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Modeling and Structural analysis of heavy vehicle chassis made of polymeric composite material by three different cross sections

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ABSTRACT: *The chassis frame forms the backbone of a heavy vehicle, its principle function is to safely carry the maximum load for all designed operating conditions.*
This paper describes design and analysis of heavy vehicle chassis. Weight reduction is now the main issue in automobile industries. In the present work, the dimensions of an existing heavy vehicle chassis of a TATA 2515EX vehicle is taken for modeling and analysis of a heavy vehicle chassis with three different composite materials namely, Carbon/Epoxy, E-glass/Epoxy and S-glass /Epoxy subjected to the same pressure as that of a steel chassis. The design constraints were stresses and deflections. The three different composite heavy vehicle chassis have been modeled by considering three different cross-sections. Namely C, I and Box type cross sections. For validation the design is done by applying the vertical loads acting on the horizontal different cross sections. Software is used in this work PRO – E 5.0 for modeling, ANSYS 12.0 for analysis.

Keywords: *heavy vehicle chassis, Static analysis, Carbon/Epoxy, E-glass/Epoxy and S-glass /Epoxy,*

I. INTRODUCTION

Automotive chassis is a skeletal frame on which various mechanical parts like engine, tires, axle assemblies, brakes, steering etc. are bolted. 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.

Automotive frames are basically manufactured from steel. Aluminum is another raw material that has increasingly become popular for manufacturing these auto frames. In an automobile, front frame is a set of metal parts that forms the framework which also supports the front wheels. It provides strength needed for supporting vehicular components and payload placed upon it.

Automotive chassis is considered to be one of the significant structures of an automobile. It is usually made of a steel frame, which holds the body and motor of an automotive vehicle. More precisely, automotive chassis or automobile chassis is a skeletal frame on which various mechanical parts like engine, tires, axle assemblies, brakes, steering etc are bolted. At the time of manufacturing, the body of a vehicle is flexibly molded according to the structure of chassis. Automobile chassis is usually made of light sheet metal or composite plastics. It provides strength needed for supporting vehicular components and payload placed upon it. Automotive chassis or automobile chassis helps keep an automobile rigid, stiff and unbending. Auto chassis ensures low levels of noise, vibrations and harshness throughout the automobile. The different types of automobile chassis include:

Ladder Chassis: Ladder chassis is considered to be one of the oldest forms of automotive chassis or automobile chassis that is still used by most of the SUVs till today. As its name connotes, ladder chassis resembles a shape of a ladder having two longitudinal rails inter linked by several lateral and cross braces.

Monocoque Chassis: Monocoque Chassis is a one-piece structure that prescribes the overall shape of a vehicle. This type of automotive chassis is manufactured by welding floor pan and other pieces together. Since monocoque chassis is cost effective and suitable for robotized production, most of the vehicles today make use of steel plated monocoque chassis.

Backbone Chassis: Backbone chassis has a rectangular tube like backbone, usually made up of glass fibre that is used for joining front and rear axle together. This type of automotive chassis or automobile chassis is strong and powerful enough to provide support smaller sports car. Backbone chassis is easy to make and cost effective.

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II. SPECIFICATION OF THE PROBLEM

The objective of the present work is to design and analyses, of steel chassis made and also polymeric composite heavy vehicle chassis made of three different composite materials viz., Carbon/Epoxy, E-glass/Epoxy and S-glass /Epoxy composites. polymeric composite heavy vehicle chassis was created in Pro-E. Model is imported in ANSYS 12.0 for analysis by applying normal load conditions. After analyis a comparison is made between exisisting conventional steel chassis and polymeric composite heavy vehicle chassis viz., Carbon/Epoxy, E-glass/Epoxy and S-glass /Epoxy in terms of deflections and stresses, to choose the best one.

III. COMPOSITE MATERIALS:

A composite material is defined as a material composed of two or more constituents combined on a macroscopic scale by mechanical and chemical bonds.

Composites are combinations of two materials in which one of the material is called the “matrix phase” is in the form of fibers, sheets, or particles and is embedded in the other material called the “reinforcing phase”.

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Another unique characteristic of many fiber reinforced composites is their high interal damping capacity. This leads to better vibration energy absorption within the material and results in reduced transmission of noise to neighboring structures. Many composite materials offer a combination of strength and modulus that are either comparable to or better than any tradional metalic metals. Because of their low specific gravities, the strength to weight-ratio and modulus to weight-ratios of these composite materials are markedly superior to those of mettalic materials.

The fatigue strength weight ratios as well as fatigue damage tolerances of many composite laminates are excellent. For these reasons, fiber composite have emerged as a major class of structural material and are either used or being considered as substitutions for metal in many weight-critical components in aerospace, automotive and other industries.

High damping capacity of composite materials can be beneficial in many automotive applications in which noise, vibration, and hardness is a critical issue for passenger comfort.

IV. SPECIFICATION OF EXISTING HEAVY VEHICLE CHASSIS:

Table 1 shows the specifications of a TATA 2515EX OF STEEL HEAVY vehicle. The typical chemical composition of the material is 0.565C, 1.8% Si, 0.7%Mn, 0.045%P and 0.045% S.

Table: 1 Specifications of heavy vehicle chassis

S.No	Parameters	Value
1	Total length of the chassis (Eye to Eye)	8200 mm
2	Width of chassis	80 mm
3	Thickness of chassis	6 mm
4	Front cabin chassis length	2400 mm
5	Front cabin chassis area	492800 mm^2
6	Front cabin chassis applying load	19620 N
7	Backbody chassis length	5800 mm
8	Backbody chassis area	1200000 mm^2
9	Backbody chassis applying load	196200 N
10	Young's Modulus of steel chassis	2.1e5 N/mm^2
11	Density of steel chassis	$7.86*10^{-6}$ N/mm^2

V. STRUCTURAL ANALYSIS OF HEAVY VEHICLE CHASSIS:

Dimensions of polymeric composite heavy vehicle chassis (PCHVC) are taken as that of the conventional steel heavy vehicle chassis (SHVC). PCHVC consists of 4 layers (thickness of each layer, 1.5mm). Width of the chassis is 80mm. Since the properties of PCHVC vary with directions of fiber, a 3-D model of chassis is used for analysis in ANSYS 12.0. The loading conditions are assumed to be static. The element choosen is SHELL LAYERED 46, which is a layered version of the 8-node structural shell model. 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 steel chassis as well as on three different types of polymeric composite heavy vehicle chassis. From the analysis the equivalent stress (Von-mises stress) and displacements

were determined and are shown in figure 1-30. Table 2 - 4 shows the comparative analysis of steel chassis and polymeric composite heavy vehicle chassis of three different materials.

VI. STRUCTURAL ANALYSIS OF C - CHANNEL SECTION:

6.1. STEEL

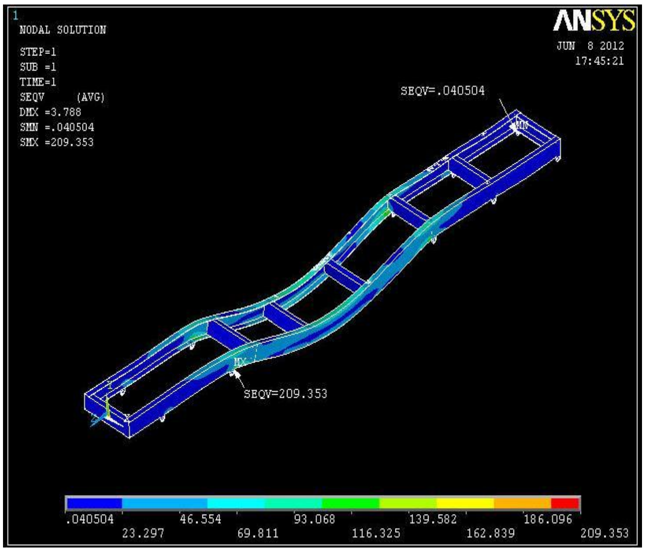


Fig1: Stress distribution for steel chassis

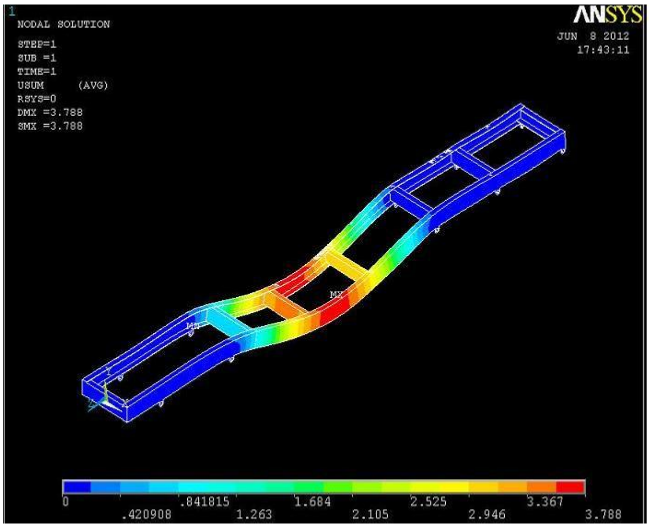


Fig 2: Displacement pattern for steel chassis

6.2 CARBON/EPOXY

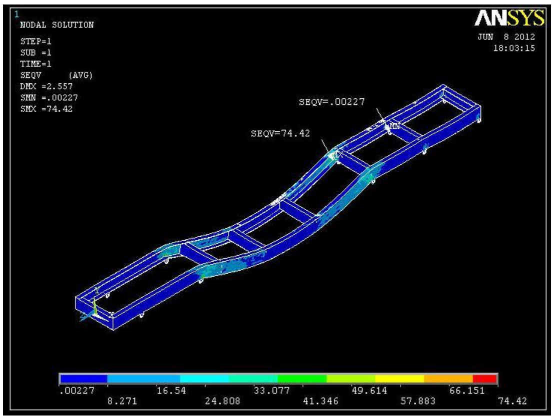


Fig 3: Stress distribution for carbon/epoxy.

6.3 E-GLASS/EPOXY

Fig 5: Stress distribution for E-glass/epoxy.

6.4 S-GLASSEPOXY

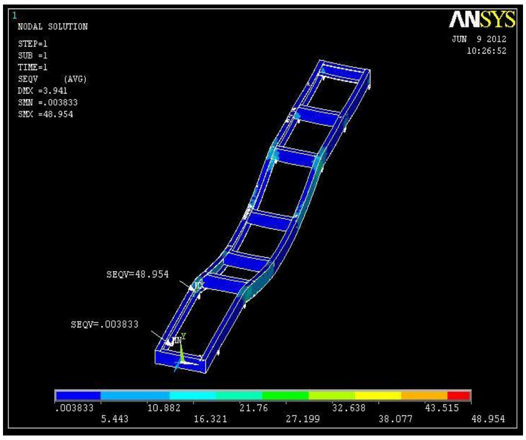


Fig 7: Stress distribution for S-glass/epoxy.

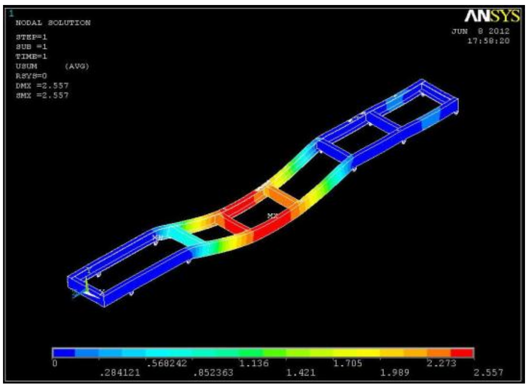


Fig 4: Displacement pattern for carbon/epoxy.

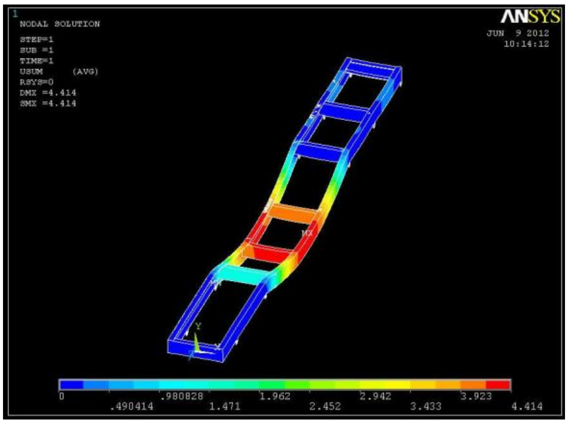


Fig 6: Displacement pattern for E-glass/epoxy.

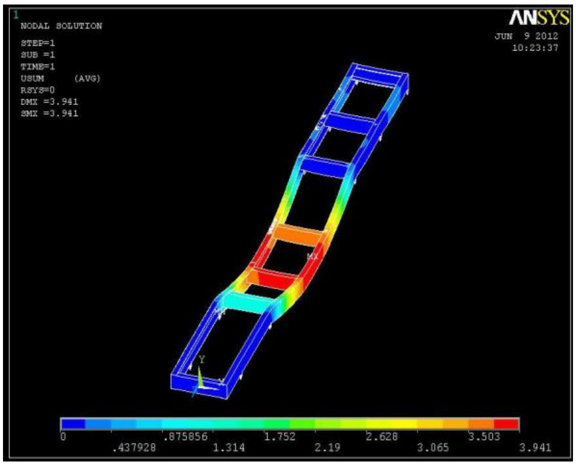


Fig 8: Displacement pattern for S-glass/epoxy

VII. STRUCTURAL ANALYSIS OF I - CHANNEL SECTION:

7.1 STEEL

Fig9: Stress distribution for steel chassis

7.2 CARBON/EPOXY

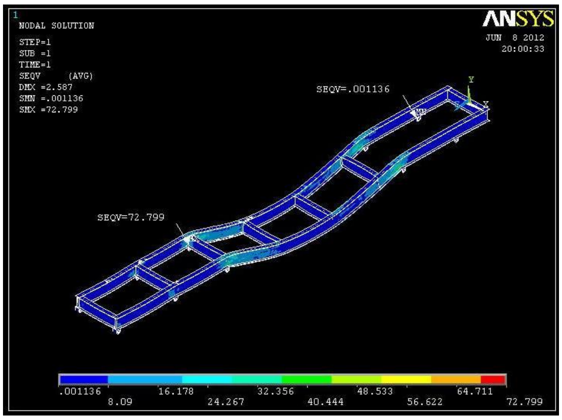


Fig 11: Stress distribution for carbon/epoxy.

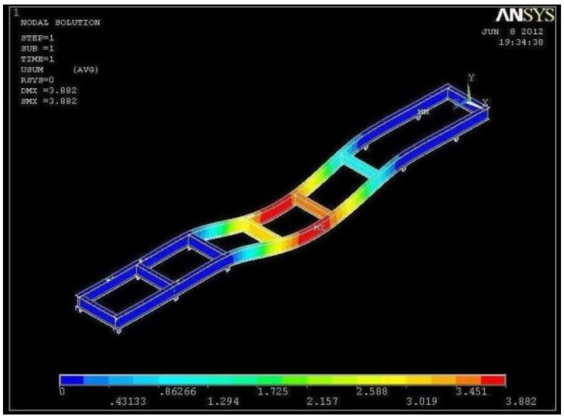


Fig 10: Displacement pattern for steel chassis.

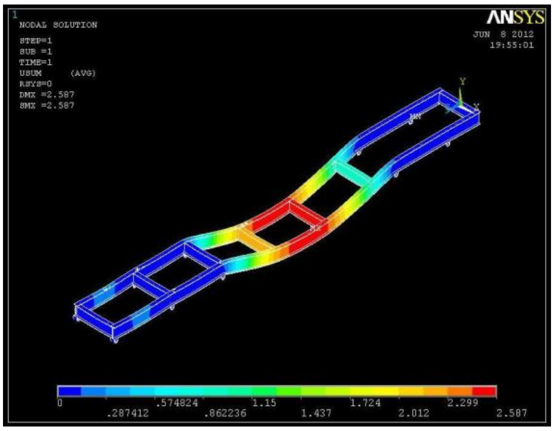


Fig 12: Displacement pattern for carbon/epoxy

7.3 E-GLASS/EPOXY

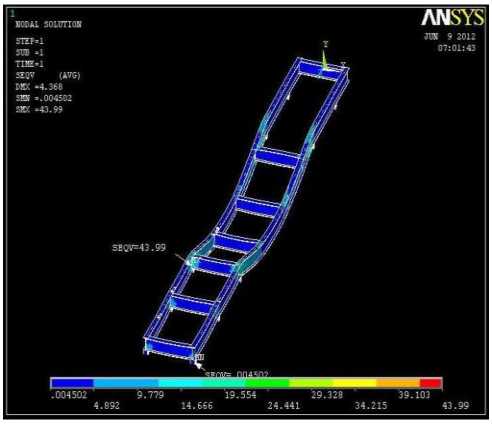
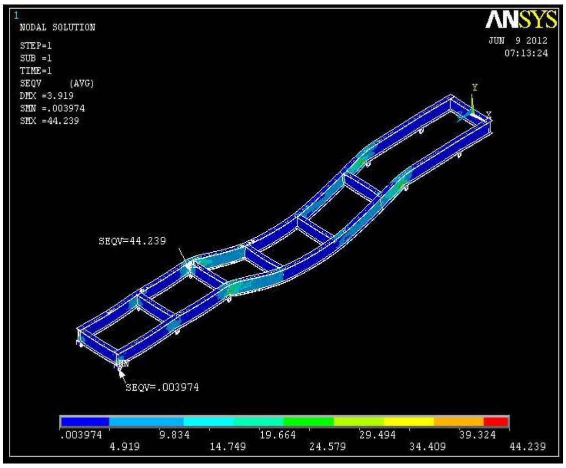


Fig13: Stress distribution for E-glass/epoxy

7.4 S-GLASS/EPOXY



. Fig 15: Stress distribution for S-glass/epoxy

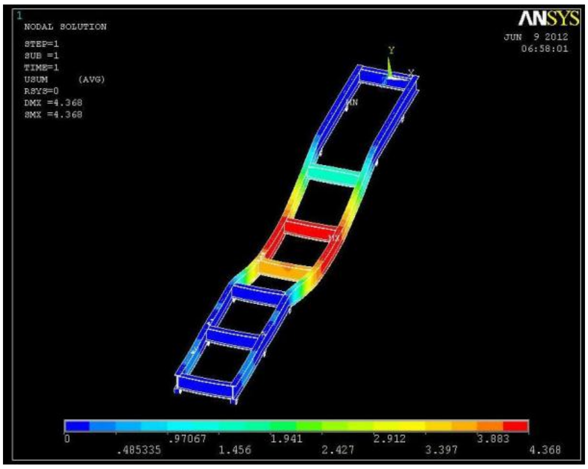


Fig 14: Displacement pattern for E-glass/epoxy

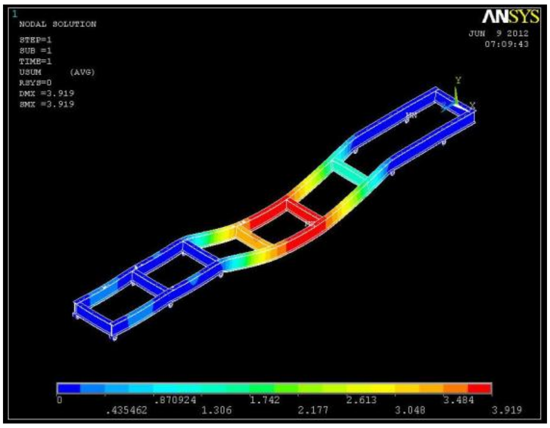


Fig 16 Displacement pattern for S-glass/epoxy

VIII. STRUCTURAL ANALYSIS OF BOX - CHANNEL SECTION:

8.1 STEEL

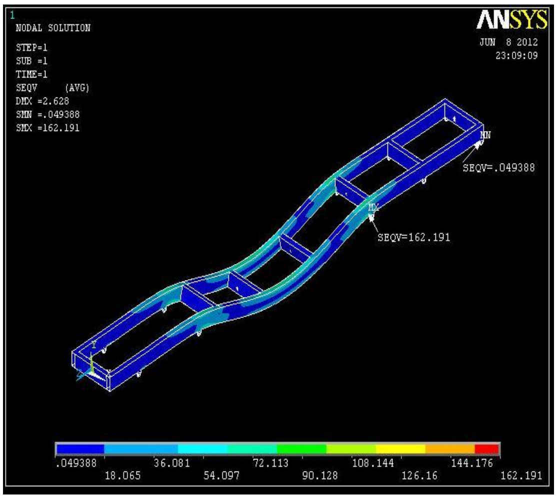


Fig17: Stress distribution for steel chassis

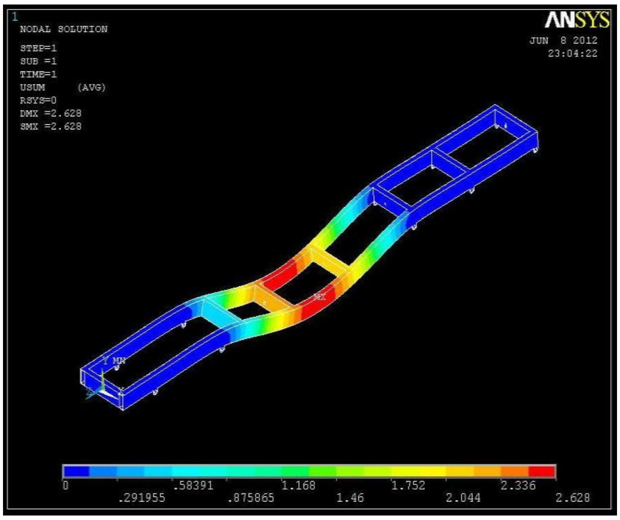


Fig 18: Displacement pattern for steel chassis.

8.2 CARBON/EPOXY

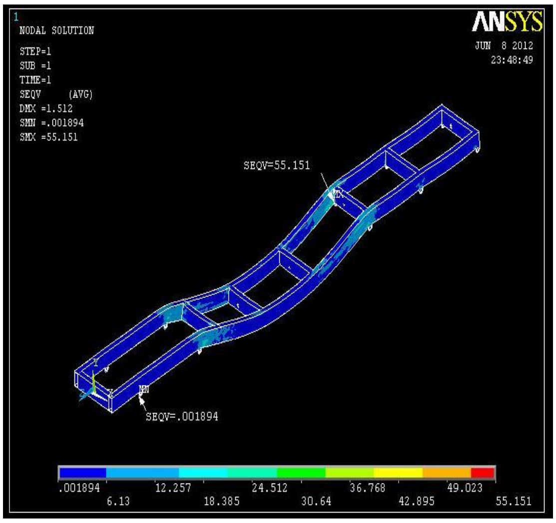


Fig 19: Stress distribution for carbon/epoxy.

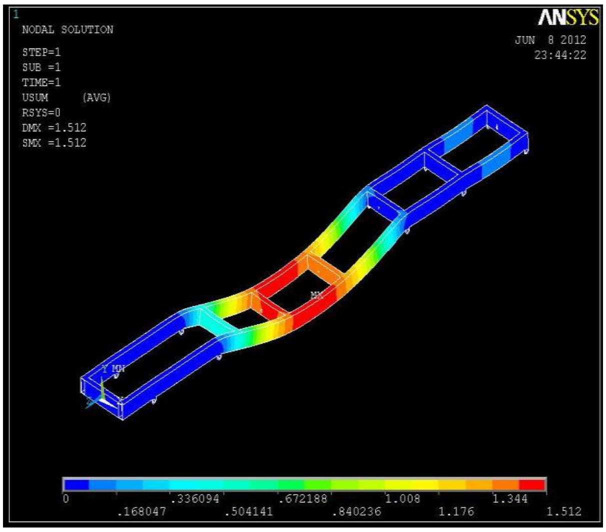


Fig 20: Displacement pattern for carbon/epoxy

8.3 E-GLASS/EPOXY

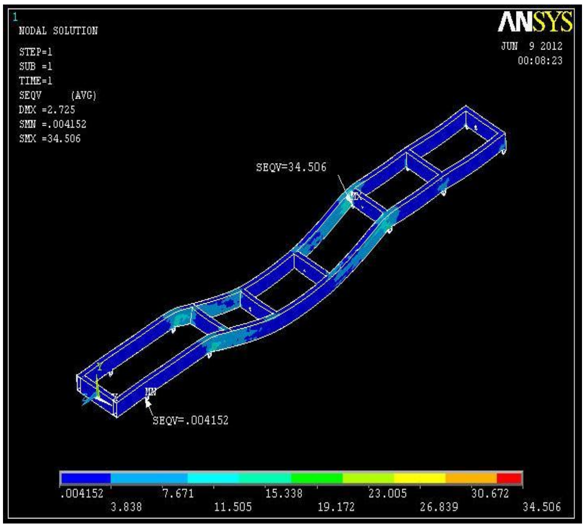


Fig 21: Stress distribution for E-glass/epoxy

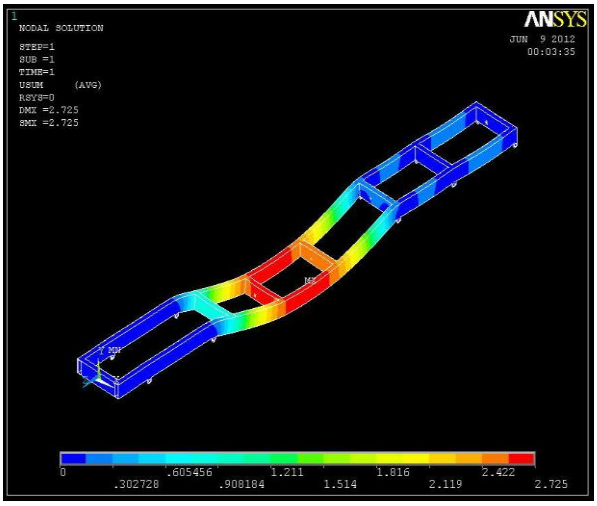
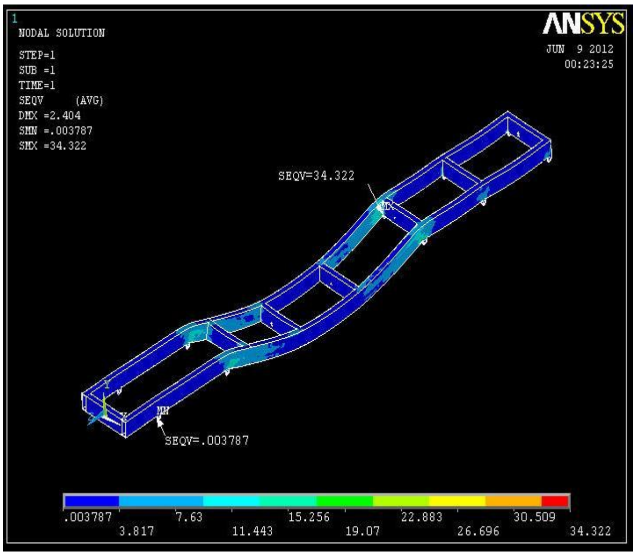


Fig 22: Displacement pattern for E-glass/epoxy

8.4 S-GLASS/EPOXY



. Fig 23: Stress distribution for S-glass/epoxy

8.

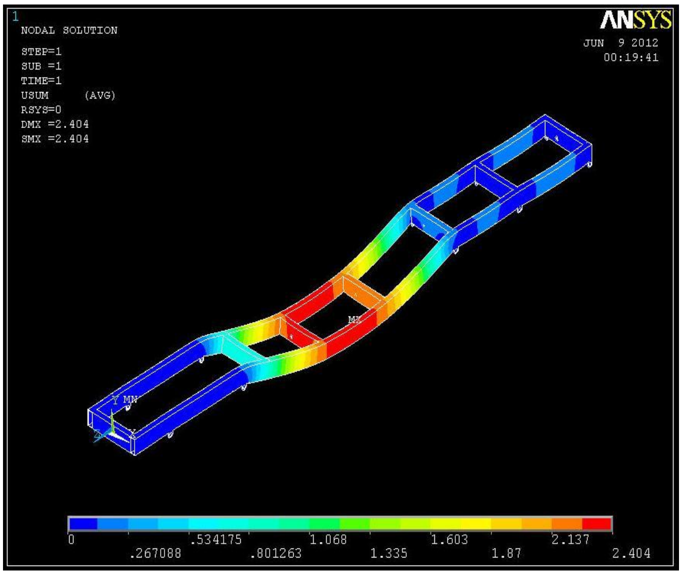


Fig 24: Displacement pattern for S-glass/epoxy

Table 2. Comparative Analysis of steel heavy vehicle chassis g and polymeric composite heavy vehicle chassis for C- Section.

S.No	parameter	steel	polymeric composite materials		
			Comp:1	Comp:2	Comp:3
1	Weight (kg)	412.6	82.953	110.258	105.00
2	Stress (N/mm^2)	209.35	74.42	48.99	48.95
3	Displacement (mm)	3.78	2.557	4.414	3.941

Table 3. Comparative Analysis of steel heavy vehicle chassis g and polymeric composite heavy vehicle chassis for I- Section

S.No	parameter	steel	polymeric composite materials		
			Comp:1	Comp:2	Comp:3
1	Weight (kg)	410.8	82.584	109.76	104.53
2	Stress (N/mm^2)	249.99	72.799	43.99	44.239
3	Displacement (mm)	3.882	2.587	4.368	3.919

Table 4. Comparative Analysis of steel heavy vehicle chassis g and polymeric composite heavy vehicle chassis for I- Section

S.No	parameter	steel	polymeric composite materials		
			Comp:1	Comp:2	Comp:3
1	Weight (kg)	608.35	122.28	162.53	154.71
2	Stress (N/mm^2)	162.89	55.151	34.506	34.322
3	Displacement (mm)	2.628	1.512	2.725	2.404

VIII. GRAPHS:

8.1. C-Section

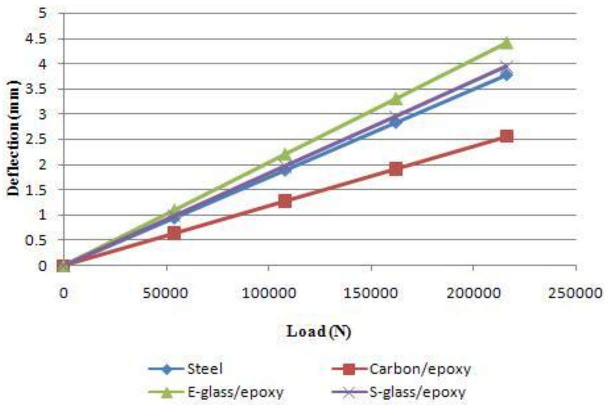


Fig 25: Load - Deflection curves for steel and polymeric composite material.

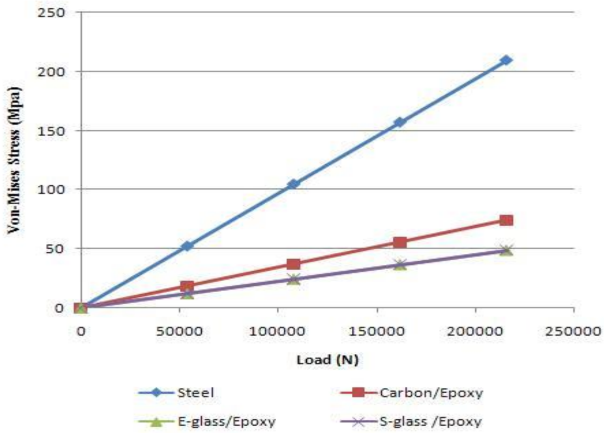


Fig 26: Load - Von-Misses Stress curves for steel and polymeric composite material

8.2.I-Section

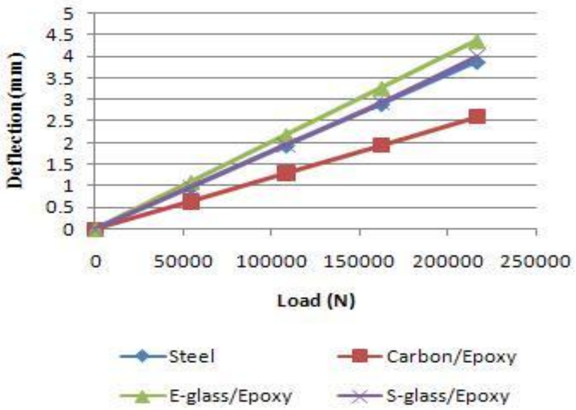


Fig 27: Load - Deflection curves for steel and polymeric composite material.

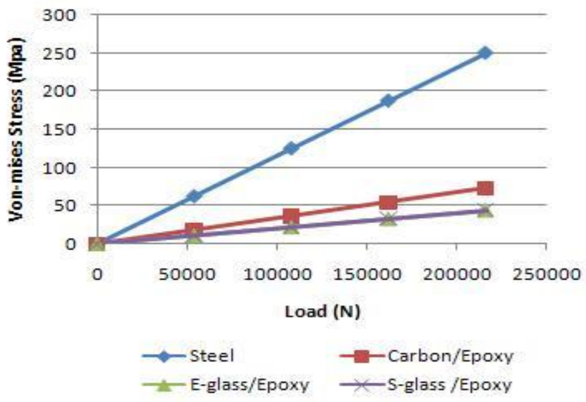


Fig 28: Load - Von-Misses Stress curves for steel and polymeric composite material

8.3. Box - Section

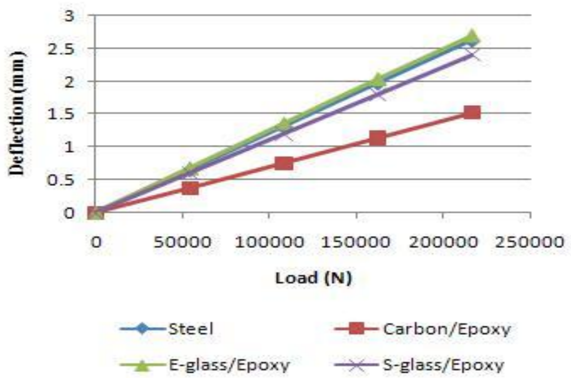


Fig 29: Load - Deflection curves for steel and polymeric composite material.

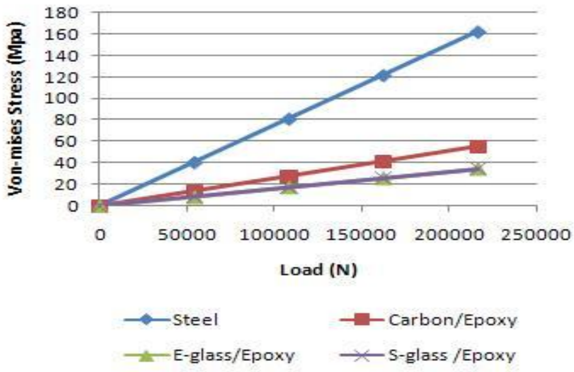


Fig 30: Load - Von-Misses Stress curves for steel and polymeric composite material

IX. CONCLUSIONS

To observe the all results and to compare the polymeric composite heavy vehicle chassis and steel heavy vehicle chassis with respect to weight, stiffness and strength.

By employing a polymeric composite heavy vehicle chassis for the same load carrying capacity, there is a reduction in weight of 73%~80%**,** natural frequency of polymeric composite heavy vehicle chassis are 32%~54% higher than steel chassis and 66~78% stiffer than the steel chassis**.**

Present used material for chassis is steel. I have considered polymeric composites Carbon/Epoxy, E-glass/Epoxy and S-glass /Epoxy for chassis material. Based on the results, it was inferred that carbon/epoxy polymeric composite heavy vehicle chassis I-SECTION chassis has superior strength and stiffness and lesser in weight compared to steel and other polymeric composite materials and other cross sections considered in this investigation.

From the results, it is observed that the polymeric composite heavy vehicle chassis is lighter and more economical than the conventional steel chassis with similar design specifications.

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10.1 Books:

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