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Structural Analysis of a Heavy Vehicle Chassis Made of Different Alloys by Different Cross Sections

Abhishek Sharma[1] – Automobile Engineering 2012-14 (M-Tech), SCME Galgotias University

Mr. Pramod Kumar[2]- Professor, SCME, Galgotias University

Abdul Jabbar[3] - Automobile Engineering 2012-14(M-Tech), SCME, Galgotias University.

Mohammad Mamoon Khan[4] - Automobile Engineering 2012-14(M-Tech), SCME, Galgotias University

***Abstract*- The chassis consists of the internal frame work which is used to support the vehicle under the certain circumstances they face during the working of the vehicle.**

This paper describes the design and analysis of the heavy vehicle chassis. The strength of the chassis is an important issue for the industry when the weight of the chassis is reduced. In the present work, the dimension of the TATA LPS 2515 EX chassis is used for the structural analysis of the heavy vehicle chassis with three different alloys subjected to the same conditions of the steel chassis.

The three material used for the chassis are grey cast iron, AISI 4130 alloy steel and ASTM A710 STEEL GRADE A (CLASS III). There are different shapes of the cross sections that were used in this work i.e. C, I and Box type cross sections. A three dimensional solid Model was built in the CAE software CATIA V5 parametric and the analysis was done in ANSYS-15.0.

I. INTRODUCTION

The chassis is considered to be the most significant component of an automobile. It is the most crucial element that gives strength and stability to the vehicle under different conditions. Automobile frames provide strength and flexibility to the automobile. The backbone of any automobile, it is the supporting frame to which the body of an engine, axle assemblies are affixed. Tie bars, that are essential parts of automotive frames, are fasteners that bind different auto parts together the chassis is usually very heavy of the vehicle especially the large vehicles for e.g. trucks, trailers, Lorries and also for some rough terrain vehicles.

Layout of Chassis and its main Components:

The following main components of the Chassis are

1. Frame: it is made up of long two members called side members riveted together with the help of number of cross members.
2. Engine or Power plant: It provides the source of power.
3. Clutch: It connects and disconnects the power from the engine fly wheel to the transmission system.
4. Gear Box
5. U Joint
6. Propeller Shaft
7. Differential

TYPES OF CHASSIS FRAMES

There are three types of frames
1. Conventional frame
2. Integral frame
3. Semi-integral frame

1. Conventional frame: It has two long side members and 5 to 6 cross members joined together with the help of rivets and bolts. The frame sections are used generally.
a. Channel Section - Good resistance to bending
b. Tabular Section - Good resistance to Torsion
c. Box Section - Good resistance to both bending and Torsion

2. Integral Frame: This frame is used now days in most of the cars. There is no frame and all the assembly units are attached to the body. All the functions of the frame carried out by the body itself. Due to elimination of long frame it is cheaper and due to less weight most economical also. Only disadvantage is repairing is difficult.

3. Semi - Integral Frame: In some vehicles half frame is fixed in the front end on which engine gear box and front suspension is mounted. It has the advantage when the vehicle is met with accident the front frame can be taken easily to replace the damaged chassis frame. This type of frame is used in FIAT cars and some of the European and American cars.

II. SPECIFICATION OF THE PROBLEM

The objective of the present work is to design and analyze the chassis of the TATA truck with the material it is manufactured and also for the other metal alloys viz., grey cast iron, AISI 4130 alloy steel and ASTM A710 STEEL GRADE A (CLASS III). The solid model of the chassis was created in CATIA V5. Model was imported in ANSYS 15.0 for analysis by applying the normal load conditions. The model was tested for stress and deformation as the design constraints. After analysis a comparison is made between existing conventional steel chassis and polymeric composite heavy vehicle chassis viz., grey cast iron, AISI 4130 alloy and ASTM A710 STEEL GRADE A (CLASS III) in terms of deflections and stresses, to choose the best one.

III. CHASSIS MATERIALS

Currently the material used for the chassis is A709M Grade 345w structural steel which is known as structure steel in simple words with the varying chemical composition leading to changes in names. The typical chemical composition of the material is 0.565C, 1.8% Si, 0.7%Mn, 0.045%P and 0.045% S.

Grey cast iron- The composition of gray cast iron in terms of its entire constituent elements can be explained as follows:

- Carbon (up to 4%)
- Silicon (up to 3%)
- Manganese (0.8%)
- Sulphur (.07%)
- Phosphorus (0.2%)
- Molybdenum (up to 0.75%)
- Chromium (0.35%)
- Vanadium (0.15%)

AISI 4130 alloy steel- AISI stands for the American Iron and Steel Institute, has given the designation to the steel alloy with the particular composition of material like AISI 4130, AISI 4140. AISI 4130 is also known as the chrome-moly alloy steel which stands for chromium-molybdenum alloy steel. The chemical composition of the AISI 4130 steel alloy is given as follows:

- Carbon (0.28-0.33)
- Chromium (0.8-1.1)
- Iron (97.3-98.22)
- Manganese (0.4-0.6)
- Molybdenum (0.15-0.25)
- Phosphorus (up to 0.035)
- Sulphur (up to 0.04)
- Silicon (0.15-0.35)

ASTM A710 STEEL GRADE A (CLASS III)- ASTM stands for American Society for Testing and Materials and has given the designation to the alloy steel the grade of ASTM A710 steel with a particular composition. The chemical composition is given as follows:

- Carbon (0.07)
- Manganese (0.4-0.7)
- Phosphorus (0.025)
- Sulphur (0.025)
- Silicon (0.035)
- Chromium (0.60-0.90)
- Nickel (0.7-1)
- Molybdenum (0.15-0.25)
- Copper (1-1.3)
- Niobium (0.02)

Table: 1 physical properties of alloys

material	modulus of elasticity (GPa)	Density (kg/m^3)	tensile strength (MPa)	yield strength (MPa)
A709M Grade 345 W Structure steel	200	7850	460	260
Grey cast iron	110	7200	240	-
AISI 4130 steel alloy	207	7798	1030	910
ASTM A710 steel grade A	205	7850	515	450

IV. SPECIFICATION OF EXISTING HEAVY VEHICLE CHASSIS

Table: 2 Specifications of heavy vehicle chassis

S. NO	Parameters	Value
1	Total length of the chassis	8200 mm
2	Width of the chassis	80 mm
3	Thickness of the chassis	6mm
4	Front chassis cabin length	2400 mm
5	Front cabin chassis area	492800 mm^2
6	Front cabin chassis applying load	60368 N
7	Back body chassis length	5800 mm
8	Back body chassis area	1200000 mm^2
9	Back body chassis applying load	196200 N
10	Engine applying load	5782 N
11	Fuel tank applying load	2853.76 N
12	Young's modulus of steel chassis	2 e5 N/mm^2
13	Density of steel chassis	7850 kg/m^3

V. STRUCTURAL ANALYSIS OF HEAVY VEHICLE CHASSIS

Dimension of the chassis for the alloys are taken from the conventional structure steel heavy vehicle chassis. The dimensions of the chassis are same as that of the conventional chassis and so does the load applied to the chassis. The element has six degrees of freedom at each node: translations in the nodal x, y, and z directions and rotations about the nodal x, y, and z-axes. The finite element analysis is carried out on the structural steel chassis as well as on the other three different types of metal alloys chassis.

From the analysis the equivalent stress (Von-misses stress) and displacements were determined and are shown in figure 1-30. Table 2 - 4 shows the comparative analysis of steel chassis and chassis of other three steel alloys.

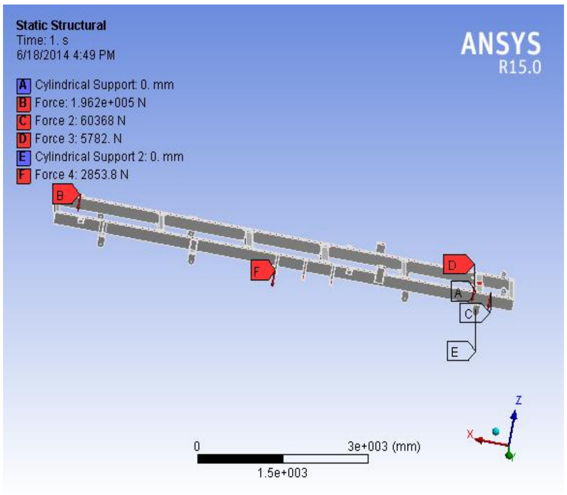

Figure 1: boundary conditions for chassis

VI. STRUCTURAL ANALYSIS OF C - CHANNEL SECTION

6.1 A709M Grade 345 W Structure steel

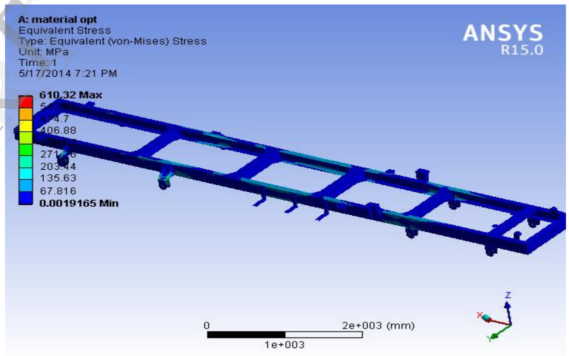

Figure 2: Stress distribution for A709M Grade 345 W Structure steel

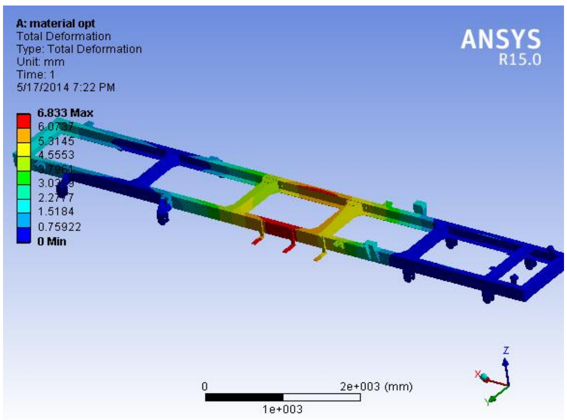

Fig 3: Displacement pattern for A709M Grade 345 W Structure steel

6.2 Grey Cast Iron

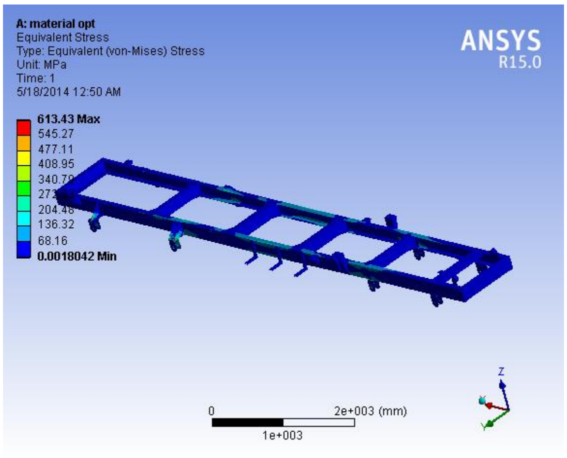

Figure 4: Stress distribution for grey cast iron

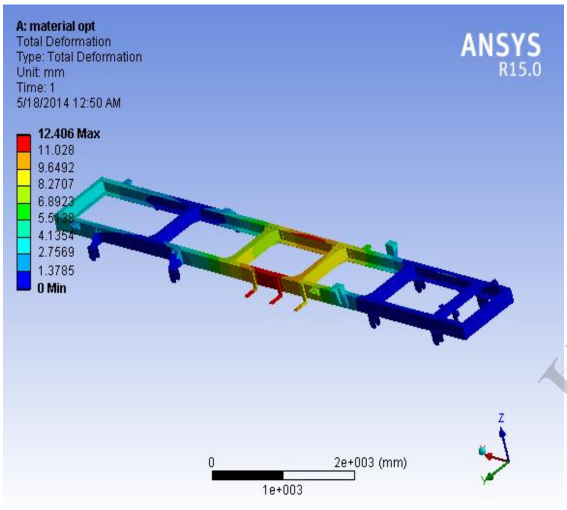

Figure 5: Displacement pattern for grey cast iron

6.3 AISI 4130 Steel Alloy

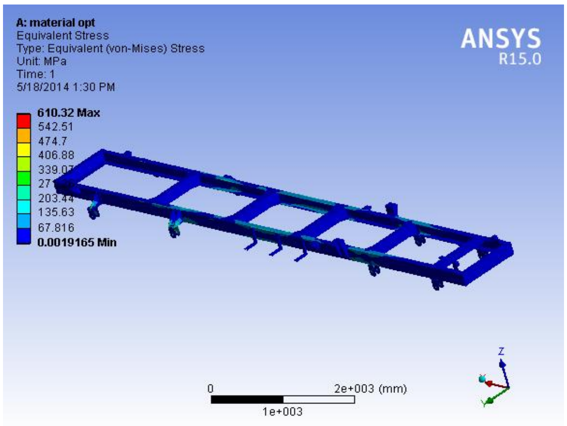

Figure 6: Stress distribution for AISI 4130 steel alloy

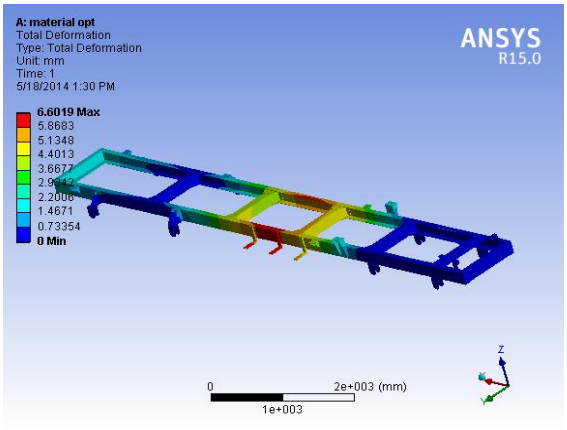

Figure 7: Displacement pattern for AISI 4130 Steel alloy

6.4 ASTM A710 steel grade A

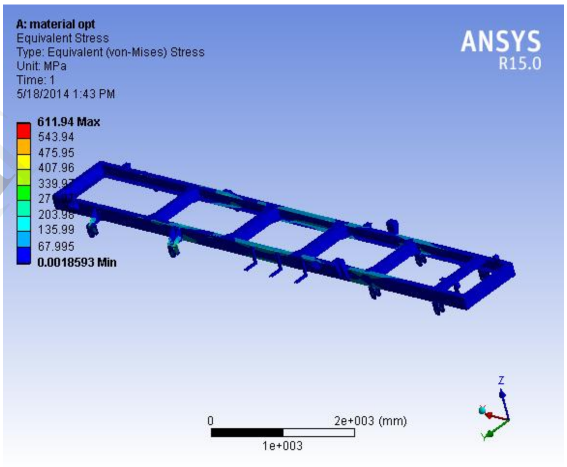

Figure 8: Stress distribution for ASTM A710 steel grade

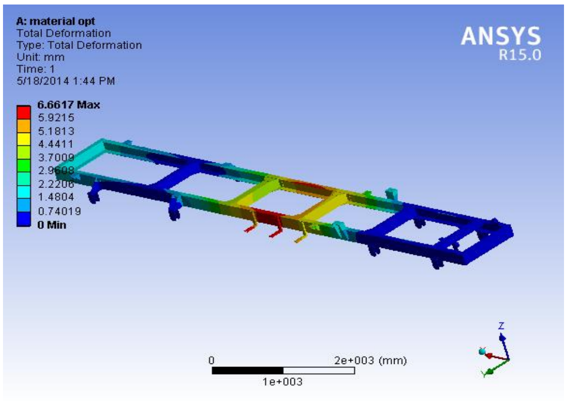

Figure 9: Displacement pattern for ASTM A710 steel grade A

VII. STRUCTURAL ANALYSIS OF I - CHANNEL SECTION

7.1 A709M Grade 345 W Structure steel

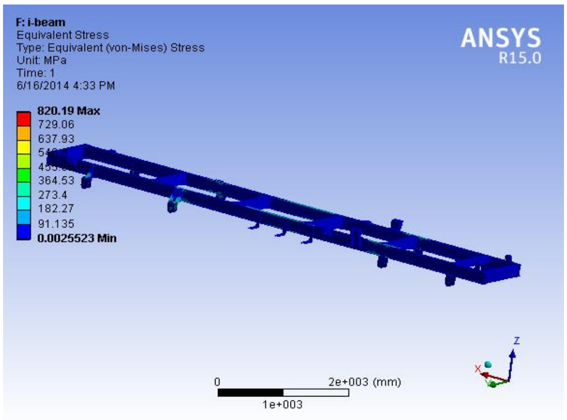

Figure 10: Stress distribution for A709M Grade 345 W Structure steel

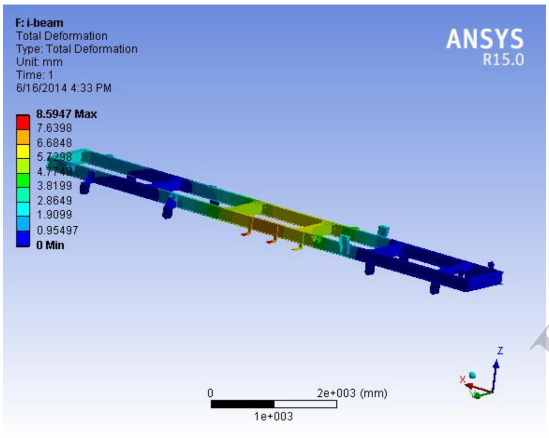

Figure 11: Displacement pattern for A709M Grade 345 W Structure steel

7.2 Grey Cast Iron

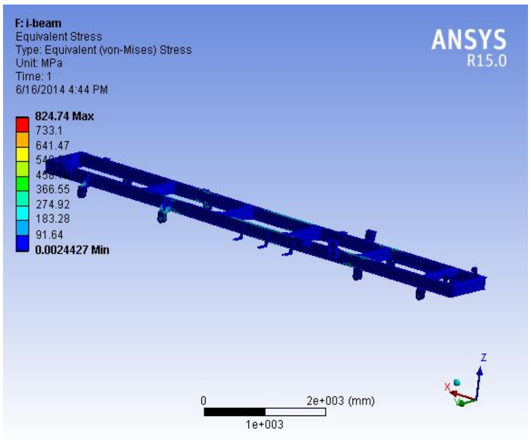

Figure 12: Stress distribution for grey cast iron

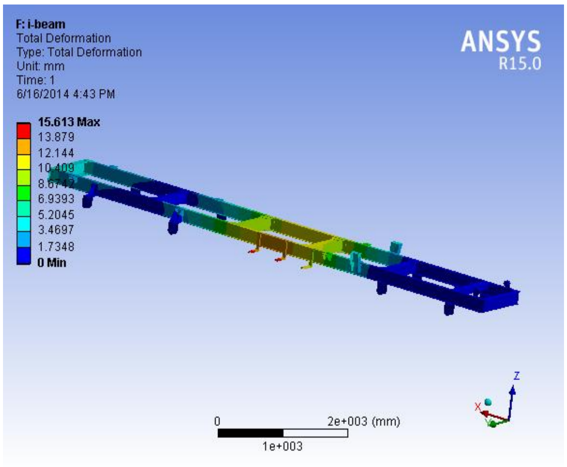

Figure 13: Displacement pattern for grey cast iron

7.3 AISI 4130 Steel Alloy

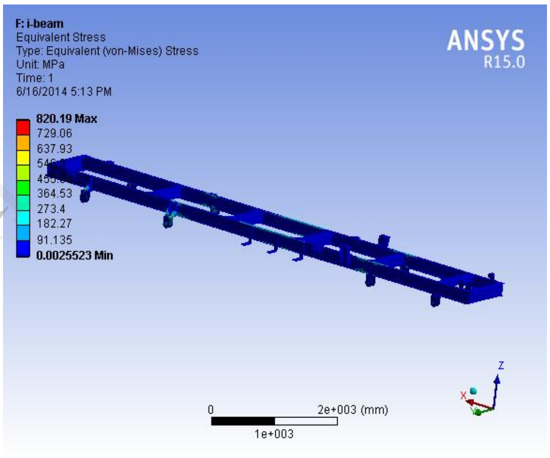

Figure 14: Stress distribution for AISI 4130 steel alloy

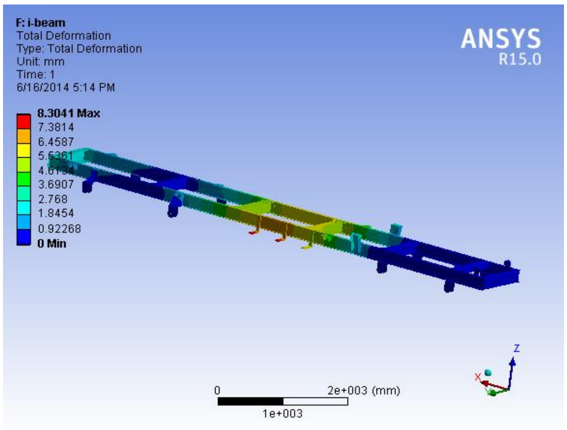

Figure 15: Displacement pattern for AISI 4130 steel alloy

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7.4 ASTM A710 steel grade A

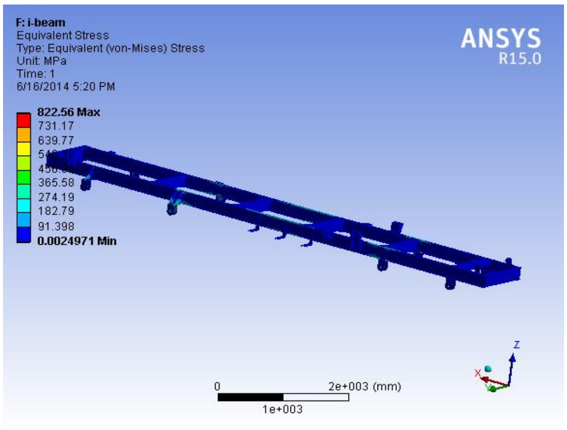

Figure 16: Stress distribution for ASTM A710 steel grade

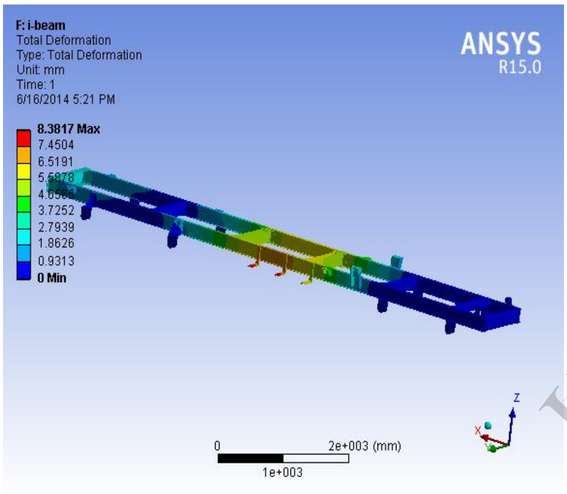

Figure 17: Displacement pattern for ASTM A710 steel grade A

VIII. STRUCTURAL ANALYSIS OF BOX - CHANNEL SECTION

8.1 A709M Grade 345 W Structure Steel

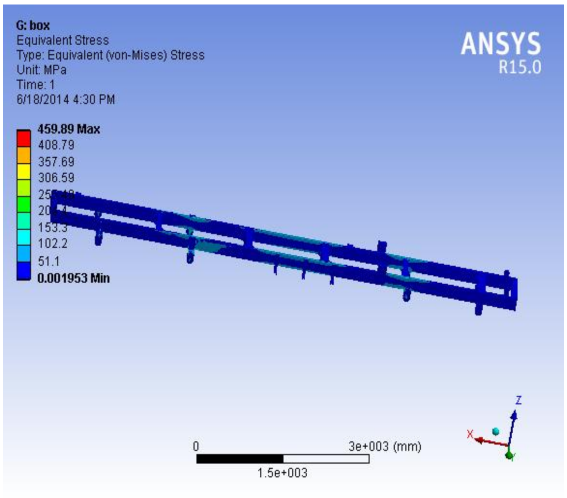

Figure 18: Stress distribution for A709M Grade 345 W Structure steel

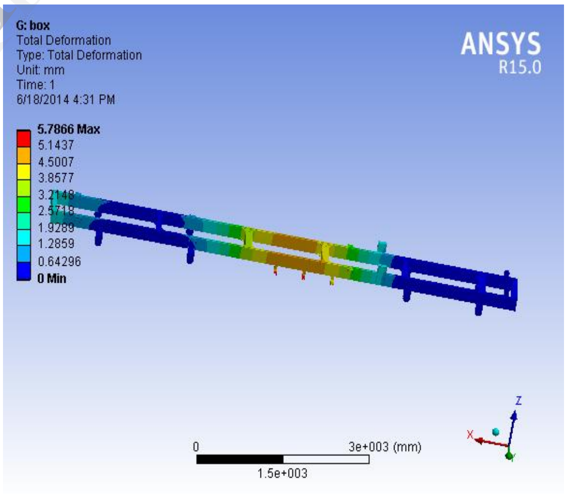

Figure 19: Displacement pattern for A709M Grade 345 W Structure Steel

8.2 Grey Cast Iron

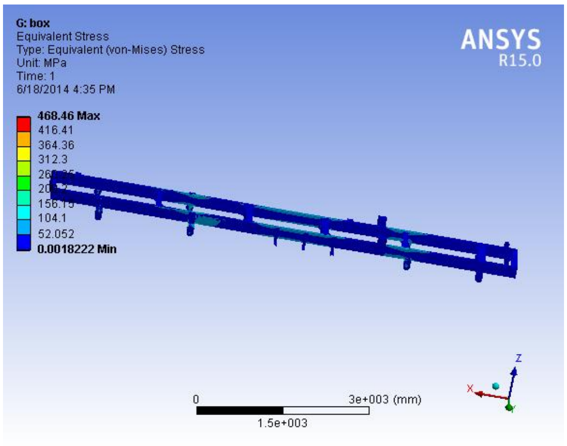

Figure 20: Stress distribution for grey cast iron

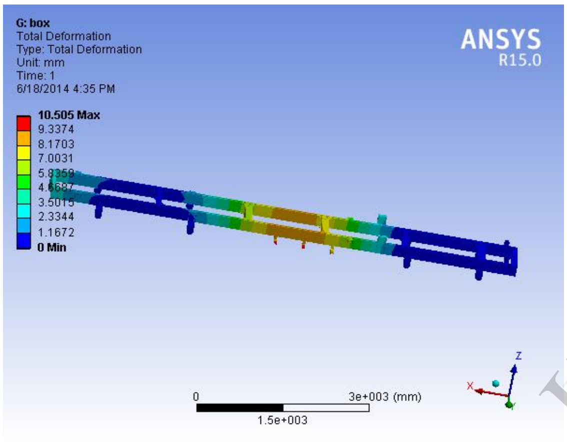

Figure 21: Displacement pattern for grey cast iron

8.3 AISI 4130 Steel Alloy

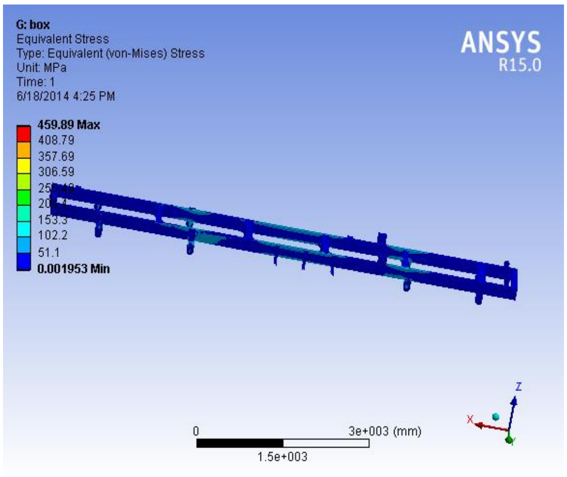

Figure 22: Stress distribution for AISI 4130 Steel Alloy

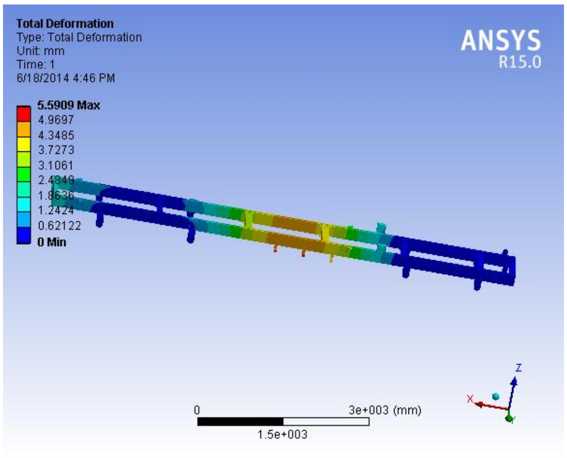

Figure 23: Displacement pattern for AISI 4130 Steel Alloy

8.4 ASTM A710 steel grade A

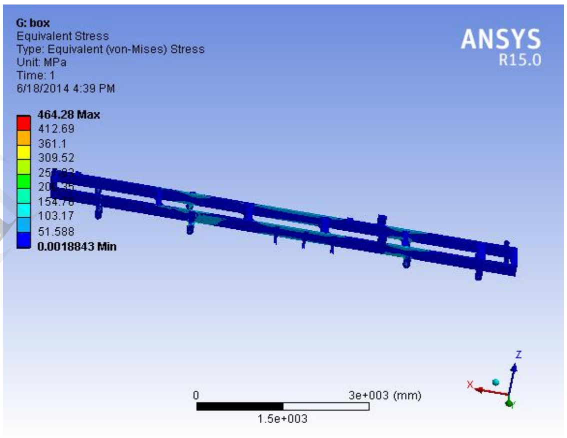

Figure 24: Stress distribution for ASTM A710 steel grade A

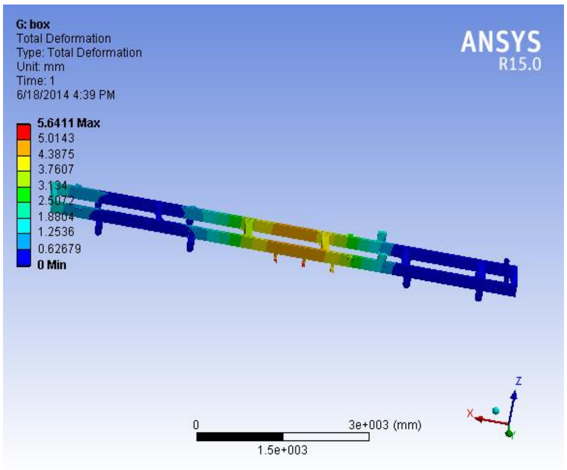

Figure 25: Displacement pattern for ASTM A710 steel grade A

Table 3: Comparative analysis of structure steel heavy vehicle chassis and other alloy steel chassis for C-section

S. No	parameter	A709M Grade 345 W Structure steel	Grey cast iron	AISI 4130 Steel Alloy	ASTM A710 steel grade A
1	Weight (kg)	527.58	483.9	524.09	527.58
2	Stress (N/mm^2)	610.32	613	610.32	611.94
3	Deformation (mm)	6.833	12.406	6.6019	6.617

Table 4: Comparative analysis of structure steel heavy vehicle chassis and other alloy steel chassis for I-section

S. No	parameter	A709M Grade 345 W Structure steel	Grey cast iron	AISI 4130 Steel Alloy	ASTM A710 steel grade A
1	Weight (kg)	509.68	467.47	506.3	509.68
2	Stress (N/mm^2)	820.19	824.74	820.19	822.56
3	Deformation (mm)	8.5947	15.613	8.3041	8.3817

Table 5: Comparative analysis of structure steel heavy vehicle chassis and other alloy steel chassis for box channel section

S. No	parameter	A709M Grade 345 W Structure steel	Grey cast iron	AISI 4130 Steel Alloy	ASTM A710 steel grade A
1	Weight (kg)	627.36	575.41	623.21	267.63
2	Stress (N/mm^2)	459.89	468.46	459.89	464.29
3	Deformation (mm)	5.7866	10.505	5.5909	5.6441

IX. CONCLUSION

The results shows that for all of the materials that have been tested in this text, AISI 4130 steel alloy shows better performance than all of the other metal alloys. It is seen that the default material for the chassis i.e. A709M Grade 345 W Structure steel shows strength equal to the AISI 4130 steel alloy but in case of the deformation AISI 4130 alloy is superior to structure steel.

In this text, different cross section shapes have been analysed, which gives the conclusion that the box channel section is best in strength and have less deformation, but the weight of the chassis is high compared to all of the cross sections. If the I-beam chassis is considered the stress and deformation are very high, it can also fail during operation.

So, for the consideration of alloy for the chassis AISI 4130 alloys is better than others and for different cross sections of the chassis C-section chassis is suitable for the heavy trucks.

From the result it can also be considered that the AISI 4130 alloy is lighter than all of the alloys and on the same side providing the strength as well.

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