VIBRATION SUPPRESSION OF HEAVY VEHICLE CHASSIS OF COMPOSITE STRUCTURE USING ANSYS

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ABSTRACT

High-technology structures often have stringent requirements for structural dynamics. Suppressing vibrations is crucial to their performance. Passive damping is used to suppress vibrations by reducing peak resonant response. Viscoelastic damping materials add passive damping to structures by dissipating vibration strain energy in the form of heat energy. The incorporation of damping materials in advanced composite materials offers the possibility of highly damped, light-weight structural components that are vibration-resistant.

The aim of the project is to analyze the heavy vehicle chassis without damping material and with damping material, damping material is hard rubber. The materials for heavy vehicle chassis are steel, carbon Epoxy and E – Glass Epoxy. The Static structural analysis is done to verify the strength of the heavy vehicle chassis and compare the results for three materials.

We are conducting analysis with the different number of layers 3, 5,11with in the limit of same thickness. Modal analysis is also done on the heavy vehicle chassis to determine mode shapes. In this project vibrations are reduced by using above materials in number of layers. Software used for modeling is Pro/Engineer and for analysis is ANSYS.

KEYWORDS: Chassis frame, Carbon Epoxy, E-Glass Epoxy, Structural analysis.

1.0 INTRODUCTION

A chassis consists of an internal framework that supports a man-made object. It is analogous to an animal's skeleton. An example of a chassis is the under part of a motor vehicle, consisting of the frame (on which the body is mounted) with the wheels and machinery.

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.

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.

The automotive chassis provides the strength necessary to support the vehicular components and the payload placed upon it. The suspension system contains the springs, the shock absorbers, and other components that allow the vehicle to pass over uneven terrain without an excessive amount of shock reaching the passengers or the cargo. The steering mechanism is an integral portion of the chassis, as it provides the operator with a means of controlling the direction of travel. The tyres grip the road surface to provide good traction that enables the vehicle to accelerate, brake, and make turns without skidding.

Automobile chassis is usually made of light sheet metal or composite plastics. The different types of automobile chassis include.

a) 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.

b) 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.

c) 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 robotised production, most of the vehicles today make use of steel plated monocoque chassis.

2.0 STRUCTURAL ANALYSIS

Static analysis calculates the effects of steady loading conditions on a structure, while ignoring inertia and damping effects, such as those caused by time-varying loads. A static analysis, however, includes steady inertia loads (such as gravity and rotational velocity), and time-varying loads that can be approximated as static equivalent loads. (such as the static equivalent wind and seismic loads commonly defined in many building codes).

2.1 LOADS IN A STRUCTURAL ANALYSIS

2.2 MATERIAL PROPERTIES

Sl. No.	Properties	Units	Steel	Carbon Epoxy	E-Glass Epoxy	Rubber
1	Young's Modulus E11	N/mm^2	2.068e^{11}	1.34 e^{11}	50 e^9	4
2	Density	kg/m^3	7830	1600	2000	2466
3	Poisson Ratio	-	0.3	0.3	0.3	0.49

2.3 DEFLECTION AND STRESS CALCULATIONS OF MAIN CHANNEL

L =total length of channel=7000mm, W=load on both channels=10,000kg ,(i.e) on one channel w=5000kg

- **Reaction**

$$R = \frac{WL}{2} = \frac{5000 X 7000}{2} X 9.81$$

R = 1.71 e^8

Applying load at a distance of mid (i.e) 3500mm

- **Bending moment**

$$Mmax = \frac{WL^2}{8}$$

$$Mmax = \frac{5000 X (7000)^2 X 9.81}{8}$$

Mmax = 3.00431 e^{11} Nmm

Static analysis is used to determine the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that is, the loads and the structure's response are assumed to vary slowly with respect to time. The kinds of loading that can be applied in a static analysis include:

Externally applied forces and pressures

Steady-state inertial forces (such as gravity or rotational velocity)

Imposed (non-zero) displacements, Temperatures (for thermal strain) ,Fluencies (for nuclear swelling)

- **Moment of inertia**

$$I = \frac{bd^2 - h^2(b-t)}{12}$$

$$I = \frac{70(220)^2 - (208)^2(70-6)}{12}$$

I = 14119136 mm4

- **Deflection**

$$Y = \frac{wl^2}{48EI}$$

For Alloy Steel

E = 206800Mpa

$$Y = \frac{5000 X (7000)^2}{48 X 14119136 X 206800}$$

Y = 12.23mm

- **For Carbon Epoxy**

E = 181000Mpa

$$Y = \frac{5000 X (7000)^2}{48 X 14119136 X 181000}$$

Y = 13.98mm

- **For E-lass epoxy**

E = 38600 Mpa

$$Y = \frac{5000 X (7000)^2}{48 X 14119136 X 38600}$$, Y = 65.55mm

Radius of gyration = $\sqrt{\frac{bd^5 - h^5(b-t)}{12(bd-h)(b-t)}}$

$$= \sqrt{\frac{70(220)^5 - (208)^8(70-6)}{12(70X220-208)(70-6)}}$$

R.G = 82.23mm

Area =bd – h(b-t) = 70 X 220 – 208 (70-6) = 2088 mm2

- **Modulus of section**

$$Z = \frac{bd^2 - h^2(b-t)}{6d}$$

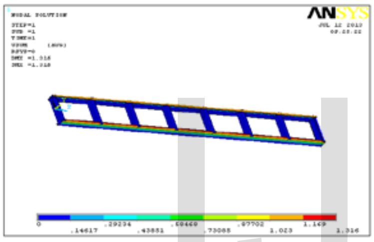
$$Z = \frac{70(220)^2 - (208)^2(70-6)}{6d} = 128355.7818$$

$$\text{Shear force} = \frac{Wb}{2} = \frac{5000 \text{ X } 70}{7000} = 50 \text{ X } 9.81 = 490.5\text{N}$$

3.0 STRUCTURAL AND MODAL ANALYSIS OF CHASSIS

WITHOUT DAMPING MATERIAL AND LAYERS

3.1 STEEL



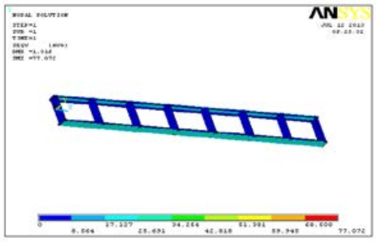
DISPLACEMENT

$$\text{Shear stress} = \frac{\text{shear force}}{\text{area}} = \frac{4905}{2088}$$

Shear stress = 0.2349N / mm2

$$\text{Stress at critical point} = \frac{Wl}{8z} = \frac{5000 \text{ X } 7000}{8 \text{ X } 128355.7818} \text{ X } 9.81 = 334.373\text{N/mm2}$$

$$\text{Stress at critical point} = \frac{Wl}{4z} = \frac{5000 \text{ X } 7000}{4 \text{ X } 128355.7818} \text{ X } 9.81 = 668.746\text{N/mm2}$$



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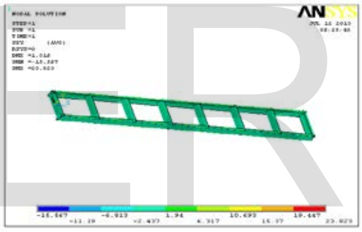
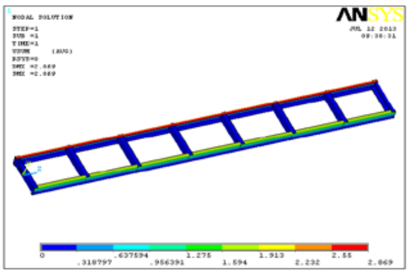


SHEAR STRESS IN XY

3.2 CARBON EPOXY



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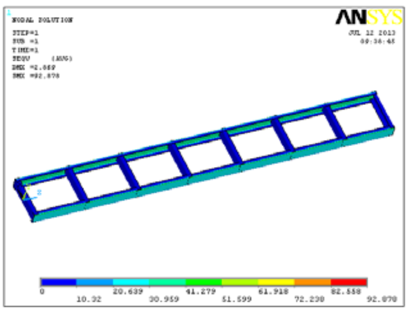

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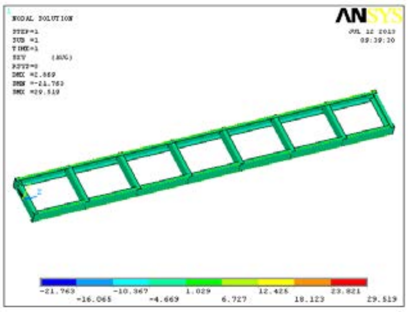
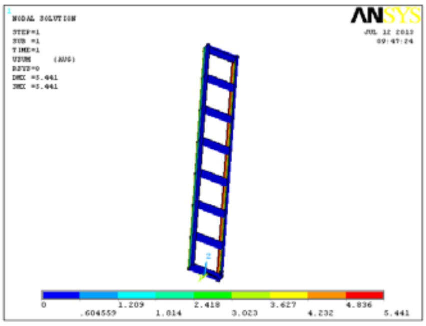


SHEAR STRESS IN XY

3.3 E - GLASS EPOXY



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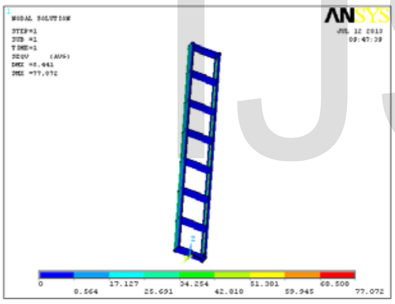

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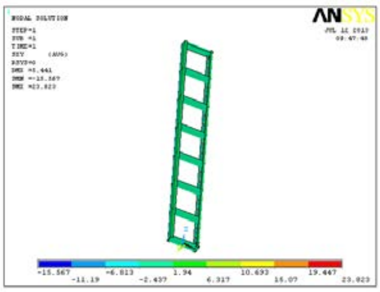
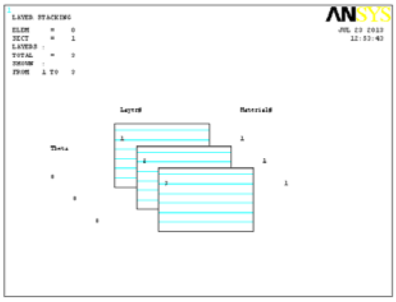


SHEAR STRESS IN XY

4.0 3LAYERS OF STACKING AND WITHOUT DAMPING

4.1CARBON EPOXY



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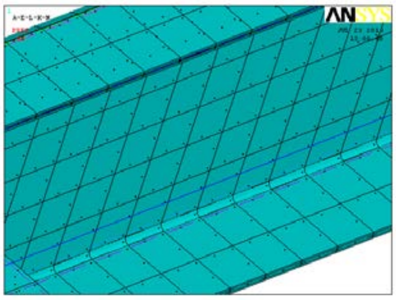

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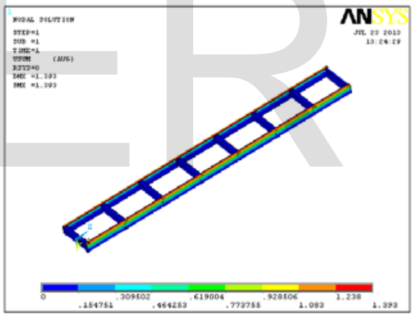

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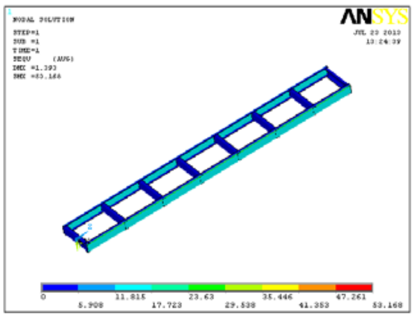

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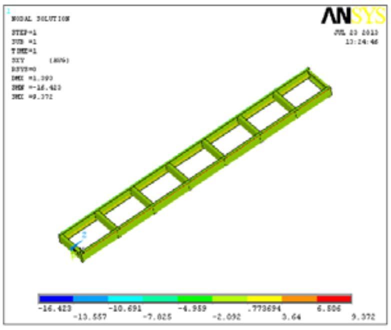
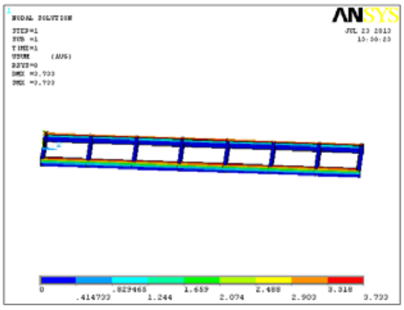


SHEAR STRESS IN XY

4.2 E - GLASS EPOXY



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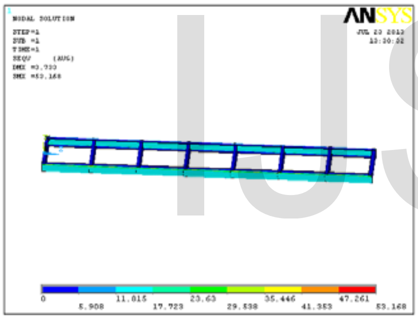

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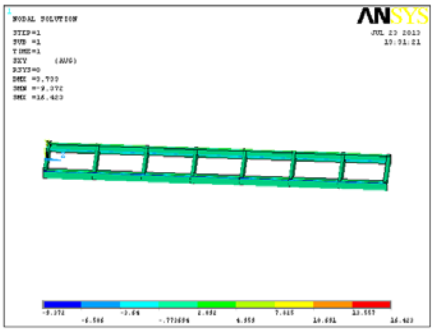
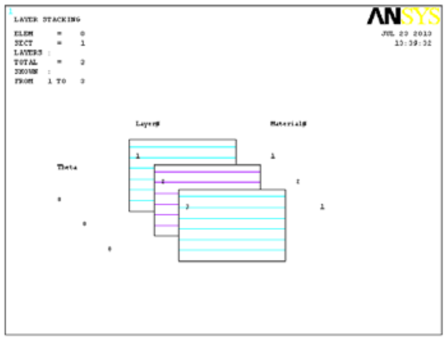


SHEAR STRESS IN XY

5.0 3LAYERS OF STACKING AND WITH DAMPING

5.1 CARBON EPOXY



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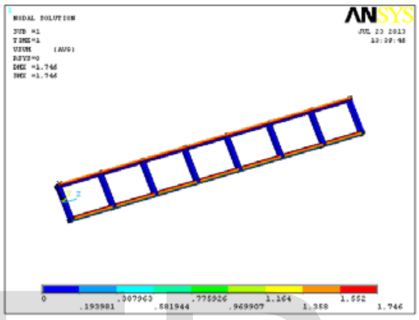

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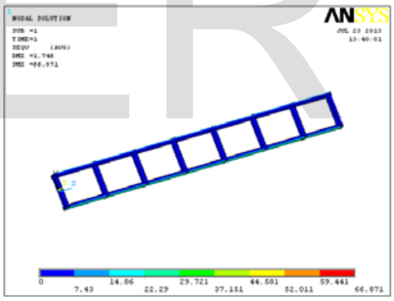

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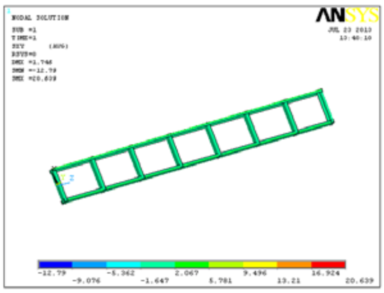
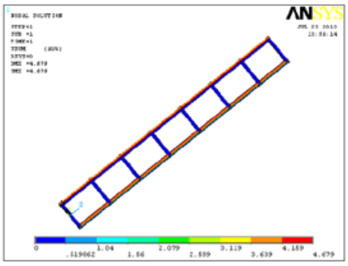


SHEAR STRESS IN XY

5.2 E – GLASS EPOXY



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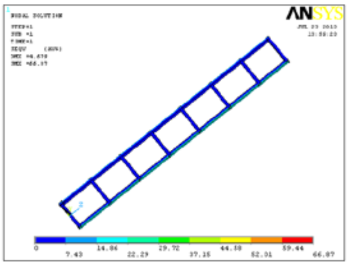

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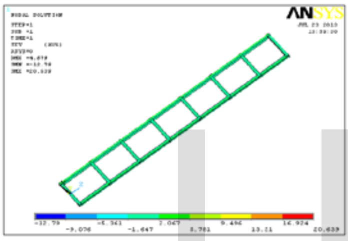
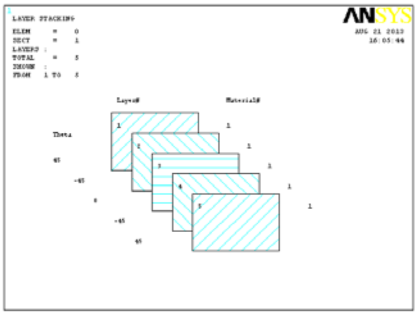


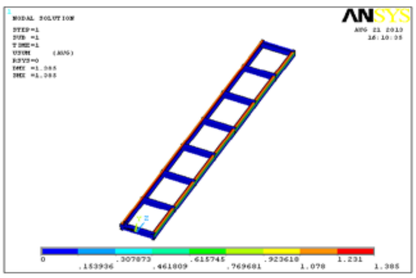
SHEAR STRESS IN XY

6.0 5LAYERS OF STACKING AND WITHOUT DAMPING

6.1 CARBON EPOXY



LAYER STACKING



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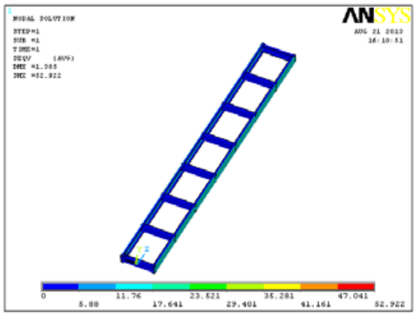

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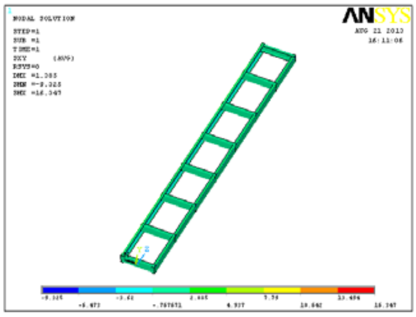
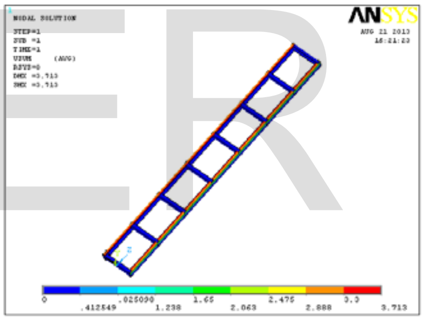


SHEAR STRESS IN XY

2 E – GLASS EPOXY



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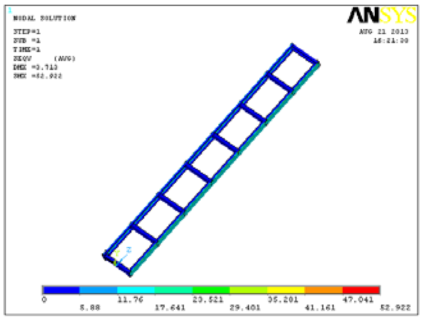

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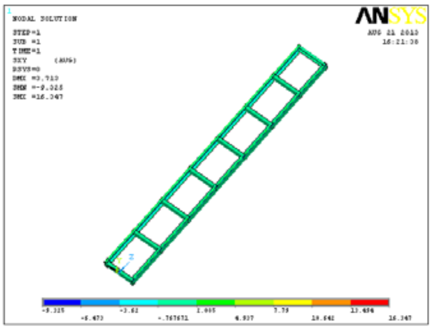
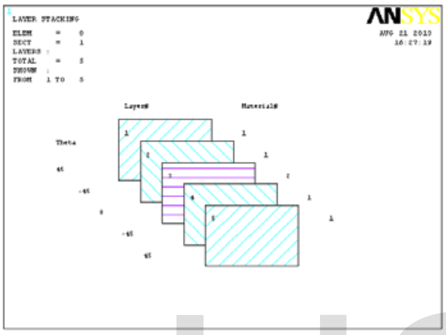


SHEAR STRESS IN XY

7.0 5LAYERS OF STACKING AND WITH DAMPING

7.1CARBON EPOXY



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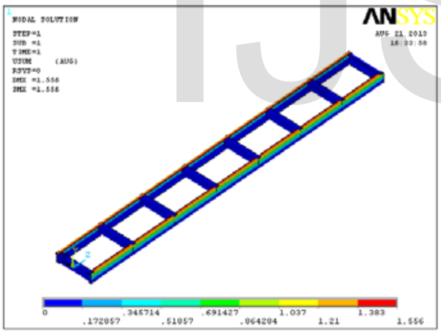

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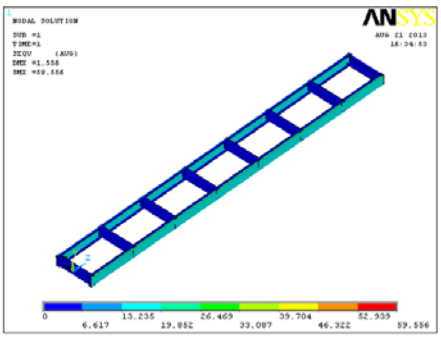

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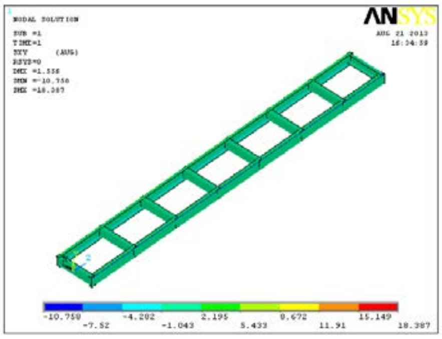
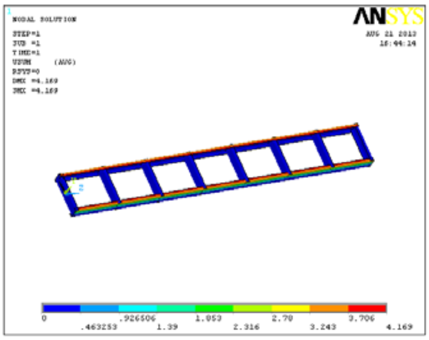


SHEAR STRESS IN XY

7.2 E – GLASS EPOXY



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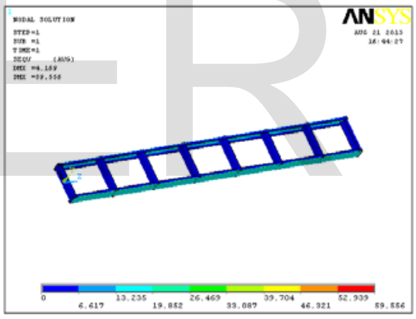

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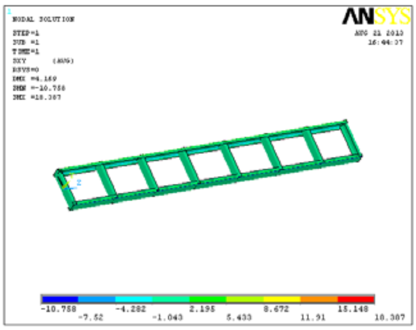
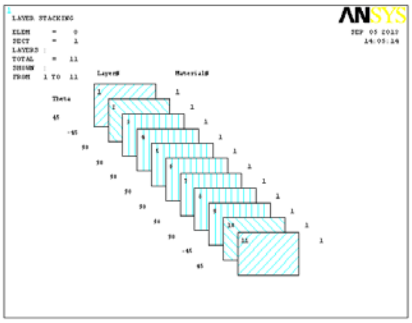


SHEAR STRESS IN XY

8 0 11LAYERS OF STACKING AND WITHOUT DAMPING

8.1 CARBON EPOXY



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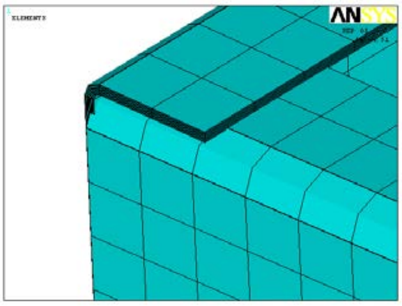
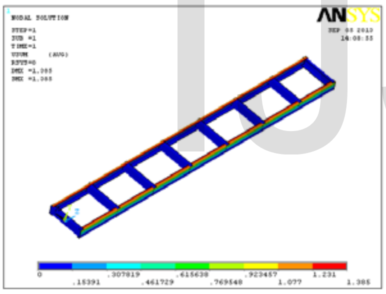


LAYERS



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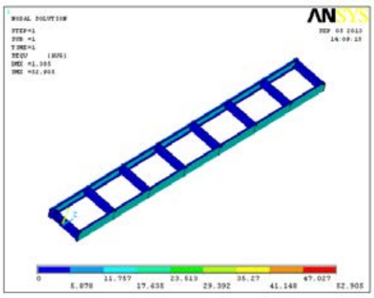

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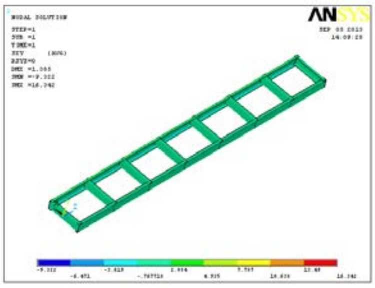
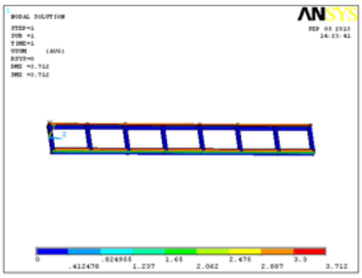


SHEAR STRESS IN XY

8.2 E - GLASS EPOXY



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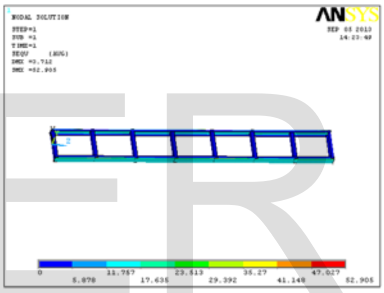

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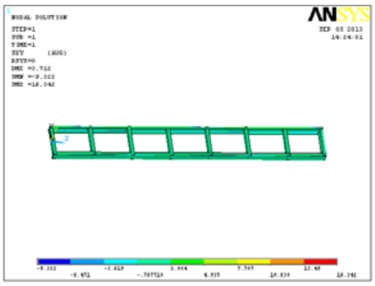
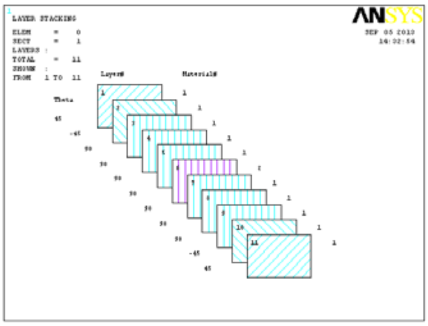


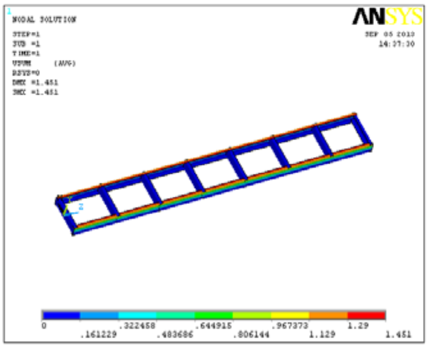
SHEAR STRESS IN XY

9.0 11LAYERS OF STACKING AND WITH DAMPING

9.1CARBON EPOXY



LAYER STACKING



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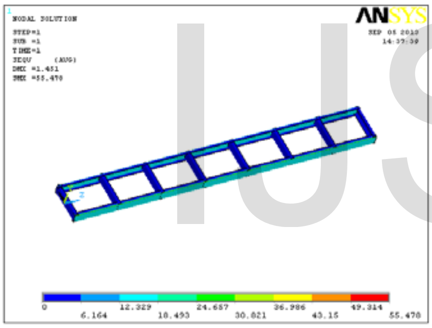

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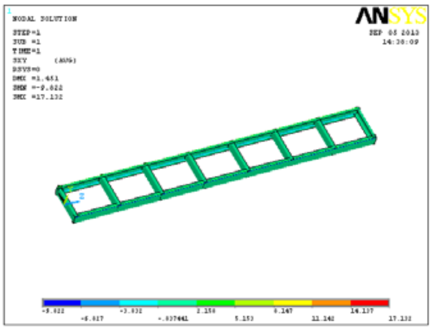
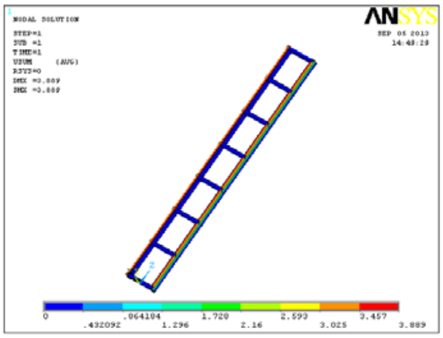


SHEAR STRESS IN XY

9.2 E – GLASS EPOXY



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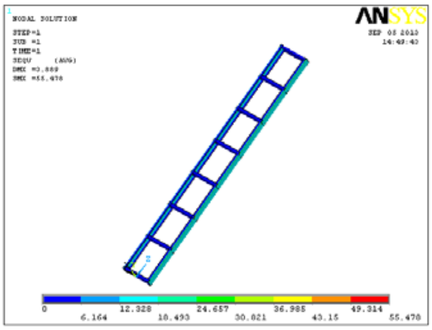
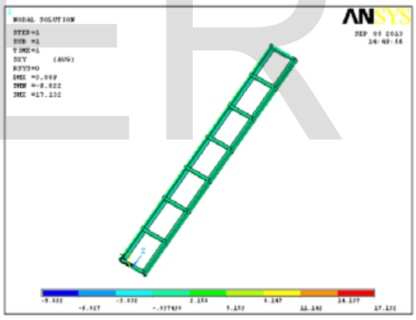


STRESS



SHEAR STRESS IN XY

10.0 RESULTS

10.1 STRUCTURAL ANALYSIS

10.2.1 SINGLE LAYER (WITHOUT RUBBER)

	STEEL	CARBON EPOXY	E – GLASS EPOXY
DISPLACEMENT (mm)	1.316	2.869	5.441
STRESS (N/mm^2)	77.072	92.878	77.072
SHEAR STRESS IN XY (N/mm^2)	23.823	29.519	23.823

10.3 MODAL ANALYSIS

10.3.1 SINGLE LAYER (WITHOUT RUBBER)

	STEEL	CARBON EPOXY	E – GLASS EPOXY
FREQUENCY (Hz)	10.253	10.365	10.487
DEFLECTION (mm)	0.282693	0.754949	0.516973
FREQUENCY (Hz)	11.184	12.907	10.881
DEFLECTION (mm)	0.436909	0.702322	0.864484

10.2.2 LAYERS

		3 LAYERS		5 LAYERS		11 LAYERS	
		CARBON EPOXY	E-GLASS	CARBON EPOXY	E-GLASS	CARBON EPOXY	E-GLASS
DISP (mm)	WITHOUT RUBBER	1.393	3.733	1.385	3.713	1.385	3.712
	RUBBER	1.746	4.679	1.556	4.169	1.145	3.889
STRESS (N/mm^2)	WITHOUT RUBBER	53.168	53.168	52.922	52.922	52.905	52.905
	RUBBER	66.871	66.87	59.556	59.556	55.458	55.478
SS IN XY (N/mm^2)	WITHOUT RUBBER	9.372	16.423	16.347	16.347	16.342	16.342
	RUBBER	20.639	20.639	18.387	18.387	17.132	17.132

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10.3.2 LAYERS

		3 LAYERS		5 LAYERS		11 LAYERS	
		CARBON EPOXY	E-GLASS	CARBON EPOXY	E-GLASS	CARBON EPOXY	E-GLASS
WITHOUT RUBBER	FREQ (Hz)	11.484	10.626	12.161	10.63	10.458	10.63
	DEF (mm)	0.77111	0.535469	0.741566	0.535734	0.741483	0.535026
WITH RUBBER	FREQ (Hz)	10.456	10.255	10.458	10.52	10.193	10.612
	DEF (mm)	0.741723	0.594189	0.741475	0.573445	0.757182	0.553569
WITHOUT RUBBER	FREQ (Hz)	13.84	11.24	14.624	11.297	12.945	11.297
	DEF (mm)	0.660034	0.526808	0.688868	0.441397	0.657333	0.512095
WITH RUBBER	FREQ (Hz)	12.943	11.142	12.945	11.247	12.616	11.246
	DEF (mm)	0.690787	0.503659	0.685244	0.525117	0.71186	0.525088

11.0 CONCLUSION

Chassis used in a heavy vehicle modeled using Pro/Engineer. Structural and modal analysis is done on the chassis using ANSYS. The analysis is done using three materials STEEL, CARBON EPOXY and E-GLASS EPOXY. And using different layers 3, 5 and 11 without and with damping material as RUBBER.

Presently steel is used for chassis composites Carbon Epoxy and E – Glass Epoxy are considered. By observing structural analysis results, the stress values for Carbon Epoxy and E –Glass Epoxy are less than their respective allowable stress values. So using composites for chassis is safe. By using composites instead of steel, the weight of the chassis reduces 4 times than by using steel because density of steel is more than the composites.

By using layers for same thickness of the chassis, the displacement and stress values are reduced than using as single layer. So it is better to take layers than as single layer.

By observing modal analysis results, vibrations produced are less by using damping material rubber than vibrations produced without using damping material. So using damping material reduces the vibrations in the chassis.

When comparing the composite materials Carbon Epoxy and E – Glass epoxy, the vibration's are less using E – Glass Epoxy than by using Carbon Epoxy. Based on a analysis result it is concluded using E-Glass E-poxy , composite is better for chassis.

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