MODELLING AND ANALYSIS OF FRONT AXLE OF COMMERCIAL VEHICLE

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Abstract

The front axle of every vehicle is its structural core. The front axle beam carries the majority of the 30% cargo and goods. The front axle beam must sustain the accumulated stress and deformations within a certain range. The front axle beam of the Eicher Pro 2049 in this research was developed in Solid Works software, and static and dynamic analysis was performed in ANSYS 21. This study covers design modelling, structural analysis, and dynamic analysis of the front axle beam of a heavy vehicle. The results of analytical design were compared to those of finite element analysis. The modified model is subjected to modal analysis using four different materials: SAE 1020, AISI 4150, and AISI 1045. The front axle beam has also been investigated for random vibrations. The study's data are reviewed to identify the best material for modifying the front axle beam. The front axle is the principal load-bearing component of the heavy vehicle.

Keywords – *Front Axle, SolidWorks, Ansys, Deformation, Stress, Finite Element Method*

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1. INTRODUCTION

The most major element, particularly in a load-carrying vehicle, is the front axle (FA). Commercial vehicles' front axle failure is a major issue. Therefore, it is important to examine the front axle's ability to handle heavy loads. [1] The front axle supports the weight of the front portion of the vehicle and absorbs stress caused by changes in the road surface. The front axle's function is to transfer the weight of the car from the spring to the front wheels, hence it must be properly designed.

An axle is the Centre shaft for a wheel or gear that rotates. Axles on wheeled vehicles may either be fastened to the wheels and rotate alongside them or fixed to the vehicle and rotate around the wheels. In the first scenario, the mounting locations where the axle is supported have bearings or bushings. In the latter scenario, a bushing or bearing is positioned within the wheel's Centre hole to permit rotation around the axle. The latter kind of axle is sometimes referred to as a spindle, particularly when used to bicycles. One front axle is operating under 30% of the vehicle's weight, making it the principal component. As a forged component, the front axle often has a greater strength to weight ratio than is ideal. The I cross section offers higher performance with less weight since it has a lower section modulus. This kind of assembly results in an axle that is both strong and light. For generic viscous or hysteretic multi-degree-of-freedom systems, the descent-based descent sub gradient technique is presented to optimize the lowest damping of modes in a defined frequency range (MDOF) tuned- Since the mass is not moving, the axle's primary responsibility is to keep the wheels straight and sustain a portion of the weight.[2] The axle experiences twisting loads from braking and driving while the vehicle is driving.

One of the significant and vital areas of the Indian economy is the automobile industry. The auto industry includes trucks and other commercial vehicles. The auto business includes passenger cars, multi-utility vehicles, two-, three-, and four-wheeled vehicles, thus it is crucial for an automotive designer to fulfil system safety requirements and to reduce the weight of the vehicle in order to satisfy fuel economy and vehicle performance. One of the axle's key components is a hub on which a wheel or gear rotates. [3]

Figure 1 shows axle is attached to the wheels that are revolving around it or connected to the vehicle. When the axle is supported by mounting pairs, bearings or bushings are offered. There are three distinct axle kinds. Front axle, rear axle, and stub axle, among others. The front axle transfers the car's weight from the spring to the front wheels. The axle might be seen as a beam in static state, supported at both ends vertically upward. Road roughness creates an increase in the vertical bending moment under dynamic conditions, which increases the loads and fluctuations on the axles. As a result, it is crucial to confirm that the axle can withstand fatigue failure for the duration of its expected service life. [4-5]

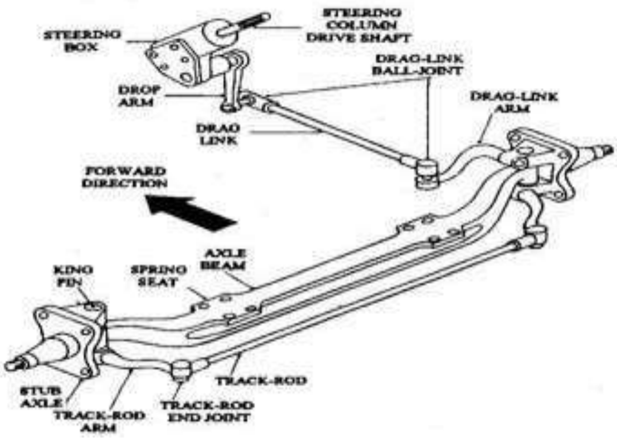

Figure 1: Layout of Front Axle

Three materials were tested on a vehicle model's front axle, which was built and examined using finite element methods for large industrial vehicles. In the ANSYS 21.0 workbench, analysis is done on the stress distribution and deflection characteristics. Every model goes through a dynamic analysis for two design situations, the I section and the elliptical section.

The goal of this study is to enhance the front axle beam strength data gathering in terms of materials and design. For this front axle simulation in Ansys, a static analysis is carried out in specific dimensions, and certain design parameters are examined in ANSYS 21.0.

2. FINITE ELEMENT ANALYSIS

The experimental front axle model was studied using ANSYS, a software programme combined with frequently used engineering simulations. ANSYS offers a full group of products covering the entire spectrum of physics, enabling the use of nearly all of the engineering replicas required by the design process. The software programme makes use of its capabilities to put a fictitious product through a rigorous testing procedure, such as by measuring the front axle of a large item under various loading conditions. The ANSYS is capable of doing complex engineering studies, primarily on loading times and non-linear materials, in a quick, secure manner using a variety of contact algorithms. In this study, we examine front axle modelling under static loading situations using several models.[6]

3. METHODOLOGY OF RESEARCH

Once the mathematical models are complete, the mechanism for solving the problem is decided. The mathematical representation of the issue may consider a qualitative or quantitative component. Qualitative studies evaluate mathematical versions of the topic without providing a definitive answer. On the other hand, theoretical, physical, and computational methodologies may be used in quantitative analysis. The Front Axle is typically loaded statically using FEM research. Figure 2 shows the complete layout for this research.

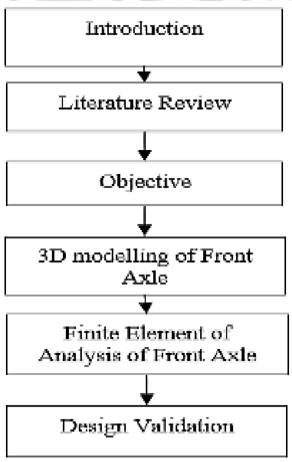

Figure 2: Flow Chart of Methodology

3.1 MATERIAL SELECTION FOR LEAF SPRING

High strength material mostly used for designing the leaf spring. This article has contrasted the result of namely SAE 1020, AISI 4150, AISI 1045. As shown in Table 1, the properties of the materials used in the present research.[8]

Table 1: properties of the materials

Properties	**Unit**	**AISI 1045**	**AISI 4150**	**SAE 1020**
Density	kg/m	7870	7861.1	7872
Young's Modulus	Gpa	2.00E+02	2.10E+02	2.05E+02
Poisson's Ratio		0.29	0.3	0.3
Bulk Modulus	Pa	1.58E+00	1.75E+11	1.67E+11
Shear Modulus	Pa	7.68E+11	8.07E+10	7.60E+10
Tensile Yield Strength	MPa	3.10E+02	7.31E+02	2.05E+02

3.1.1 MODELLING OF FRONT AXLE

Front axle model in Solid work was explained in detail in vehicle performance. The goal of final-element research is to recreate the actual engineering structure's mathematical behaviour. Here are two types of front axle designed with I section and Elliptical section.[8] The design incorporates all of the physical device nodes, components, functions of materials, specific constants, circumstances and extra features. First model be generated then specific boundary conditions will be applied on the specific nodes then final analysis will be conducted.
Design of Front Axle are shown in images below [Figure 3 ,4] :

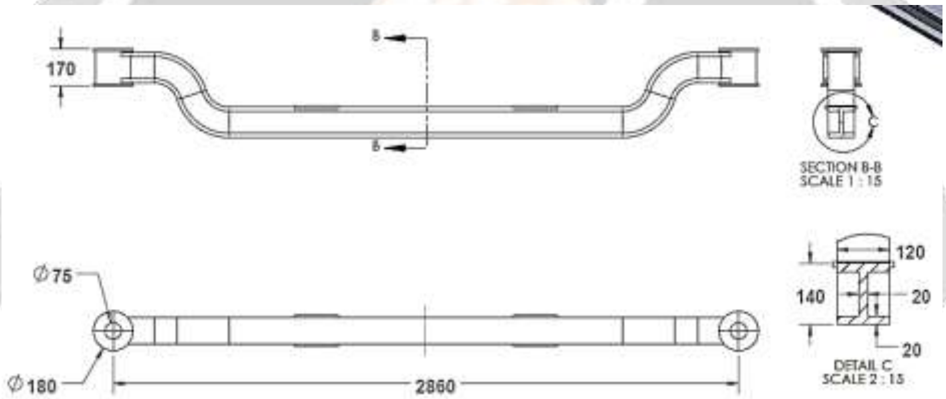

Figure 3: Model of Front axle of vehicle with I section

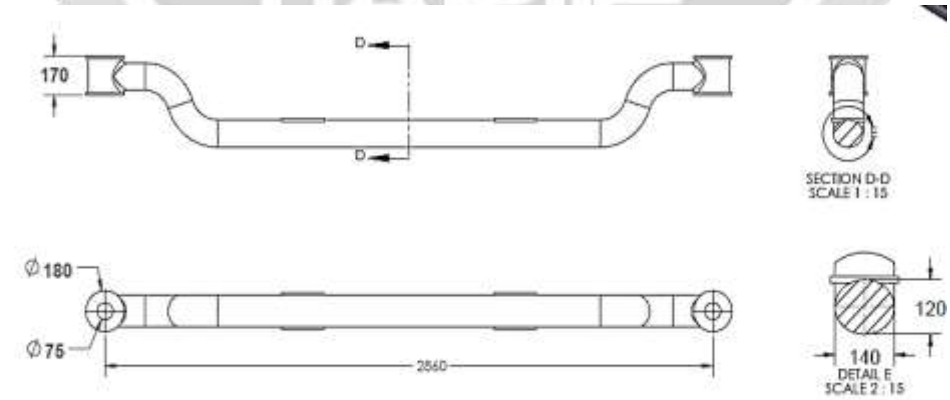

Figure 4: Model of Front axle of vehicle with Elliptical section

3.1.2 Design Calculation for Loading Condition for Front Axle

For designing of Front axle, Vehicle model EICHER Pro 2049 selected and its gross weight is 4995 kg.

Gross vehicle weight = 4995 Kg

Considering 3g condition (3G bump load condition) = 3 x 4995

= 14985 Kg

Total weight on Axle given by = 14985x 9.81

= 147002 N = (147 KN)

Weight on each spring seat = 147002 / 2

= 73.50 KN

3.1.3 Boundary conditions for analysis of Font Axle using ANSYS

After design the model of front axle is meshed, we need to apply the suitable boundary condition under which the structural Analysis will be completed.

Figures 4 and 5 represent the applied boundary conditions on front axle have been kept fixed while convection on the outer surface of the front axle has been applied, to optimize failure of front axle. Figures 4 and 5 show the applied Load of 73.50 KN for boundary conditions of front axle. [9-10]

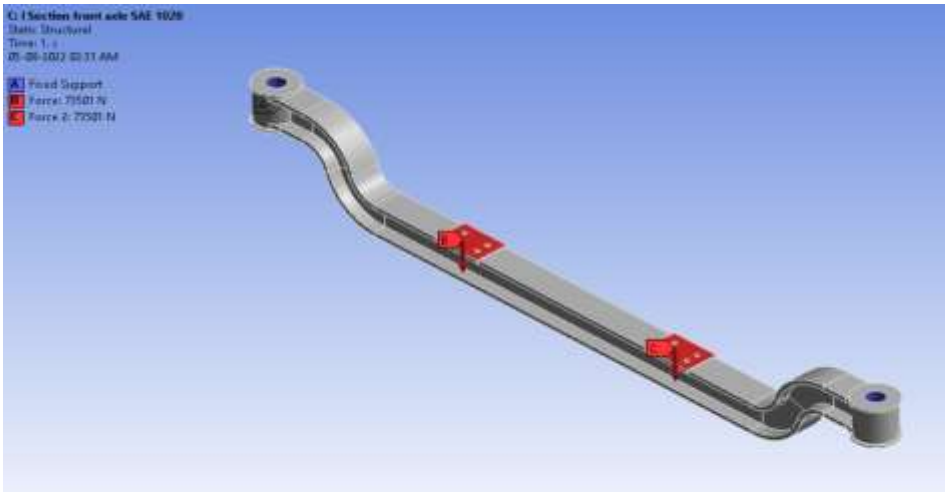

Figure 4: Boundary conditions of I section in Axle

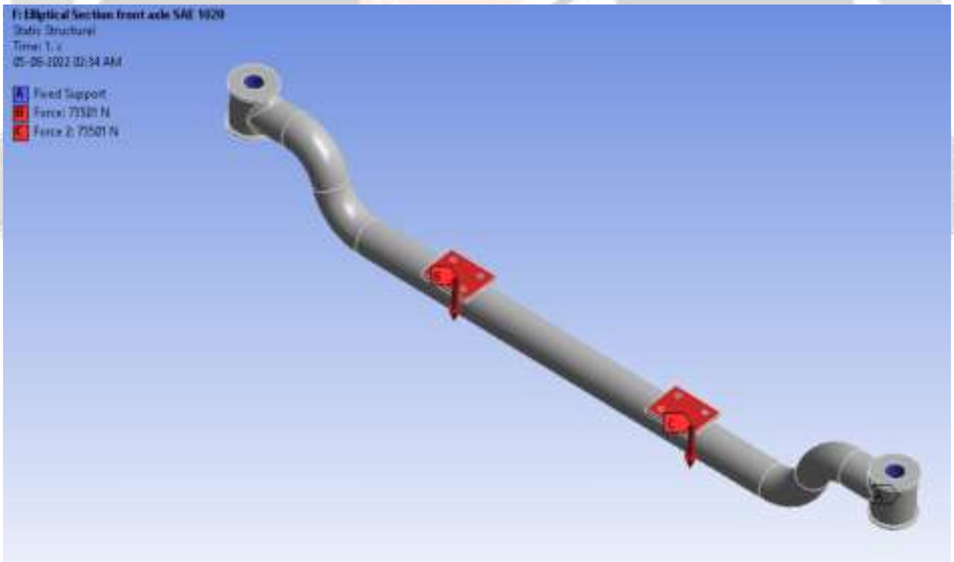

Figure 5: Boundary conditions of Elliptical section in Axle

Figures show the boundary conditions on the model of front axle beam in both models in which we have applied 73.50 KN load which is calculated on the selected vehicle load.

4. Results and Discussion

Front axle beam analyzed in Ansys for deflection, stress, factor of safety and fatigue analysis for comparison of data, to find out best and suitable design for axle beam. Three types of material used for front axle beam analysis, two sections used to compare the axle strength.

4.1 Analysis of front Axle with I Section

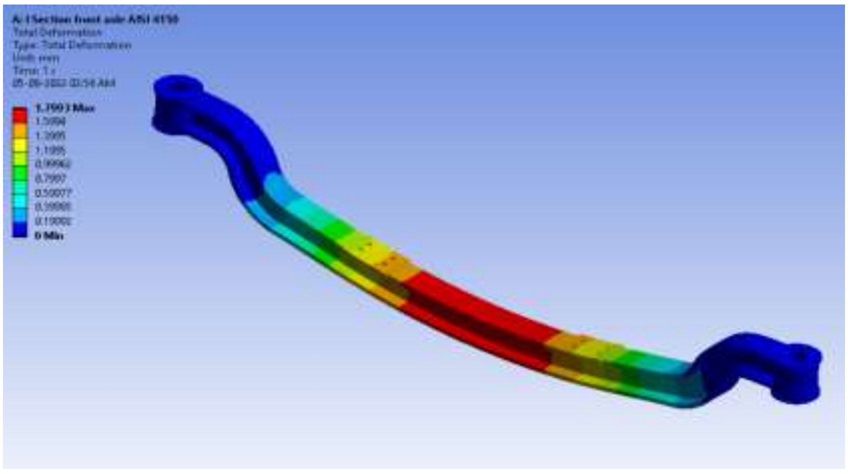

Figure 6: Deformation in front axle with I section

Figure 6 shows the maximum deformation of the I section used front axle in which maximum deformation found 1.79 mm.

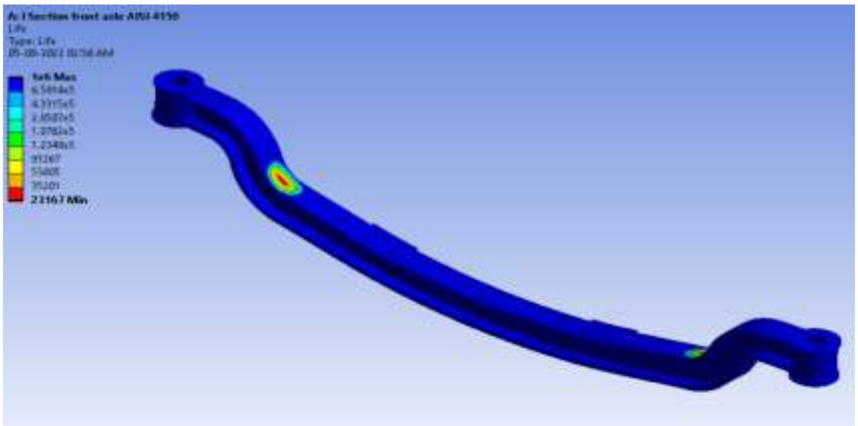

Figure 7: Fatigue life of front axle with I section

4.2 Analysis of front Axle with Elliptical Section

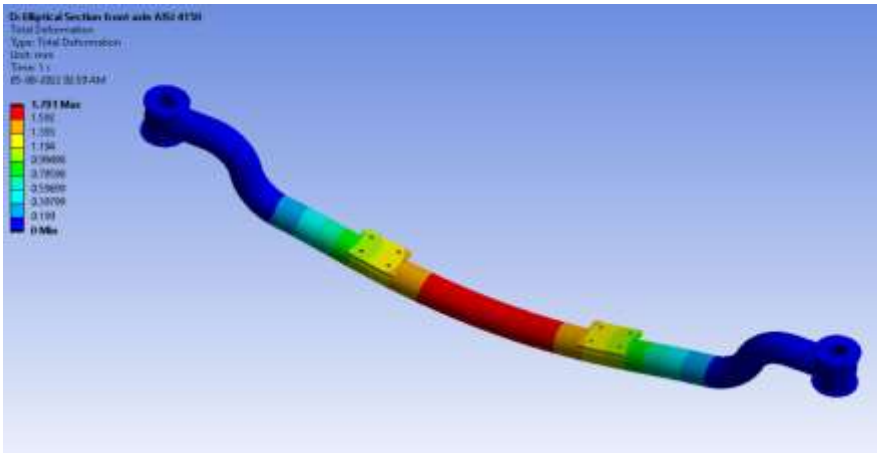

Figure 8: Deformation in front axle with Elliptical section

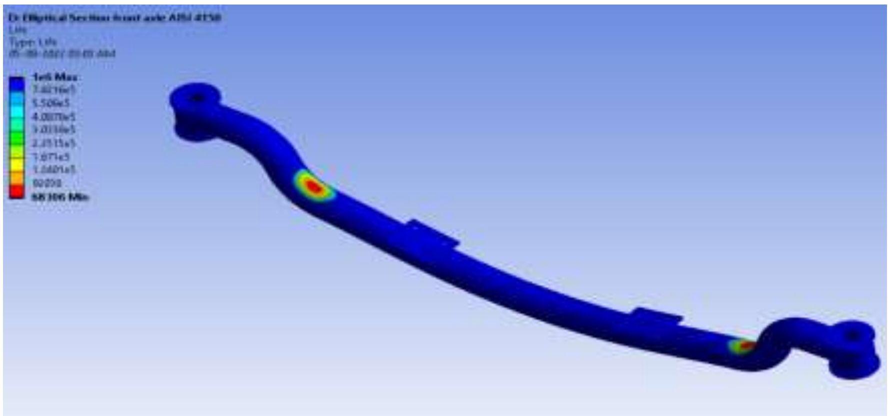

Figure 9: Fatigue life of front axle with Elliptical section

As per above study figure 9 shows the fatigue life of front axle beam using I section is 23167, figure 8 shows the deformation due to loading in Elliptical section of axle in which maximum deformation found 1.791 mm.

4.3 Data Analysis of Front Axle beam with I sections

Table 2: Output parameters of Front axle with I section

	Front Axle with I Sections		
Results	**AISI 4150**	**AISI 1045**	**SAE 1020**
Stress (MPa)	205.59	206.63	205.88
Deformations (mm)	1.79	1.88	1.88
Safety factor	3.5	1.5	1.38
Weight (kg)	203.15	203.38	203.43
Fatigue Life	23167	22745	23049

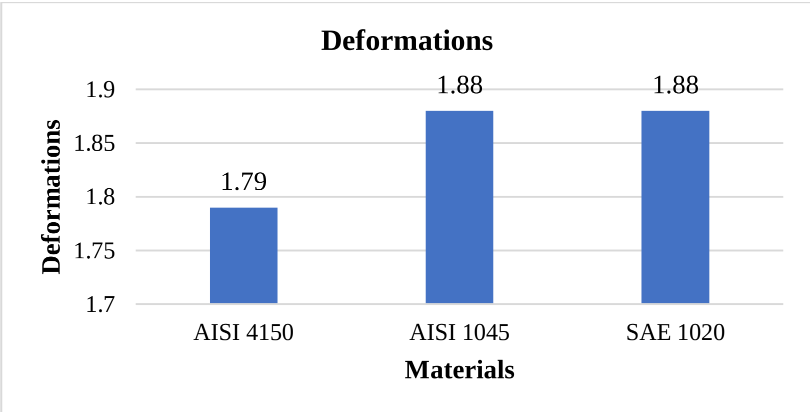

Figure 10: Deformation of Front Axle beam using I section

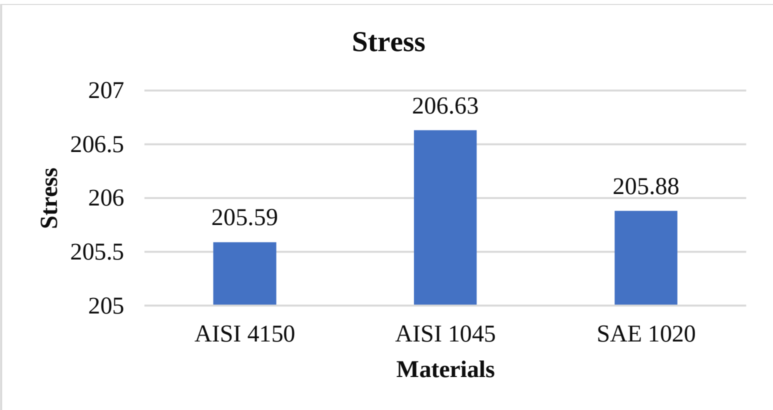

Figure 11: Stress of Front Axle beam using I section

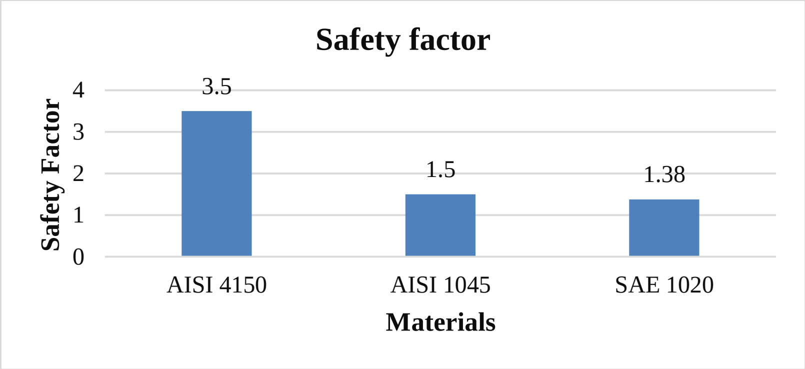

Figure 12: Safety factor of Front Axle beam using I section

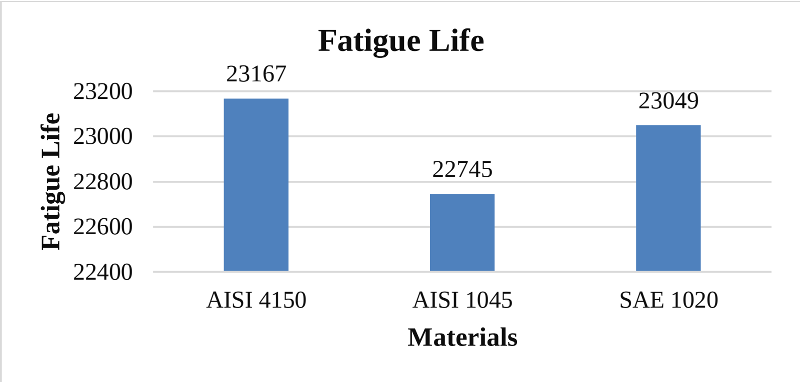

Figure 13: Fatigue life of Front Axle beam using I section

4.4 Data Analysis of Front Axle beam with Elliptical sections

Table 3: Output parameters of Front axle with Elliptical section

	front Axle with Elliptical Sections		
Results	**AISI 4150**	**AISI 1045**	**SAE 1020**
Stress	153.11	152.96	153.11
Deformations	1.79	1.88	1.88
Safety factor	4.77	2	1.82
Weight	354.92	355.32	355.41
Fatigue Life	68306	68557	68306

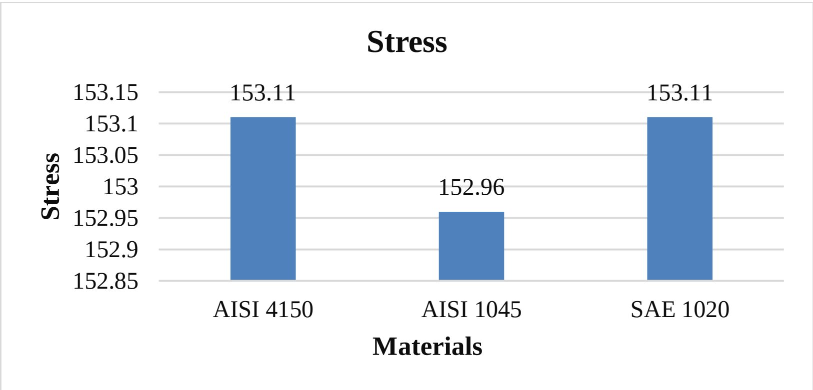

Figure 14: Stress of Front Axle beam using Elliptical section

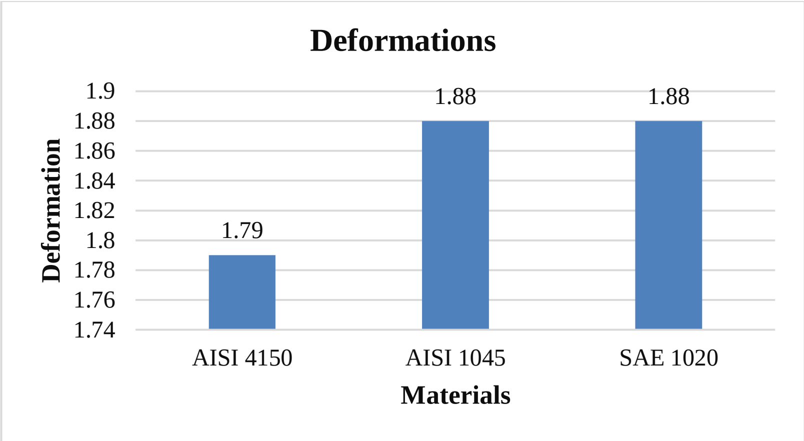

Figure 15: Deformation of Front Axle beam using Elliptical section

Figure 14 shows the Stress of Front Axle beam using Elliptical section. Figure 15 show the deformation of axle model between materials in which minimum deformation found on the AISI 4150 material, and maximum deformation found on the AISI 1045 and SAE 1020.

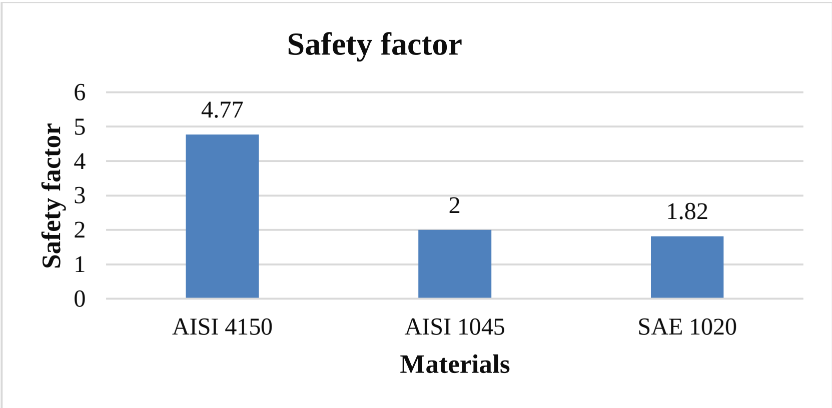

Figure 16: Safety factor of Front Axle beam using Elliptical section

Figure 16 shows the variations of safety factor in materials of front axle in which maximum safety factor due to stresses found on the AISI 4150 material.

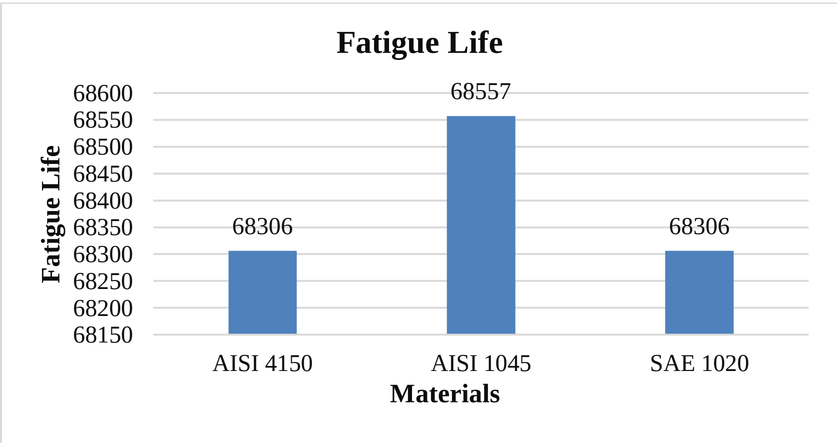

Figure 17: Fatigue life of Front Axle beam using Elliptical section

Figure 17 shows the variations in fatigue life in materials used in front axle, in which the maximum fatigue life found on the AISI 1045 material is 68557.

4.5 Comparison of Fatigue life between I section and Elliptical section

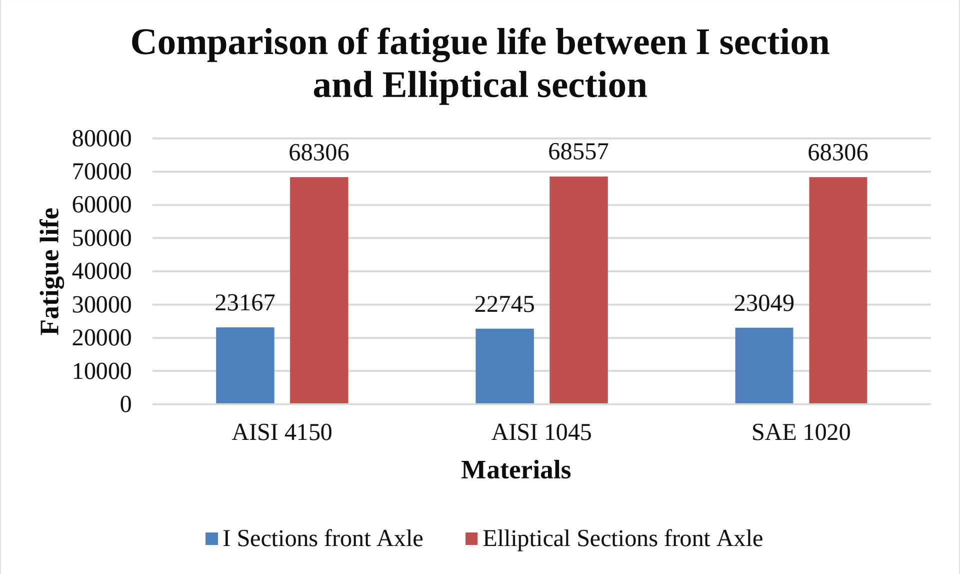

Figure 18: Comparison of fatigue life between I section and Elliptical section of front axle

Figure 18 shows the comparison of fatigue life of front axle beam used for commercial vehicle in we found the maximum fatigue life on the Elliptical section used to design the front axle, I section shows lower fatigue life as comparison of Elliptical section so the as per loading behaviour of axle in fatigue life found better on the elliptical section**.**

5. CONCLUSION

Using finite element analysis, the stress distribution analysis of the front axle was explored. CAD software was used to create the axle model. Based on the data gathered, the front axle's dimensions match the actual dimensions. The model has to be mesh in order to conduct the simulation with the FE programmer. The outcome will be more accurate if smaller element size values are used. Before running the simulation, the front axle's parameters and boundary conditions were all established in the FE analysis. The research effort mentioned above leads to the following conclusions:

- As per study of material variations in front axle we found the minimum deformation in AISI 4150 Material and maximum deformation found on AISI 1045, SAE 1020.
- while comparing the front axle with I section and axle with elliptical section, the deformation variations shows same there are no changes in deformation between I section and Elliptical section.
- As per comparison of stress in front axle maximum stress found in I section element, maximum stress of 206.63 MPa in AISI 1045 material found and minimum stress found in front axle with elliptical section is 152.96 MPa on AISI 1045 material.
- While comparison of Safety factor of front axle between I section and elliptical section, we found maximum safety factor on elliptical section with AISI 1045 material.
- Fatigue life of Elliptical section front axle beam found maximum as compared to I section front axle beam, maximum fatigue life found on the 68557 on AISI 1045 material.
- As per comparing all data we found the strength in elliptical section as compared to the I section.
- Based on materials analysis in Front axle design, we found AISI 4150 material on this material maximum fatigue life found, and minimum stress found so the comparison shows the AISIS 1045 material shows the good results in Elliptical section front axle model.
- In the I section axle beam maximum fatigue life found on the AISI 4150 material with less stress so if we design the I section front axle then the material AISI 4150 will be suitable as per our study.

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