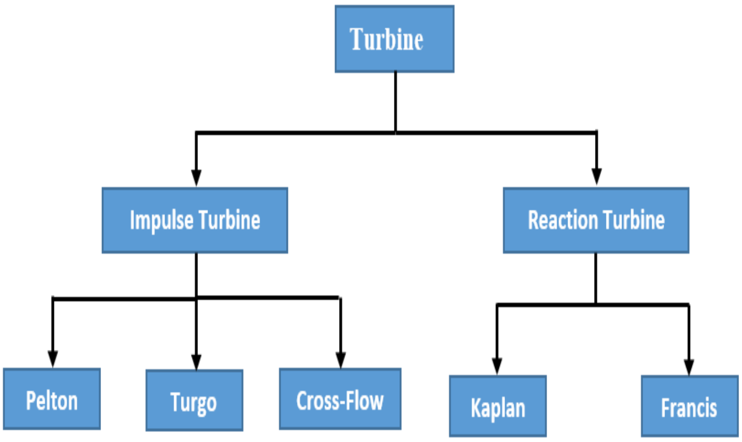

Fig. 1. Classification of Hydro Turbine

In the 1870s an American inventor named Lester Allan Pelton invented the impulse type water turbine called as Pelton Turbine. In comparison to water's dead weight, like the conventional overshot water wheel, the Pelton wheel drives energy from the impulse of moving water [II]. There were several earlier variations of impulse turbines, but they were less powerful than the design of Pelton. Pelton turbine generally used for high head greater than 300 m [III]. Li Ji-Qing and May Myat Saw researched on simple and advanced hoop Pelton bucket buckets based on fatigue analysis and for comparison of results three material has been considered named as stainless steel, aluminum alloy and cast iron and suggested the stainless steel is the best material for operating performance [IV]. Nikhil Jacob George et al. worked for static analysis of the Pelton wheel bucket by using material CA6NM. The findings thus produced are contrasted with the theoretical outcomes and accurate interpretations are made [V]. B.Vinod et al. researched for analysis of the Pelton wheel for new design with hoops for supporting Pelton buckets. Solidworks 2014 software has been used for CAD modeling and simulation by using two materials named 1020 Steel and 1060 Alloy. The obtained results showed that 1020 steel is the best material among both due to the less stress developed [VI]. N. Nava Indrasena Reddy and T. Sive Prasad worked for design and analysis for Pelton bucket by using three different materials steel, cast iron, and fiberglass-reinforced plastic and suggested fiberglass material for Pelton bucket due to less stress and strain compared to steel and cast iron [VII]. Gaurang Chaudhaary et al. worked for analyzing Pelton bucket and hooped runner with the use of ANSYS and achieved results suggested that new design (Hoop runner) has fewer stresses compared to traditional one, further the hooped runner is fabricated to validate the new design concepts [VIII]. Varun Sharma used ANSYS software to investigate stress variations on the Pelton turbine bucket and discovered that the highest stress occurred at 0° angle of the jet when inducing the blade and the lowest stress occurred at the blade's outermost periphery [IX]. The shapes of the bucket, jet, deflectors and turbine casings are all optimized during the design process. Validation of numerical solutions, on the other hand, remains a difficult task due to the current mesh consistency. Nonetheless, advances in computational methods and computing power have been made in the last 15 years [X]. The simulation of the bucket model in CATIA has been accomplished in two ways [XI].

1. Consider the first jet impact force along with the bucket's splitter.
2. The pressure distribution along the bucket profile is taken into account.

The bucket model is created using the measured parameters, and SOLIDWORKS is used to analyze the different parameters. The FOS obtained from the analysis is 3.5, indicating that the design model is safe [XII].

II. Operation

It is fairly easy to run a Pelton turbine. High-speed jets of water emerge from the nozzles that surround the turbine in this type of turbine. These nozzles are arranged such that at splitters, the middle of the bucket where the water jet is separated into two streams, the water jet would reach the buckets. The two different streams then flow along the bucket's inner curve and leave it in the reverse direction it came in. This shift in water momentum produces an impulse in the turbine blade, producing torque and rotation in the turbine.

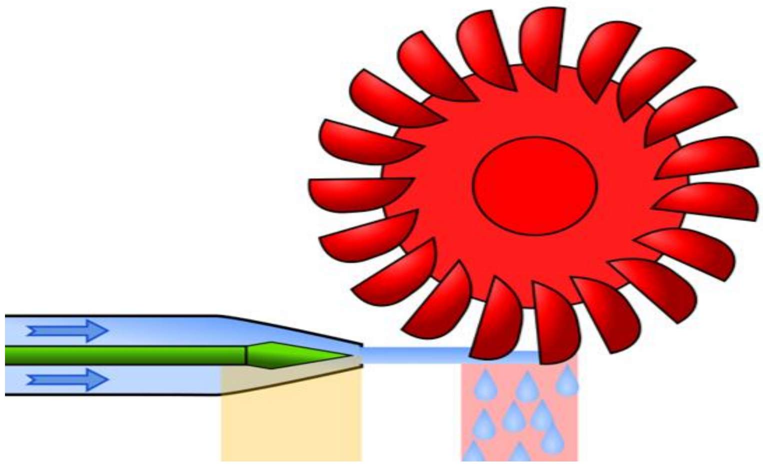

Fig 2. Operation of Pelton Turbine

III. Methodology

Selection of Materials

For starting of methodology selection of material is very important because this work is based on a comparison of two materials named AISI 1020 steel and Structural Steel, selection of both materials according to the review of different literature. The following table shows the different properties of AISI 1020 steel and Structural Steel materials.

Table 1: Properties of AISI 1020 and Structural Steel Material

Properties	AISI 1020	Structural Steel
Density	7900 kg/m^3	7850 kg/m^3
Young's Modulus	2 x10^{11}Pa	2x10^{11}Pa
Poison's Ratio	0.29	0.3
Bulk Modulus	1.5873 x10^{11}Pa	1.6667 x10^{11}Pa
Shear Modulus	7.75 x10^{11}Pa	7.692 x10^{10}Pa
Yield Strength	351.570 x10^{6}Pa	250 x10^{6}Pa
Ultimate Strength	420 x10^{6}Pa	460 x10^{6}Pa

3D CAD Model

For CAD designing of the Pelton bucket, Solidworks software has been used. Solidworks is the CAD Modeling tool and Mechanical design software that has a friendly user interface. Traditionally Pelton bucket act as a cantilever beam as one end is fixed with disk and on another side the force of the jet act.

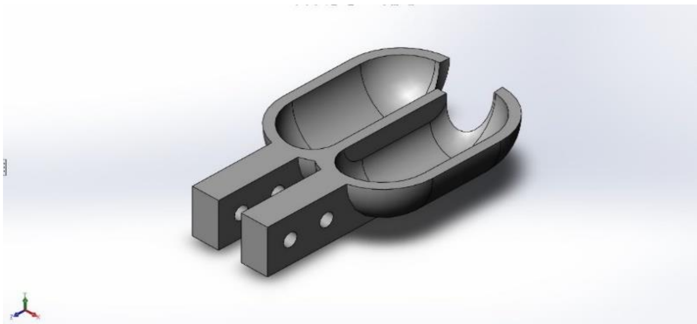

Fig 3. 3D CAD Model of Pelton Bucket

Analysis of Pelton Bucket

For simulation of CAD model of Pelton bucket, Ansys 15.0 version has been used. After designing the 3D CAD model, it is imported into the Ansys workbench for further work. In the Ansys workbench from the analysis system, a static structural analysis system has been selected after that material properties are modified from the engineering data source tab.

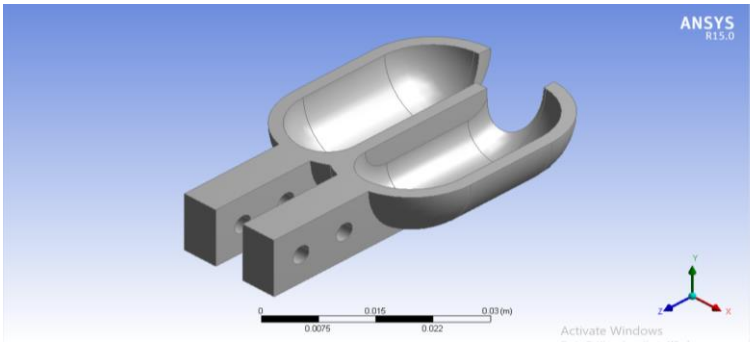

Fig 4. Imported model of Pelton Bucket in Ansys

Governing Equation

For static finite element analysis, the governing equation is as follows:

$$[K_T]\{\Delta\mu\}=\{R_{unb}\}.$$

Where the tangent stiffness matrix, $[K_T]$, has three components

$$[K_T]=[K1]+[K_2(\mu)]+[K_3(\sigma)].$$

Where $[K_1]$, $[K_2(\mu)]$ and $[K_3(\sigma)]$ are the linear, displacement, and stress-dependent contributions.

Meshing

After importing the geometry next step is to go for meshing. Meshing is the engineering technique in which engineering geometries are divided into discrete parts for the accuracy of simulated results.

Table 2: Details of Mesh

Relevance Center	Fine
Relevance	100
Element Size	0.4 mm
Span Angle Center	Fine
Nodes	209172
Element	128942
Mesh Metric	Skewness

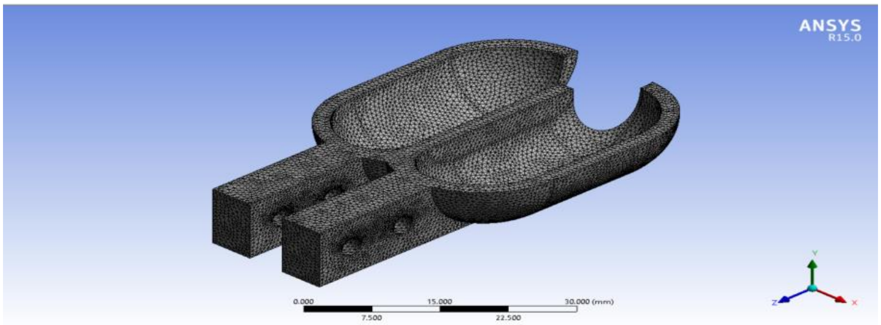

Fig 5: Meshed model of AISI 1020 Steel Pelton Bucket

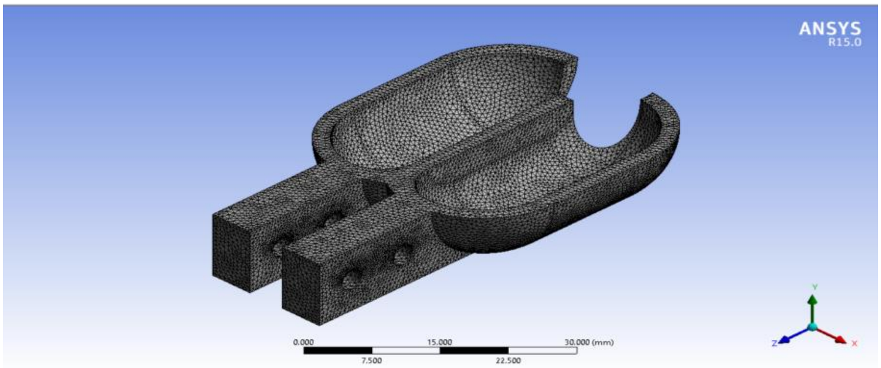

Fig 6: Meshed model of Structural Steel Pelton Bucket

IV. Results and Discussion

The 3D CAD model of the Pelton bucket is simulated in Ansys 15.0 by using a workbench platform with static structural in the analysis system. Pelton bucket is assumed as cantilever beam one side is fixed where 2 small holes are and force of 500 N is applied on the other side for both material AISI 1020 steel and Structural Steel.

Von-Mises stresses of Pelton bucket for both material

In this section von-mises stress analysis are present for both material AISI 1020 steel and Structural Steel.

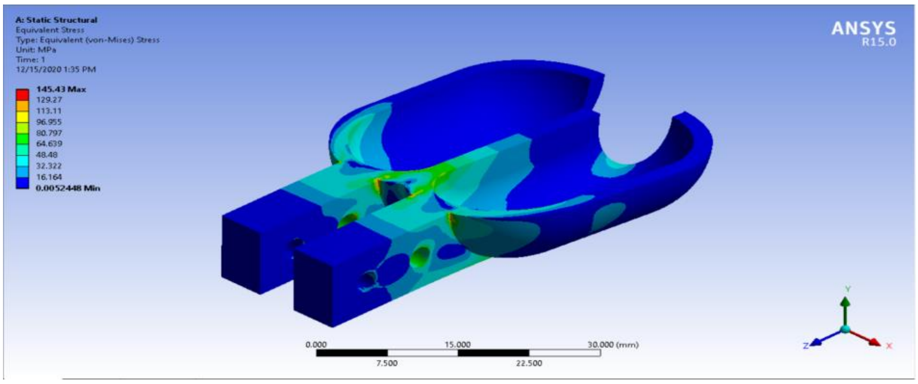

Fig 7. Von-Mises Stresses of AISI 1020 Material

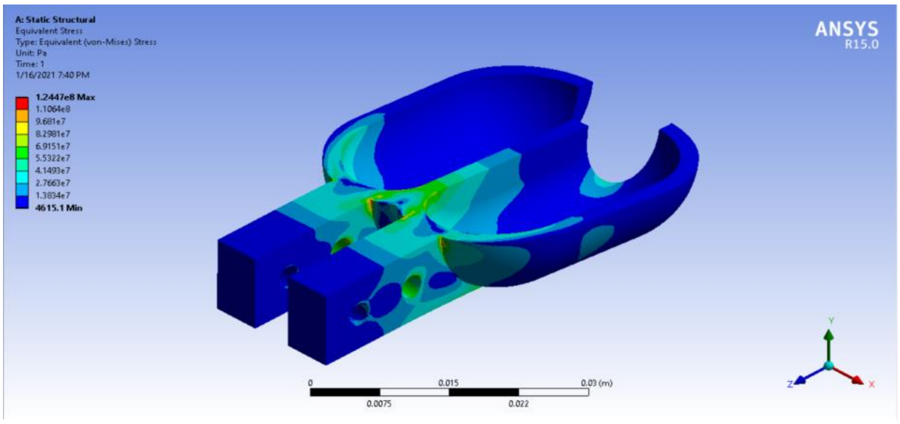

Fig 8. Von-Mises Stresses of Structural Steel Material

Fig: 7 and Fig: 8 Show the analyzed results achieved from Ansys 15.0 for Von-Mises stresses of AISI 1020 Steel and Structural steel. From fig 7 & 8, it is observed that structural Steel contain less stress in the same loading condition which is equal to a maximum stress of 124.7 MPa while AISI 1020 Steel has maximum stress of 145.43 MPa.

Total deformation of Pelton bucket for both material

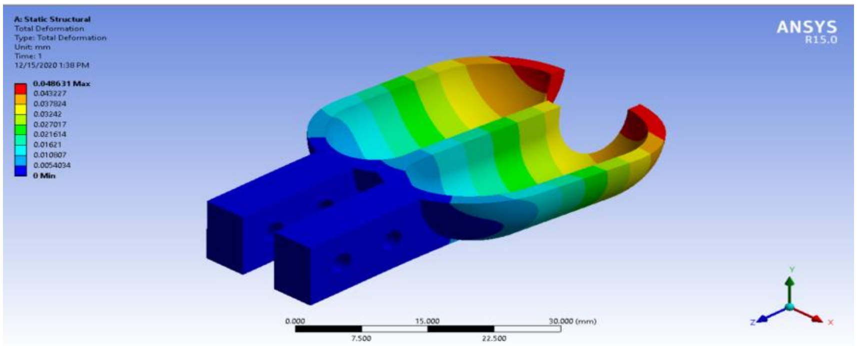

Fig 9. Total deformation of AISI 1020 Material

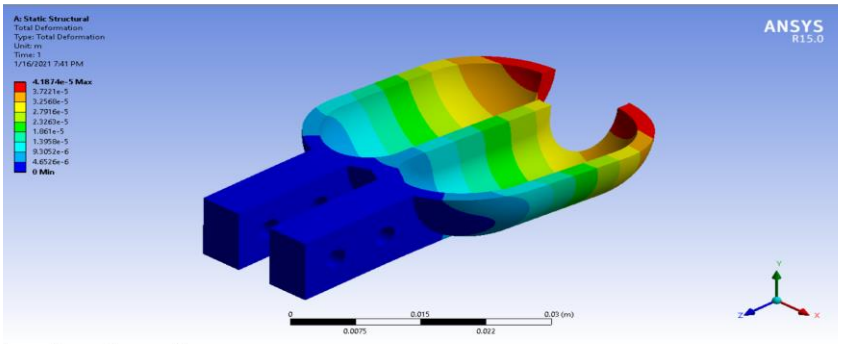

Fig 10. Total deformation of Structural Steel Material

Fig: 9 and Fig: 10 Show the simulated results obtained by Ansys 15.0 for total deformation of AISI 1020 Steel and Structural steel. From figure 9 &10 it is observed that structural Steel contain less deformation in the same loading condition which is equal to maximum deformation of 4.187×10^{-5}m while AISI 1020 Steel has maximum deformation of 4.86311×10^{-5}m.

Von-Mises strain of Pelton bucket for both material

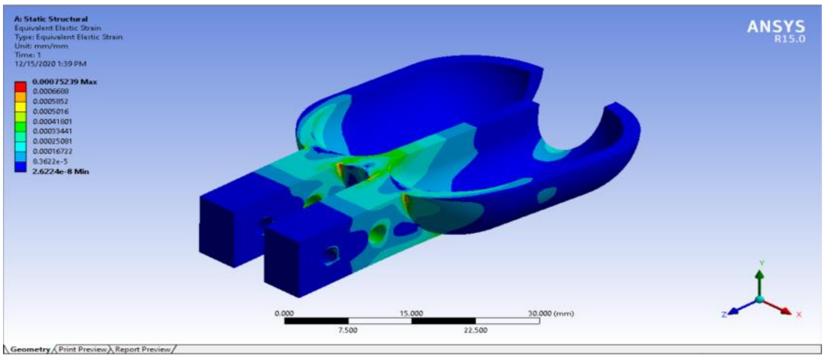

Fig 11. Von-Mises Strain of AISI 1020 Material

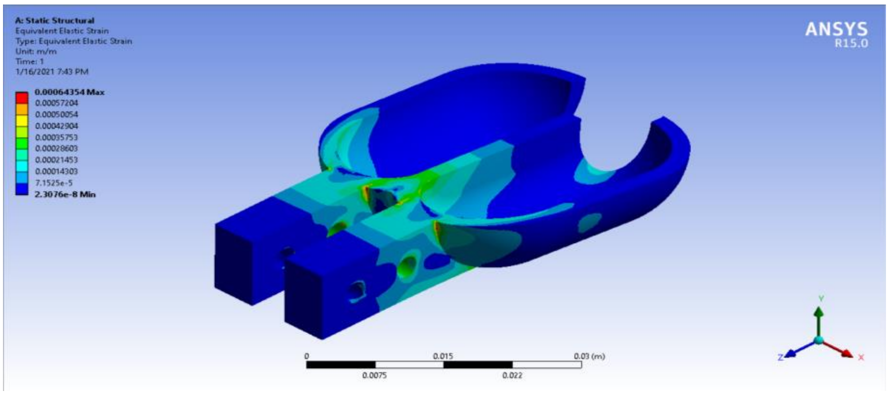

Fig 12. Von-Mises Strain of Structural Steel Material

Fig: 11 and Fig: 12 Shows the results for Von-Mises strain of AISI 1020 Steel and Structural steel. From figure 11 &12 it is observed that structural Steel contain less strain in the same loading condition which is equal to a maximum strain of 6.43×10^{-7} while AISI 1020 Steel has a maximum strain of 7.5239×10^{-7}.

Comparative study of AISI 1020 Steel and Structural Steel

Table 3. Comparative analysis of both material

Results	AISI 1020	Structural Steel
Von-Mises Stress (MPa)	145.43	124.7
Total Deformation(m)	4.86311×10^{-5}	4.1874×10^{-5}
Von-Mises Strain	7.5239×10^{-7}	6.43×10^{-7}

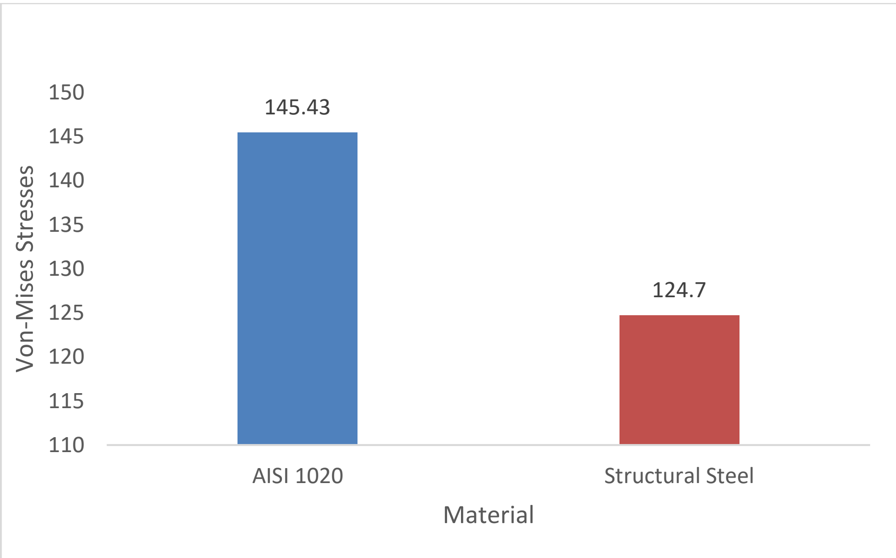

Fig 13. Von-Mises Stresses of AISI 1020 and Structural Steel

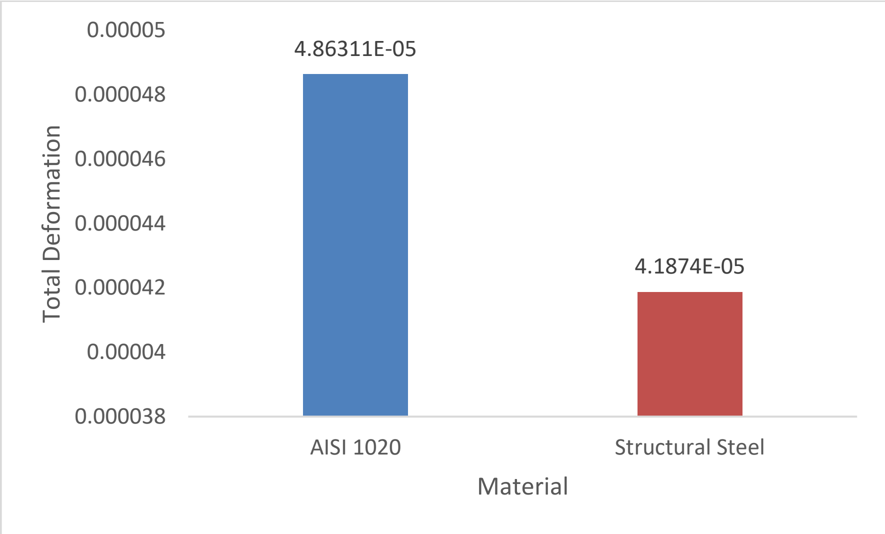

Fig 14. Total Deformation of AISI 1020 and Structural Steel

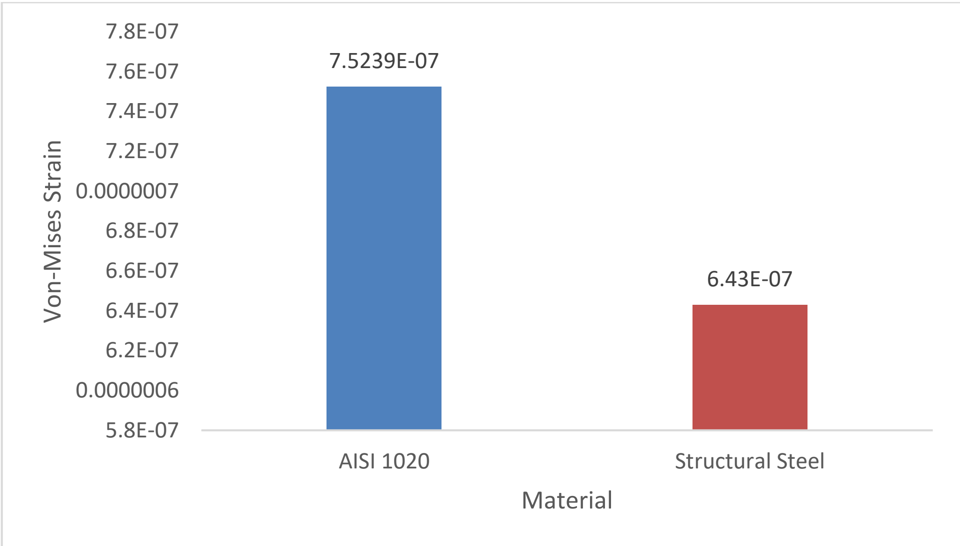

Fig 15. Von-Mises Strain of AISI 1020 and Structural Steel

In table 3 and figure 13-15 comparative study for von-mises stresses, total deformation and von-mises strain has been discussed. From table 3 and figure 13-15 respectively it is observed that the lowest value of von-mises stresses, total deformation, and von-mises strain gone for structural steel, hence structural steel is more suitable than AISI 1020 due to low values of stress, deformation and strain.

V. Conclusions

The objective of this research was to select the suitable material for the Pelton bucket under constant loading condition of 500 N. The design of the Pelton bucket during this work is carried out in Solidworks for 3D CAD model and for analysis Ansys software has been used. In this work for the comparison of material two materials were selected such as AISI 1020 Steel and Structural Steel. The finding of this research are as follows:

- Result of Von-Mises stress distribution under 500 N loading condition maximum stress and minimum stress generated for AISI 1020 and structural steel which are 145.43 MPa and 124.7 Mpa respectively.
- Result of total deformation distribution under 500 N loading condition maximum and minimum deformation generated for AISI 1020 and Structural Steel which are equal to 4..86311×10^{-05} m and 4.1874×10^{-05} m.
- Result of Von-Mises Strain distribution under 500 N loading condition maximum and minimum generated for AISI 1020 and structural steel which are 7.5239×10^{-07} and 6.43×10^{-07} .

In conclusion among both materials structural steel is suitable material for designing of Pelton bucket due to the low stresses, low deformation and low strain values.

Conflict of Interest:

There is no conflict of interest regarding this article

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