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STRUCTURAL AND MODEL ANALYSIS OF A HEAVY VEHICLE CHASSIS FOR VIBRATION SUPRESSION

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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.*

I. 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.

Examples Of Use

Vehicle

In the case of vehicles, the term chassis means the frame plus the "running gear" like engine, transmission, driveshaft, differential, and suspension. A body (sometimes referred to as "coachwork"), which is usually not necessary for integrity of the structure, is built on the chassis to complete the vehicle. For commercial vehicles chassis consists of an assembly of all the essential parts of a truck (without the body) to be ready for operation on the road. The design of a pleasure car chassis will be different than one for commercial vehicles because of the heavier loads and constant work use. Commercial vehicle manufacturers sell “chassis only”, “cowl and chassis”, as well as "chassis cab" versions that can be outfitted with specialized bodies. These include motor homes, fire engines, ambulances, box trucks, etc.

In particular applications, such as school busses, a government agency like National Highway Traffic Safety Administration (NHTSA) in the U.S. define the design standards of chassis and body conversions.

II. GENERAL INFORMATION

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

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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:
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) Monologue 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.

III. TYPES OF AUTOMOBILE CHASSIS

***a) Motorcycle Chassis*:** An important type of automotive chassis, motorcycle chassis comprise of different auto parts and components like auto frame, wheels, two wheeler brakes and suspension. Its basically the frame for motorbikes that holds these components together. A motorbike chassis can be manufactured from different materials. But the commonly used materials are steel, aluminum, or magnesium.

***b) Car Chassis*:**
The main structure of a car is known as chassis. Car chassis functions as a support for the different car parts. Automotive parts like engine, suspension & steering mechanism, braking system, auto wheels, axle assemblies and transmission are mounted on the car chassis.

***c) Bus Chassis*:**
Bus chassis is the design and quality of bus chassis depends on the capacity of bus. It can be tailor made according to the needs and can be availed with features like transverse mounted engine, air suspension as well as anti-roll bars. A well manufactured bus chassis offers various benefits like high torque from low revs, superior brake performance and more. Bus chassis designed for urban routes differs from the one manufactured for suburban routes.

d) ***Truck Chassis*:**
Truck chassis, the backbone of any truck is designed to provide a comfortable and dependable ride. New invention in automotive sector has influenced the automobile chassis manufacturers to adopt latest trends and come up with new designs. In the present world, a truck chassis comes with enhanced geometry, power steering, disc brakes and other truck parts.

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IV. EARLY CHASSIS DESIGNS & LADDER-FRAME CHASSIS

Many of the principles and techniques used to build cars evolved from the manufacture of horse-drawn vehicles, and early chassis design reflects this. The image on the left shows a 1920's Dodge minus it's body, and is a typical example of pre-war chassis design: Two long rails running the length of the vehicle, with the engine mounted between them and the axles suspended underneath. The body would then be mounted on top of the chassis. This kind of chassis is generally known as a *ladder-frame* design, as the members that run between the two rails resemble the rungs of a ladder when viewed from above. To start with, the rails would have been simple, straight lengths, but over time the design of these chassis incorporated bends to clear axles, and to bring the rails closer together at the front where the engine mounts and so on. Aside from such minor changes, the essense of a ladder-frame chassis is unaltered since it's inception.

Building a chassis like this is technically undemanding: As long as you align everything properly, you can weld all the joints manually, and the materials used are cheap and easy to come by. However, it takes time to make all the joints, and the resulting structure suffers from a lack of diagonal bracing - it can be easily twisted along it's length. Also, the accepted technique for making a stronger, more rigid chassis involved adding extra members and using thicker material, which adds weight.

In general, a ladder-frame chassis is a crude, heavy structure that does not really provide a good platform for building a vehicle on. But why, then, did the design last so long - the chassis on the right is from a '60s Land Rover, and is pretty much identical to the design use in a 2005-model Defender?

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Fig:. Ladder Frame ***Chassis***

Monocoque chassis

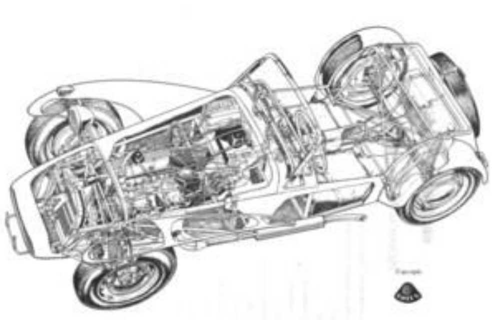

Fig: Monocoque chassis

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Ok, up until now, we've been looking at designs where a chassis takes all the structural loading, and the body panels just sit on the outside and look nice. The problem with this is that no matter how light you make the chassis, you're going to be adding weight when you put the body panels in place. There are two solutions to this problem. First, you could fit only the bare minimum of panels required to cover the chassis, made from the thinnest, lightest material easily available to you (say, sheet aluminium). If you did, then, you'd probably end up with something like the Lotus Seven pictured left, which is little more than a thinly-skinned chassis.

V. CHASSIS MATERIALS

Traditionally, the most common material for manufacturing vehicle chassis has been steel, in various forms. Over time, other materials have come into use, the majority of which have been covered here.

1) Steel

Let's face it. Steel is easy to get. Machinery to manipulate steel is easy to get. People who know how to work with steel are easy to get. Steel is easy - and it's also cheap. This is the main reason why 99% of the cars you find are made from steel, although the fact that it's actually a very useful material plays no small part. Steel is by no means a "does the job" or "poor man's" option - the material has many attributes that render it perfect for vehicle chassis manufacturing. First, yes, the cost and availability (of both the material and what you need to process it) are a major advantage for commercial production, but the physical properties are also highly beneficial.

2) Aluminium

Aluminium is probably the material that springs to mind when you think about lighter alternatives to steel, and with good reason - the density of aluminium is in the region of 35% of that of steel. However, the first thing we should cover is the fact that when we talk about aluminium as a structural material, we are almost always talking about an *alloy* of aluminium - with an addition of magnesium, zinc etc depending upon the intended end use of the metal. The reason for this is that raw aluminium has too low a yield strength for structural use in a vehicle chassis.

3) Titanium

Titanium has an association with space tech, and is regarded by many people as an "ultimate" material. It has a density roughly half that of steel, and also a little over half the stiffness value. It's a similar situation with regards to ultimate and yield strengths. Understandably, this means that the methods used to build with titanium are similar to those for building with aluminium: Tubing should be larger in diameter than for steel, to compensate for the lower inherent stiffness, though this does not need to be as pronounced as with aluminium. Again, when we talk about using titanium to build structures, we are referring to alloys rather than raw metal, though straight titanium is not as weak as straight aluminium.

4) Magnesium

Magnesium is the lightest metal that's likely to be used in a vehicle chassis, with a density about quarter that of steel. This weight advantage helps to compensate for the fact that it's strength and rigidity is below even aluminium, and with careful design can be used to build a light, stiff structure. Magnesium can react quite easily, and will ignite under extreme circumstances. Although in most cases the sections of material used in vehicles are too thick to be at risk from this, it does mean that special care needs to be taken during manufacture - particularly with filings from machining operations etc.

5) Fibreglass

Raw plastics do not have anywhere near enough stiffness to be used for structural components in cars. If strands of glass are added to the mixture, though, their properties improve remarkably. This gives you a Glass Fibre Reinforced Plastic (GFRP or GRP), most commonly referred to as fibreglass.

Like a plastic, fibreglass can be moulded to practically any shape. Although nowhere near as stiff or strong as steel, the ability to create practically any shape allows you to compensate for this. A bodyshell or tub may be created in a single piece, with no seams that could be weak points, and made with variable thickness - Extremely thick near high-load areas such as suspension mountings, and very thin in unstressed panels, all in the same unit. It is this infinite variability across a structure that allows a properly designed fibreglass construction to be both stiff and light.

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Traditionally, fibreglass has been used for specialist applications like sports cars most of all, and is often used in conjunction with a separate chassis or subframes rather than alone. Even if a bodyshell is made to be a stand-alone fibreglass structure, metal inserts are still usually used to spread the load at mounting points etc.

6) Carbon fibre

Carbon fibre is very similar to fibreglass, only with carbon strands rather than glass strands as the reinforcing medium - it's correct description would be Carbon Fibre Reinforced Plastic (CFRP/CRP), though almost everyone refers to it as simply "carbon fibre".

It is a lot like fibreglass, only despite a density that is almost exactly the same, it can have the strength of an aluminium alloy and the stiffness of steel. The key to this is that, unlike fibreglass, where the strands are pretty much random, carbon fibre uses a woven matt of fibres - this is what gives it it's distinctive appearance. Getting the full strength and stiffness advantages requires maintaining the correct alignment of this weave, and so carbon fibre structures cannot be compression moulded, they have to be laid up in layers. This requires time and skill, and is probably the biggest factor in the high cost of using carbon fibre.

VI. FUTURE DESIGNS

Indy cars and F-1 race cars are complex machines. In order to optimize the car performance, engineers and constructors commit large amounts of time and money to R&D. Aerodynamic efficiency is the goal of each team in developing a competitive car for the next racing season. Testing techniques vary from wind tunnels, to on-track data, and even computational methods, such as Computational Fluid Dynamics (CFD). Originally employed in aerospace design techniques, CFD applications are now used in structural analysis, automoblile design and other non-aerospace fields. In Indy car and F-1 racing, teams can spend up to 100 days (per year) testing in wind tunnels and have full time aerodynamicists analyzing new chassis designs. Each team seeks an aerodynamic advantage which will result in a competitive edge.

In 1993 the Rahal/Hogan Indy car team began building a new chassis. Team designers included a CFD application in component design. The project was headed by MIT researcher and lecturer David P. Keenan. "CFD", says Keenan "has matured to the point where we can use it in the conceptual design phase for exploratory work. It should cut out a lot of model building early on, allowing us to get through a lot of concepts more quickly than was previously possible." Keenan used an airfoil shape that allowed the Indy car design team to specify the pressure distribution over its surface. "What we do is build a computational model of the full vehicle, run CFD calculations, and use powerful visualization tools that come with the software (Rampant, from Fluent Inc. Lebanon N.H.) to explore the complete flow domain". Keenan and the design team look for such things as high and low pressure regions and vortices, measurements that cannot be duplicated in wind tunnels. According to Keenan, the use of CFD in Indy car racing, "is a two-pronged effort. We are not only exploring CFD to understand the flow over the car, but also developing tools that will be advantageous to race engineers. We can tell them what the flow will do, but they have to figure out how to make the Indy car take advantage of it."

Throughout the motorsports world of today, and in particular the Indy Car (CART) series, the seasons are becoming longer. No sooner has one season ended that another is beginning. Test teams and engine developers are employed year round to meet the challenge of the upcoming season. To remain competitive, a team must undergo continous development, even if there are strict rules on modification. As a result, there is a demand for advanced design and analysis techniques which are practical, cost-effective and above all, accurate. Computer simulation will continue to to be used as a design and development tool in order to:

1. Reduce time scales (elapsed time from computer model to component design).
2. Increase performance.
3. Enhance engineering knowledge.

Pultrusion

Pultrusion is a process in which dry, continuous fibers are pulled through a bath of resin and then through a die. The die serves two purposes: it forces the bundle of wet fibers to conform to the shape you want to create and, since the

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die is heated, it will cure the resin to set the bundle of fibers into its final shape. After the composite comes out of the die, it is allowed to post-cure while being pulled to the saw where it will be cut to stock lengths.

How pultrusion works:

Developed in the 1950s by the person considered by many to be "the father of composites," W. Brandt Goldsworthy, pultrusion is the process of "pulling" raw composites through a heated die to create a continuous composite profile.The term pultrusion combines the words, "pull" and "extrusion". Extrusion is the pushing of material, such as a billet of aluminum, through a shaped die. Pultrusion is the pulling of material, such as carbon fiber and resin, through a shaped die.The typical pultrusion process starts with racks or creels holding spools of bundled continuous fiber (roving). Most often the reinforcement is fiberglass, but it can be carbon, aramid, or a mixture. This raw fiber is pulled off the racks and guided through a resin bath or resin impregnation system.The raw resin is almost always a thermosetting resin, and is sometimes combined with fillers, catalysts, and pigments. The fiber reinforcement becomes fully impregnated (wetted-out) with the resin such that all the fiber filaments are thoroughly saturated with the resin mixture.

As the resin rich fiber exits the resin impregnation system, the un-cured composite material is guided through a series of tooling. This custom tooling helps arrange and organize the fiber into the correct shape, while excess resin is squeezed out, also known as "debulking." This tooling is known as a "pre-former." Often continuous strand mat and surface veils are added in this step to increase structure and surface finish.

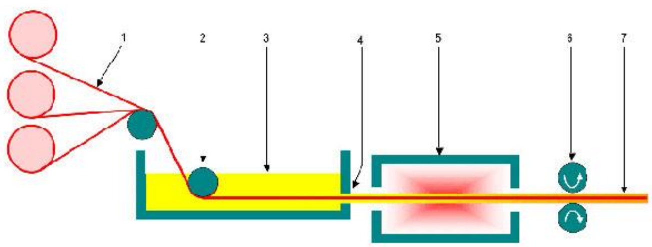

Fig: Pultrusion process steps

Advantages of pultrusion:

a) High stiffness to weight ratio
b) High strength to weight ratio
c) The ability to easily make tubes with specific wall-thicknesses
d) Easy tomachine

VII. TEST EQUIPMENT AND PROCEDURE

1) Tensile test

For measuring tensile modulus of produced rods, one specimen was prepared from each type for tensile test. Rods were cut into pieces of 400 mm as per ASTM D638-02a. The specimens were tested by universal testing machine (UTM). The tension test is generally performed on flat or round specimens [3]. A uniaxial load is applied through the ends. The ASTM standard test recommends that the length of the specimen should be 400 length for 15mm diameter rod. Ultimate tensile strength is the force required to fracture a material. The tensile strength can be experimentally determined by the given formula.

$$\text{Tensile Strength} = \frac{Maximumtensileloadapplied}{Originalcrosssectionarea} = \frac{Pmax}{A}$$

The ultimate tensile strength Pmax can be determined by the stress strain graph. The unit used for tensile strength is N/m2.

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VIII. RESULTS AND DISCUSSIONS

Tensile Strength:
Using the data measured in the tensile test, load Vs displacement curves for all rod types were plotted From these figures some phenomena can be well identified.

Fig: Before Testing

Fig: After Testing

IX. INTRODUCTION TO ANSYS

The ANSYS program is self contained general purpose finite element program developed and maintained by Swason Analysis Systems Inc. The program contain many routines, all inter related, and all for main purpose of achieving a solution to anan engineering problem by finite element method.
ANSYS finite element analysis software enables engineers to perform the following tasks:

- Build computer models or transfer CAD models of structures, products, components, or systems.
- Apply operating loads or other design performance conditions
- Study physical responses ,such as stress levels, temperature distributions, or electromagnetic fields
- Optimize a design early in the development process to reduce production costs.
- Do prototype testing in environments where it otherwise would be undesirable or impossible

The ANSYS program has a compressive graphical user interface (GUI) that gives users easy, interactive access to program functions, commands, documentation, and reference material. An intuitive menu system helps users navigate through the ANSYS Program. Users can input data using a mouse, a keyboard, or a combination of both. A graphical user interface is available throughout the program, to guide new users through the learning process and

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provide more experienced users with multiple windows, pull-down menus, dialog boxes, tool bar and online documentation.

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

Structural and modal analysis of chassis without damping material and layers

1) Steel

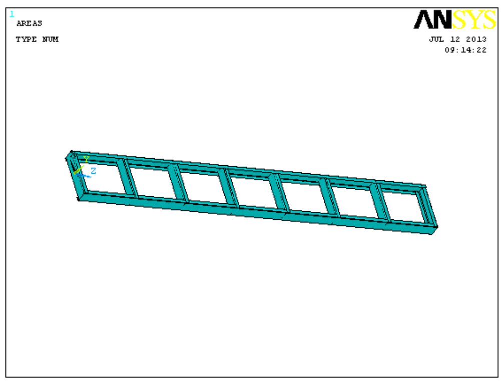

Fig. Imported Model

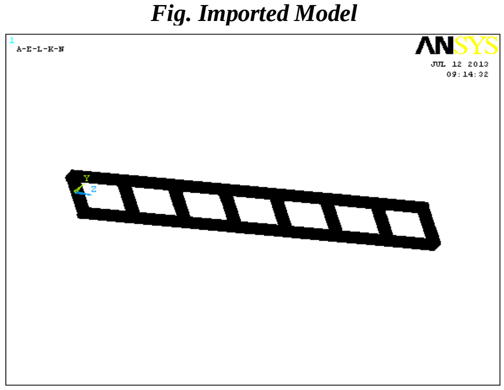

Fig. Meshed Model   Pressure – 0.06N/mm²

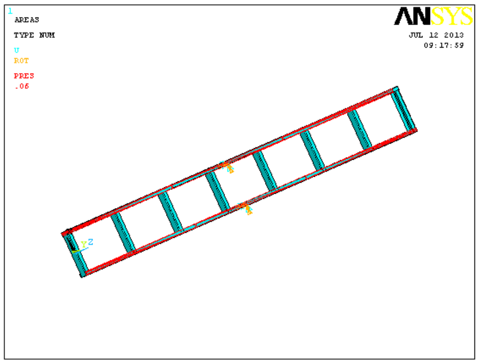

Fig. Load

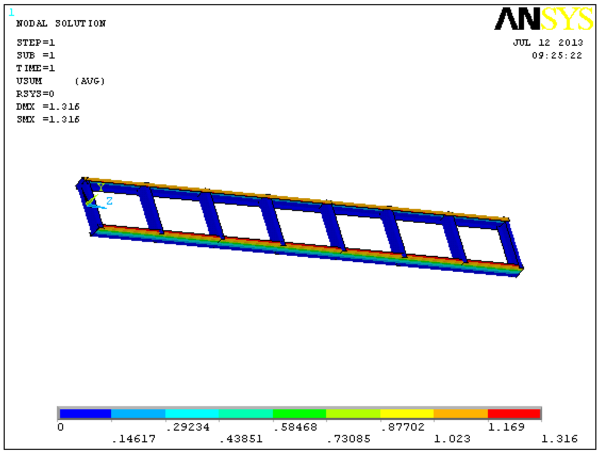

Fig. Displacement

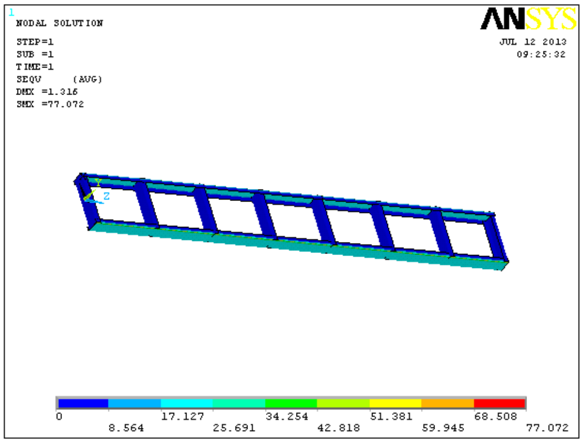

Fig. Stress

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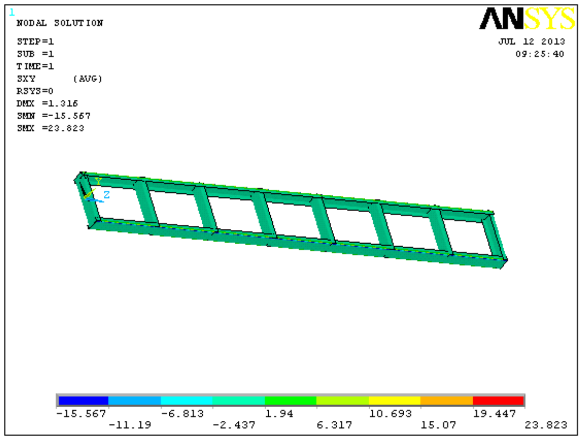

Fig. SHEAR STRESS IN XY

Structural analysis 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

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

X. 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.

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