ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Design and Analisys of Heavy Vehicle Chassis by Using Composite Materials

K. Venkatarao
M-Tech (CAD/CAM)
Mechanical Engineering Department
Malla Reddy College Of Engineering

J. Chandra Sekhar
Assistant Professor
Mechanical Engineering Department
Malla Reddy College Of Engineering

ABSTRACT

The automobile is divided into two parts body and chassis. The chassis is basic structure of a vehicle. It contains all the engine parts and power systems but the frame is the main portion of chassis which do not contain any other assemblies like engine parts. Its principle function is to safely carry the maximum load for all designed operating conditions. Composite material is a material composed of two or more distinct phases (matrix phase and dispersed phase) and having bulk properties significantly different from those of any of the constituents. Different types of composite material are available and one of it is Polymer matrix composite. It is very popular due to their low cost and simple fabrication methods. It has the benefits of high tensile strength, high stiffness and good corrosion resistance etc. At present this polymer matrix composite materials are used in aerospace, automobile industries due to it high strength to low weight ratio.

In the present work, the dimensions of an existing heavy vehicle chassis of a TATA 1109 EX2 vehicle is taken for modeling and analysis. The vehicle frame is initially modeled by considering 'C' cross section in CATIA V5 SOFTWARE and then it is imported to ANSYS 13.0. The analysis is done with two different composite materials namely E-glass/Epoxy and S-glass/Epoxy subjected to the same pressure as that of a steel frame. The design constraints are stresses and deformations. The results are then compared to finalize the best among all the four frames.

Key Words: **CATIA V5 R20, ANSYS 13.0.**

I. INTRODUCTION

Automotive chassis is a French word that was initially used to represent the basic structure. It is a skeletal frame on which various mechanical parts like engine, tires, axle assemblies, brakes, steering etc. are bolted. It gives strength and stability to the vehicle under different conditions. 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. It ensures low levels of noise, vibrations and harshness throughout the automobile.

Automobile chassis without the wheels and other engine parts is called frame. 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.
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

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

for supporting vehicular components and payload placed upon it.

1.1 Functions of the chassis

1. To carry load of the passengers or goods carried in the body.
2. To support the load of the body, engine, gear box etc.,
3. To with stand the forces caused due to the sudden braking or acceleration.
4. To with stand the stresses caused due to the bad road condition.
5. To with stand centrifugal force while cornering.

1.2 Various loads acting on the chassis

1. Short duration Load – While crossing a broken patch.
2. Momentary duration Load – While taking a curve.
3. Impact Loads – Due to the collision of the vehicle.
4. Inertia Load – While applying brakes.
5. Static Loads – Loads due to chassis parts.
6. Over Loads – Beyond Design capacity.

2. Problem Identification

Weight reduction is now the main issue in automobile industries. Because if the weight of the vehicle increases the fuel consumption increases. At the same time as the weight of the vehicle increases the cost also increases which becomes a major issue while purchasing an automobile. For example if we take frame of TATA 1109 EX 2 heavy vehicle frame. It is manufactured with Structural Steel. Steel structures exposed to air and water, such as bridges are susceptible to corrosion. In conditions of repeated stress and more temperatures it can suffer fatigue and cracks. These are the main problems of steel and these are compensated by inducing composite materials.

2.1Composite Materials

A composite material is defined as a material composed of two or more materials combined on a macroscopic scale by mechanical and chemical bonds. Unique characteristic of many fiber reinforced composites is their high internal damping capacity. This leads to better vibration energy absorption within the material and results in reduced noise transmission to neighboring structures. Many composite materials offer a combination of strength and modulus that are either comparable to or better than any traditional metallic 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 metallic materials. The fatigue strength to weight ratios as well as fatigue damage tolerances of many composite laminates are excellent. For these reasons, fiber composites have emerged as a major class of structural material and are either used or being considered as substitutions for metals in many weight-critical components in aerospace, automotive and other industries.

2.2 Classification of FRP:

A great majority of materials are stronger and stiffer in fibrous form than as bulk materials. A high fiber aspect ratio (length: diameter ratio) permits very effective transfer of load via matrix materials to the fibers, thus taking advantage of their excellent properties. Therefore, fibers are very effective and attractive reinforcement materials.

2.2.1 Glass Fibers:

The most common reinforcement for the polymer matrix composites is a glass fiber. Most of the fibers are based on silica (SiO_2), with addition of oxides of Ca, B, Na, Fe, and Al. The glass fibers are divided into three classes' -- E-glass, S-glass and C-glass. The E-glass is designated for electrical use and the S-glass for high strength. The C-glass is for high corrosion resistance, and it is uncommon for civil engineering application. Of the three fibers, the E-glass is the most common reinforcement material used in civil structures. It is produced from lime-alumina borosilicate which can be easily obtained from abundance of raw materials like sand. The glass fiber strength and modulus can degrade with increasing

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

temperature. Although the glass material creeps under a sustained load, it can be designed to perform satisfactorily. The fiber itself is regarded as an isotropic material and has a lower thermal expansion coefficient than that of steel.

• E-glass:

Family of glassed with a calcium aluminum borosilicate composition and a maximum alkali composition of 2%. These are used when strength and high electrical resistivity are required.

Composition of E-Glass

Constituent	Weight Percentage
SiO_2	54
Al_2O_3	14
CaO + MgO	12
B_2O_3	10
$Na_2O + K_2O$	Less than 2
Impurities	Traces

Table – I

Mechanical Properties of E-Glass/Epoxy

Properties	E-Glass/Epoxy
Young's modulus in fiber direction, E_1 (GPa)	53.8
Young's modulus in transverse direction, E_2 (GPa)	17.9
Shear modulus, G_{12} (GPa)	8.96
Major Poisson's ratio, υ_{12}	0.25
Minor Poisson's ration, υ_{21}	0.08
Strength in the fiber direction, X_L (MPa)	1.03 X 10^3
Strength in the transverse direction, X_T (MPa)	27.58
Shear strength, S (MPa)	41.37

Table – II

• S-glass:

Fibers have a magnesium alumino-silicate composition, which demonstrates high strength and used in application where very high tensile strength required.

Typical Properties of E-Glass and S-Glass

Typical Properties	E-Glass	S-Glass
Density (g/cm^3)	2.60	1.6
Young's Modulus (GPa)	72	87
Tensile Strength (GPa)	1.72	2.53
Tensile Elongation (%)	2.4	2.9

Table – III

3. DESIGN OF CHASSIS

Design may be done in two ways one way is the component design which is done by improving the existing ones. The other is conceptual design where there is no reference and creation of new machines. A new or better machine is one which is more economical in the overall cost of production and operation. The process of design is a long and time consuming one. From the study of existing ideas, a new idea has to be conceived. The idea is then studied keeping in mind its commercial success and given shape and form in the form of drawings. In the preparation of these drawings, care must be taken about the availability of resources like money, man power and materials required for the successful completion of the new idea into an actual reality. In designing a machine component, it is necessary to have a good knowledge of many subjects such as Mathematics, Engineering Mechanics, Strength of Materials, Theory of Machines, Workshop Processes and Engineering Drawing. Generally the design of a component involves various steps in it. Initially, the drawings must be drawn in user friendly software and they must be converted into a 3D model. This 3D

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

model must be imported into an analyzing medium where it is structurally or thermally analyzed to sustain the need.

Specifications of Existing Heavy Vehicle TATA 1109 EX2 Frame

Sl. No.	Description	Dimension (mm)
1	Wheel base	3600
2	Front track	1800
3	Rear track	1690
5	Max. width	2270
6	Frame length	5620

Table-IV

S.no	Description	Weight (kg)
1	Max. permissible FAW	7950
2	Max. permissible RAW	3950
3	Max. permissible GVW	11900
4	Passing payload for cab load body	8315

Table-V

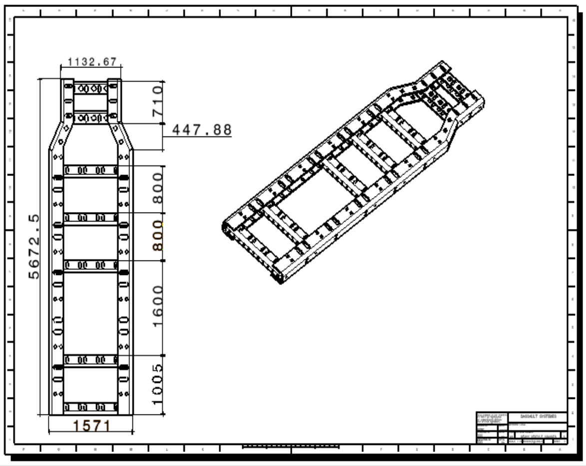
Different steps involved in designing a component are

1. Part drawing
2. Modeling
3. Structural analysis

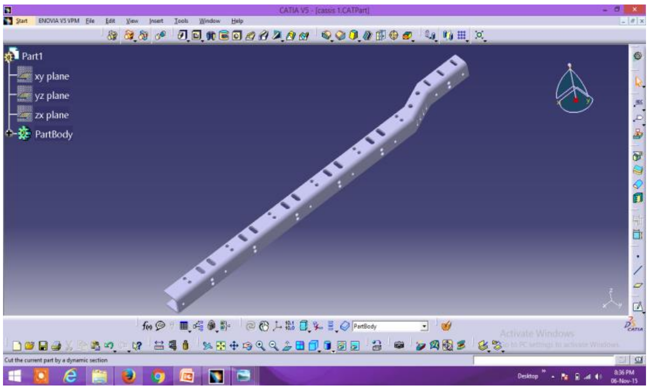
The present frame is divided in to individual components and each component is drawn, modeled and structurally analyzed by using software and its procedure is explained as below.

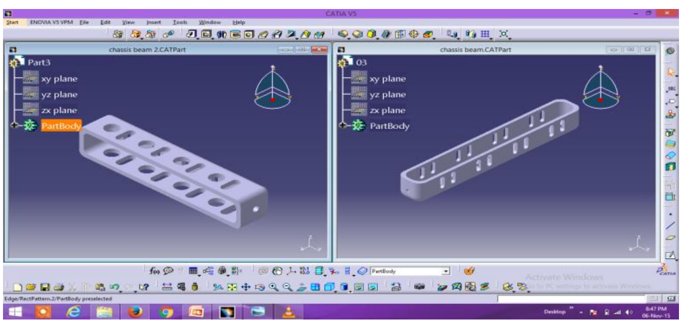
3.1 Part Drawing

It is a document that includes the specifications for a part's production. Generally the part drawings are drawn to have a clear idea of the model to be produced. The part drawing of the entire frame is drawn with all the views in CATIA V5 R20.



Part drawing of assembly in CATIA V5 R20.



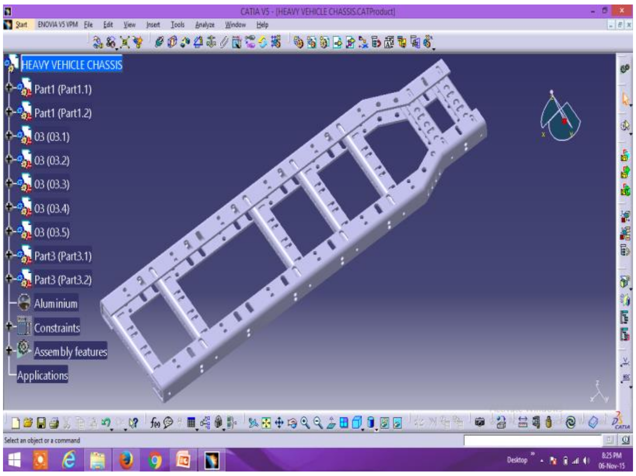


Part modeling of components in CATIA V5 20.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

3.2 Assembly

The components that are generated in part module are imported to assembly module and by using 'insert components' command and all these components are mated together to form the required assembly. The different views of assembly and the drawing generated in CATIA V5 R20 are as shown below.



The frame assembly in CATIA V5 R2O

4. ANALYSIS OF CHASSIS

4.1 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).

4.2 Application of Loads

The load application is the major part in the analysis of a component. There may be different types of loads like Uniformly Distributed Load, Uniformly Varying Load and Point Load.

The present frame carries the UDL throughout its length.

From the vehicle specifications FAW = 7950 Kg

RAW = 3950 Kg

Total GVW = 11900 Kg

As the frame supports the bolt by its two side frames

T he load on each side member = 11900/2 = 5950 kg

The total area on which the UDL is placed = 5620 × 100 = 562000 mm2

Total pressure applied = Total load /Total area

= 5950/562000 = 0.01058 kg/mm2

= 0.1038 N/mm^2

= 0.1038 MPa

4.3 Analysis by Using Structural Steel

It is steel construction material, a profile, formed with a specific shape or cross section and certain standards of chemical composition and mechanical properties. Structural steel shape, size, composition, strength, storage, etc. is regulated in most industrialized countries. Composition 0.565%C, 1.8% Si, 0.7%Mn, 0.045%P and 0.045% S

4.4 Mass of Frame

The mass of an object is a fundamental property of the object, a numerical measure of its inertia, a fundamental measure of the amount of matter in the object. Mathematical equation for mass is

Mass = Volume × Density

We know, Density of steel = $7850 kg/m^3$

Volume of frame = 4.9104×10^{-2} m^3

Total mass of frame = 7850 × 0.049104

= 385.46 kg.

4.5 Stresses developed in Frame

It is a physical quantity that expresses the internal forces that neighboring particles of a continuous material exert on each other. For example, when a solid vertical bar is supporting a weight, each particle in the bar pulls on the particles immediately above and below it. These macroscopic forces are actually the average of a very large number of intermolecular forces and collisions between the particles in those molecules. There are many types of stresses developed in a component. The frame is analyzed by considering Equivalent stress and normal stress.

Maximum normal stress = 3359 Mpa

Minimum normal stress = - 6317 Mpa

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

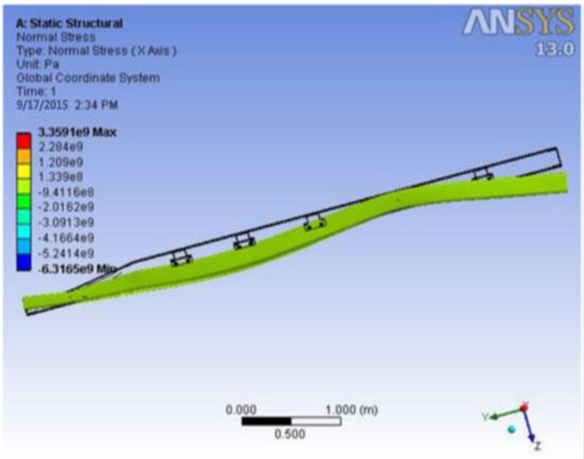


Figure 5.5-Normal Stress Distribution in Frame (Structural Steel)

4.6Equivalent stress

When an elastic body is subjected to loads in its three dimensions, the stresses will get developed along the principle axis of the body stresses. These stresses should not exceed the yield stress of the material. VonMises postulated that, even though none of the principal stresses exceeds the yield stress of the material, it is possible for yielding of the same from the combination of stresses. So all these stresses in three dimensions are together called as Equivalent stress. Von Mises stress is considered to be a safe haven for design engineers. Using this information an engineer can say his design will fail, if the maximum value of Von Mises stress induced in the material is more than strength of the material. It works well for most of the cases, especially when the material is ductile in nature.

The Equivalent stress distribution in the frame for structural steel is as shown in Figure it can be inferred that

Maximum Equivalent stress = 17686 MPa (Approx.)

Minimum Equivalent stress = 0 MPa

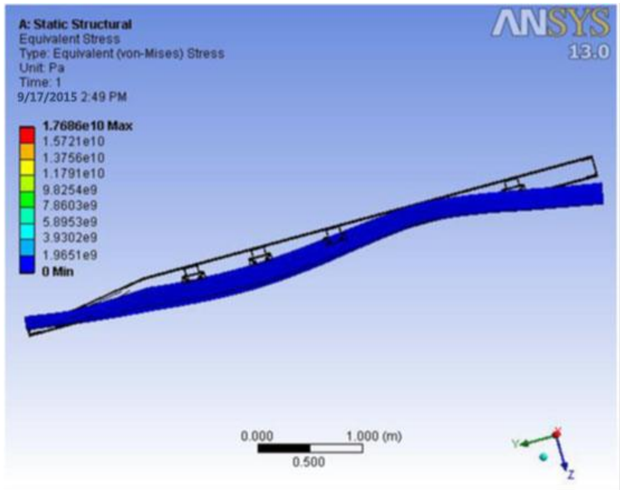


Figure 5.6-Equivalent Stress Distribution in Frame (Structural Steel)

4.7 Deformation

When an object is subjected to loading its shape may be changed temporarily or permanently due to applied force. This change in shape is called deformation. If the object deforms permanently it is called plastic deformation or failure. If it deforms temporarily it is called elastic deformation. While analyzing a frame the frame should deform elastically within the maximum loading limit so that the design is safe. The values of deformation obtained in ANSYS 13.0 for structural steel are as shown in Figure

Maximum deformation = 5.7 mm (Approx.)

Minimum deformation = 0 mm

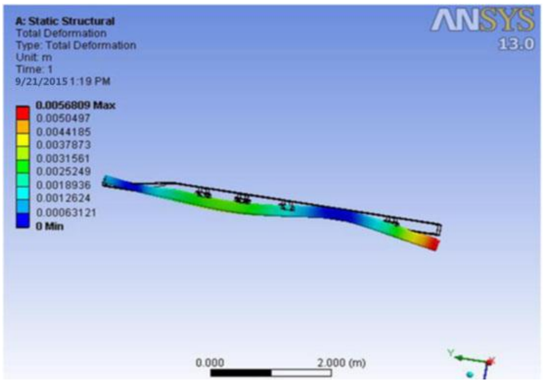


Figure 5.7-Total deformation in frame (Structural steel)

5. Analysis by Using E-glass/ Epoxy

An individual structural glass fiber is both stiff and strong in tension and compression that is, along its

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

axis. Although it might be assumed that the fiber is weak in compression, it is actually only the long aspect ratio of the fiber which makes it seem so i.e., because a typical fiber is long and narrow, it buckles easily. On the other hand, the glass fiber is weak in shear that is, across its axis. Therefore if a collection of fibers can be arranged permanently in a preferred direction within a material, and if the fibers can be prevented from buckling in compression, then that material will become preferentially strong in that direction. Furthermore, by laying multiple layers of fiber on top of one another, with each layer oriented in various preferred directions, the stiffness and strength properties of the overall material can be controlled in an efficient manner. In the case of fiberglass, it is the plastic matrix which permanently constrains the structural glass fibers to directions chosen by the designer. With chopped strand mat, this directionality is essentially an entire two dimensional plane; with woven fabrics or unidirectional layers, directionality of stiffness and strength can be more precisely controlled within the plane.

E-Glass / Epoxy Resin Composites are extremely strong materials used in roofing, pipes and automobiles. Composition: 54% SiO_2 - 15% Al_2O_3 - 12% CaO

5.1 Mass of frame

Mathematical equation for mass is Mass = Volume × Density

We know Density of E-glass/Epoxy = 2600 kg/m3

Volume of Frame = 4.9104×10-2 m³

Total mass of Frame = 2600 × 0.049104

= 127.67 kg

5.2 Stresses Developed in Frame

The two types of stresses are considered for analyzing the frame and their respective stress distributions are as shown in Fig.

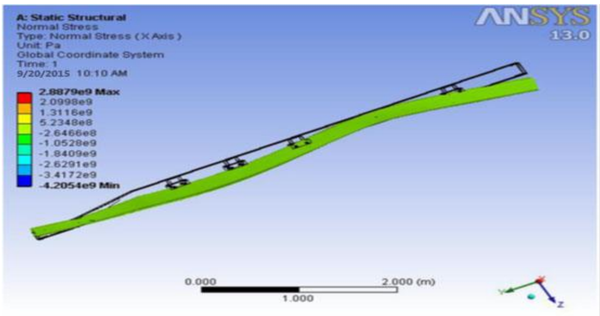


Figure 5.8- Normal Stress Distribution in Frame (E-glass/ Epoxy)

Max. normal stress = 2888Mpa(Approx.),

Min. normal stress = -4205Mpa(Approx.)

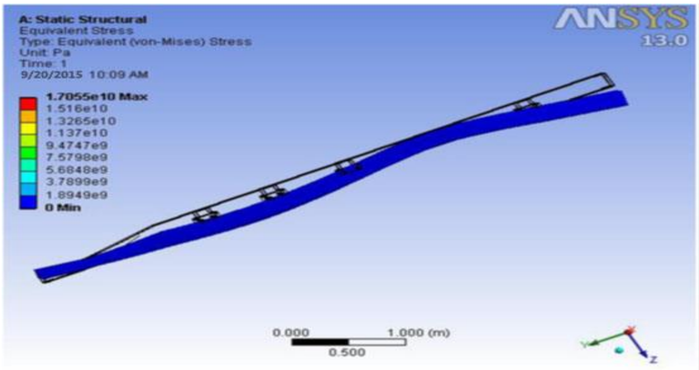


Figure 5.9- Equivalent Stress Distribution in Frame (E-glass/ Epoxy)

Maximum Equivalent stress = 17055Mpa ,

Minimum Equivalent stress = 0MPa

5.3 Deformation

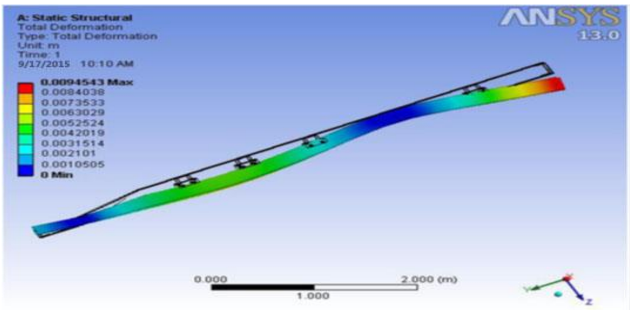


Figure 5.10-Total Deformation in Frame (E-glass/ Epoxy)

Maximum deformation = 9.4mm ,

Minimum deformation = 0mm

6. Analysis by Using S-glass/ Epoxy

The manufacturing process for glass fibers suitable for reinforcement uses large furnaces to gradually melt the silica sand, limestone, kaolin clay, fluorspar, colemanite, dolomite and other minerals to liquid

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

form. Then it is extruded through bushings, which are bundles of very small orifices (typically 5–25 micrometers in diameter for E-Glass, 9 micrometers for S-Glass). These filaments are then sized (coated) with a chemical solution. The individual filaments are now bundled together in large numbers to provide a roving. The diameter of the filaments, as well as the number of filaments in the roving determines its weight.

Common uses of S-glass include high performance aircraft (gliders), boats, automobiles, baths, hot tubs, septic tanks, water tanks, roofing, pipes, cladding, casts, surfboards and external door skins.

Composition: 64% SiO_2- 24% Al_2O_3- 10% MgO

6.1Mass of Frame

Mathematical equation for mass is Mass = Volume × Density

We know Density of S-glass/ epoxy = 1600 kg/m3

Volume of frame = 4.9104×10^{-2} m³

Total mass of frame = 1600× 0.049104

= 79kg (Approx.)

6.2Stresses developed in Frame

The two types of stresses are considered for analyzing the frame and their respective stress distributions are as shown in Fig.

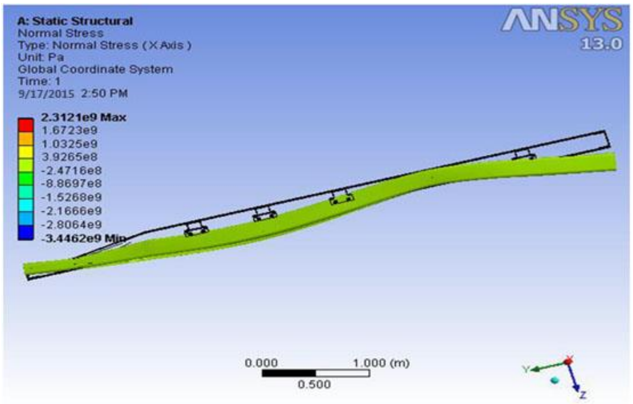


Figure 5.11- Normal Stress Distribution in Frame (S-glass/ Epoxy)

Max. normal stress = 2312MPa(Approx.),

Min. normal stress = -3446 MPa (Approx.)

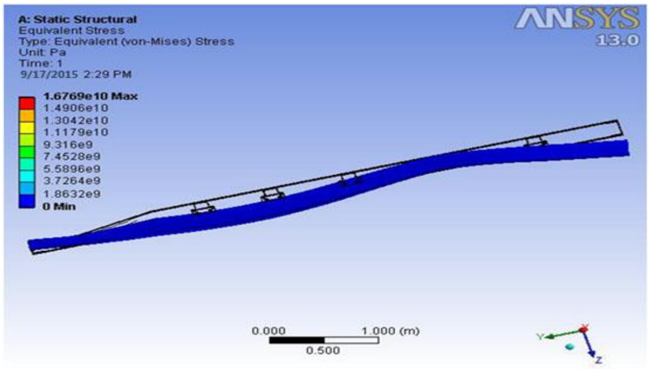


Figure 5.12-Equivalent Stress Distribution in Frame (S-glass/ Epoxy)

Maximum Equivalent stress = 16769MPa, Minimum Equivalent stress = 0Mpa

6.3 Deformation

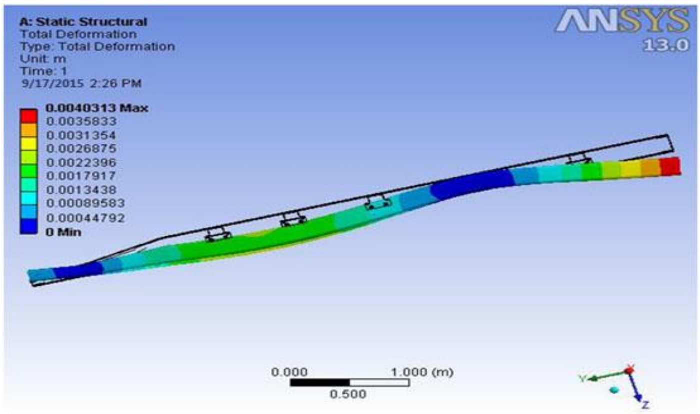


Figure 6.13- Total Deformation in Frame (S-glass/ Epoxy)

Maximum deformation = 4.03 mm , Minimum deformation = 0 mm

7. RESULTS

From the above analysis using different materials, the results obtained for stresses and deformations are Comparison of Results

Material	Mass(Kg)	Max. Normal Stress (MPa)	Max. Equivalent Stress(MPa)	Max. Defomation (mm)
Structural Steel	385	3359	17686	5.68
E-glass/ Epoxy	128	2888	17055	9.45
S-glass/ Epoxy	79	2312	16769	4.03

Table-V

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

From the above table it can be inferred that S-glass/Epoxy is having the least values when compared to remaining tow materials. For less mass the S-Glass/ Epoxy gives more strength. It can be explained by following calculations

For Structural Steel,

Density = 7850 kg/m3

Ultimate tensile strength = 900 MPa

Strength to weight ratio = 900/7850 = 0.1146 MNm/kg

= 115 Nm/g (Approx.).

For S-glass/Epoxy,

Density=1600 kg/m3

Ultimate tensile strength=600 MPa

Strength to weight ratio =600/1600

=0.375 MNm/kg

=375 Nm/g (Approx.).

The results obtained are represented graphically as shown below.

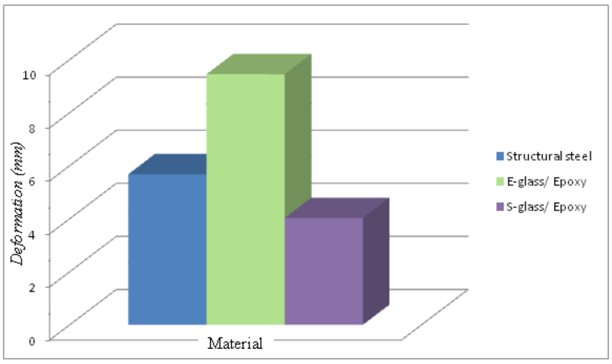


Fig. 7.1 Graphical Representation of Deformation

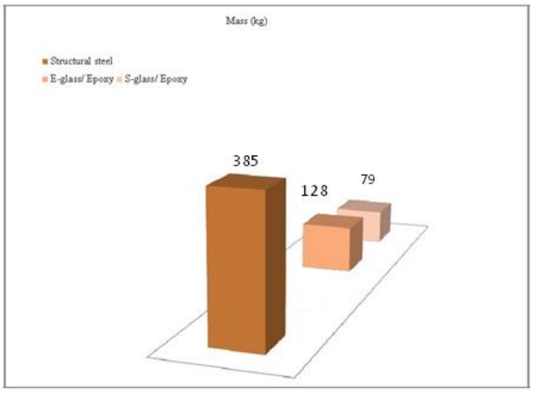


Fig. 7.2 Graphical Representation of Mass

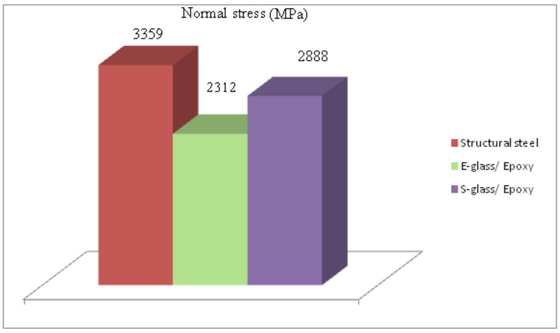


Fig. 7.3 Graphical representation of Normal stress

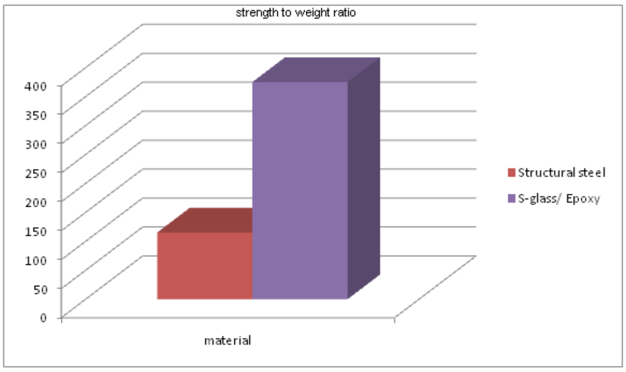


Fig. 7.4 Graphical Representation of strength to weight ratio

CONCLUSION

Present used material for chassis is steel. We have considered polymeric composites like E-glass/Epoxy and S- glass /Epoxy for chassis material. By employing a polymeric composite heavy vehicle chassis for the same load carrying capacity, there is a reduction in weight of 70% to 80%. Based on the results it was inferred that S-glass/Epoxy polymeric composite heavy vehicle chassis has superior strength, less deformation, less normal stress and less weight compared to steel, E-glass/Epoxy.

So we conclude that it is better to use S-glass/ Epoxy as a material for frames of heavy vehicle chassis. So that the fuel consumption decreases for the vehicles

SCOPE FOR FUTURE WORK

There is a high scope for further research in chassis simulation to solve vibration, frequency response and mode shape analysis related problems.

Useful future work would be to determine torsion stiffness of the chassis including the suspension, modeling infinite springs and loading differentially through the wheel hubs instead of at the chassis spring mounts. Other useful measures are to be determining camber and toe response to a lateral force at the ground contact point.

This chassis structure should be further analyzed and improved on the overall performance especially on structural dynamic behavior and quality auditing for better refinement. Based on these factors, the overall recommendation is to study the structural analysis and should be covered on the overall truck system and after that focus on the specific area such as chassis. This analysis will help to make full body refinement and improvement because it can be related to actual running condition.

REFERENCES

[1] Vijaykumar V. Patel, "Structural analysis of a ladder chassis frame," World Journal of 2(4)05-08

[2] Cicek Karao a journal on analysis Science and Technology 2012,
of a chassis frame with joints was performed by using software

[3] M. Ravi Chandra, S. Sreenivasulu & Syed Altaf Hussain, "Modeling And Structural Analysis Of Heavy Vehicle Chassis Made Of Polymeric Composite Material By Three Different Cross Sections", Journal of Mechanical and Production Engineering Research and Development (IJMPERD), ISSN 2249-6890, Vol.2, Issue 2,Sep 2012 45-60.

[4] C. Karaoglu, N. S. Kuralay, Stress analysis of a truck chassis with riveted joints, Finite Elements in Analysis and Design, 38, (2002), 1115-1130.

[5] N.V.Dhandapani, Dr. G Mohan Kumar, Dr K.K.Debnath, Static Analysis of Off-High Way Vehicle Chassis supporting Structure for the effect of various Stress distributions IJART, Vol.2 Issue 1, 2012, 1-8.

[6] Sairam Kotari, V.Gopinath,"Static and dynamic analysis on Tatra chassis" International Journal of Modern Engineering Research (IJMER), Vol.2, Issue.1, pp-086-094.

[7] K.W. Poh, P.H. Dayawansa, A.W. Dickerson, I.R. Thomas, Steel membrane floors for bodies of large rear- dump mining trucks, Finite Elements in Analysis and Design 32, (1999), 141-161.

[8] H J Beermann, English translation by Guy Tidbury, The Analysis of Commercial Vehicle Structures, Verlag TUV Rheinland GmbH Koln-1989.

[9] Mohd Husaini Bin Abd Wahab, "Stress Analysis of Truck Chassis", Project Report University Malaysia Pahang, 2009

[10] Machine Tool Design hand book by Central Machine Tool Institute Edition 1 – 2004 Mc Graw Hill Publications

[11] http://ansys.com/Industries/Academics/Tools/Curriculum+Resources