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MODELLING AND STRUCTURAL ANALYSIS OF VEHICLE CHASSIS FRAME MADE OF POLYMERIC COMPOSITE MATERIAL

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Abstract - ***The chassis frame forms the backbone of a vehicle; its principle function is to safely carry the maximum load for all designed operating conditions. This paper describes design and analysis of vehicle chassis. Weight reduction is now the main issue in automobile industries. In the present work, the dimensions of an existing vehicle chassis frame of a MAHINDRA BOLERO vehicle is taken for modeling and analysis of a vehicle chassis frame 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 frame. The design constraints were stresses and deflections. The three different composite vehicle chassis frames 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's used in this work are PRO – E for modeling, ANSYS for analysis.***

Key Words: **Chassis, Mahindra Bolero, Carbon/Epoxy, E Glass/Epoxy, S Glass Epoxy, PRO-E, ANSYS**

1.INTRODUCTION

Chassis is a French term and was initially used to denote the frame parts or Basic Structure of the vehicle. A vehicle without body is called Chassis. The components of the vehicle like Power plant, Transmission System consisting of clutch gearbox, propeller shaft and rear axle, Wheels, Suspension, and Controlling Systems like Braking, Steering etc., and electrical system parts are also mounted on the Chassis frame. So it is also called as Carrying Unit. Chassis of Automotive helps to keep an automobile rigid, stiff and unbending. Automobile chassis ensures less noise, vibrations and harshness throughout the automobile. Along with the strength, an important consideration in the chassis design is to increase the stiffness (bending and torsion) characteristics. In the conventional design procedure the design is based on the strength and emphasis is then given to increase the stiffness of the chassis, with very little consideration to the weight of the chassis. One such design procedure involves the adding of structural cross member to the existing chassis to increase its torsion stiffness. As a result weight of the chassis increases. This increase in weight reduces the fuel efficiency and increases the cost due to extra material. The design of the Chassis with adequate stiffness and strength is necessary.

All most all components weight is acting on the chassis frame, thus chassis subjected to static, dynamic and cyclic loading condition on the road. Static stress analysis is important to point out critical (highest stress) regions in the frame. These critical regions may cause fatigue failures. In this study, ladder type chassis frame is analysed. The Chassis consists of side members attached with a series of cross members to complete the ladder like structure, thus its name. The FEM is a common tool for stress analysis. FEM with required boundary conditions was used to determine critical regions in the chassis frame. Static structural analysis is performed to identify critical regions and based on the results obtained design modification has been done.

There are three types of frames:

a)**Conventional control chassis**

In which engine is mounted in front of the driver`s cabin. This type of arrangement avoids full utilization of the space. It is non-load carrying frame. The loads of the vehicle are transferred to the suspensions by the frame. The suspension in the main skeleton of the vehicle is supported on the axles through springs. The body is made of flexible material like wood and isolated frame by inserting rubber mountings in between. The frame is made of channel section or tubular section of box section.

b) Semi-forward control chassis

In which engine is mounted that half of it is in the driver`s cabin whereas the other half is in front, outside the driver`s cabin. In this case the rubber mountings used in conventional frame between frame and suspension are replaced by more stiff mountings. Because of this some of the vehicle load is shared by the frame also. This type of frame is heavier in construction.

c) Full-forward control chassis

In which engine is mounted completely insides the driver`s cabin. Obviously maximum utilization of space is achieved in this type of arrangement.

1.1 Types Of Automobile Chassis Frame

a) Conventional Frame

It is non-load carrying frame. The loads of the vehicle are transferred to the suspensions by the frame. This suspension in the main skeleton of the vehicle is supported on the axles through springs. The body is made of flexible material like wood and isolated frame by inserting rubber mountings in between. The frame is made of channel section or tubular section of box section.

b) Ladder Chassis

Ladder chassis is one of the oldest forms of automotive chassis these are still used in most of the SUVs today. It is clear from its name that ladder chassis resembles a shape of a ladder having two longitudinal rails inter linked by lateral and cross braces.

1.2 Types of ladder frame

1. C cross section type of ladder chassis frame

2. I cross-section type of ladder chassis frame.

3. Rectangular Box cross section type of ladder chassis frame.

4. Rectangular Box (Intermediate) cross section type.

2. LITERATURE REVIEW

MohdAzizi Muhammad Nor et al. (2012)this paper aims to model simulate and perform the stress analysis of an actual low loader structure consisting of I-beams design application designed in-house by Sumai Engineering Sdn. Bhd, (SESB). The material of structure is Low Alloy Steel a 710 C (Class 3) with 552 MPa of yield strength and 620 MPa of tensile strength. Finite element modeling (FEM), simulations and analysis are performed using modeling software i.e. Pro E .Firstly, a 3-D model of low loader based on design from SESB is created by using Pro E. Stress and displacement contour are later constructed and the maximum deflection and stress are determined by performing stress analysis. Computed results are then compared to analytical calculation, where it is found that the location of maximum deflection agrees well with theoretical approximation but varies on the magnitude aspect. Safety factor for the low loader structure has also been calculated. In the end, the current study is important for further improvement of the current low loader chassis design.
Swami K.I. et al. (Jan. 2014)The Automotive chassis is considered as the backbone of the vehicle. An important consideration in chassis design is to have adequate bending stiffness for better handling characteristics. So, strength and stiffness are two important criteria for the design of the chassis. This paper related with work performed towards the static structural analysis of the truck chassis. Structural systems like the chassis can be easily analyzed using the finite element techniques. So a proper finite element model of the chassis is to be developed. The chassis is modeled in ANSYS. Analysis is done using the same software.

RoslanAbd Rahman does stress analysis on heavy duty truck chassis by finite element package ABAQUS. To improve the fatigue life of components at critical point by design modifications the stresses can be reduced. Used ASTM low alloy steel a 710 C (Class 3) with 552 MPa of yield strength and 620 MPa of tensile strength for chassis founds the maximum stress 386.9 MPa at critical point occurred at opening of chassis which was in contacted with the bolt from it concludes, that this critical point is an initial to probable failure

3.COMPOSITE MATERIALS

A composite material is usually made up of at least two materials out of which one is the binding material, also called matrix and the other is the reinforcement material. Composites are materials that comprise strong load carrying material (known as reinforcement) imbedded in weaker material (known as matrix) with physically separable phases. Reinforcement provides strength and rigidity, helping to support structural load. The matrix or binder maintains the position and orientation of the reinforcement. Significantly, constituents of the composites retain their individual, physical and chemical properties yet together they produce a combination of qualities which individual constituents would be incapable of producing alone. The reinforcement may be platelets, particles or fibers and are usually added to improve mechanical properties such as stiffness, strength and toughness of the matrix material.

A) Material properties

Properties	E-Glass	Carbon Epoxy	S-Glass Epoxy	Stainless steel
Young's modulus (GPA)	72.5	388	85	193
Poisson's Ratio	0.28	0.358	0.22	0.31
Density (kg/m³)	2580	1600	2490	7750
Tensile strength (GPA)	3.45	4.1	4.6	3.2

Table.1 Properties of materials

B) MODELING OF CHASSIS FRAME

Fig-1: I-Section Chassis frame

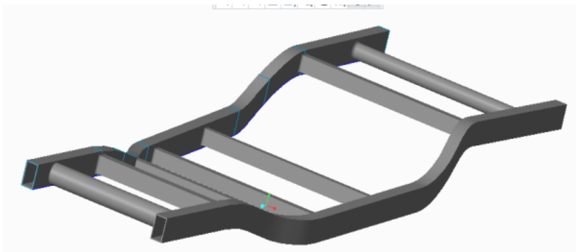


Fig-2: Box chassis frame

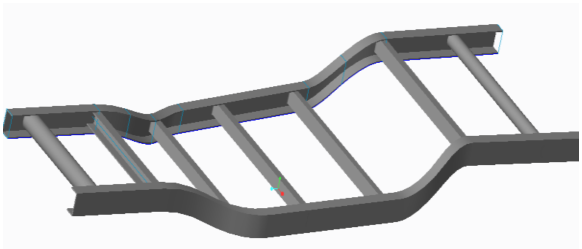
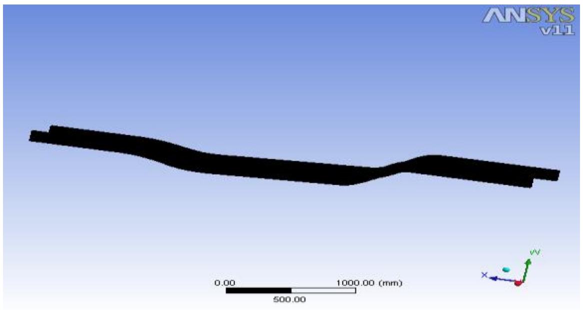


Fig-3: C-section Chassis frame

4.STRUCTURAL ANALYSIS OF RECTANGULAR CHASSISFRAME:



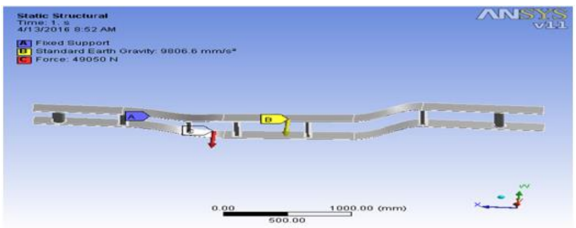


Fig -4: Fixed support and force application on rectangular section chassis frame

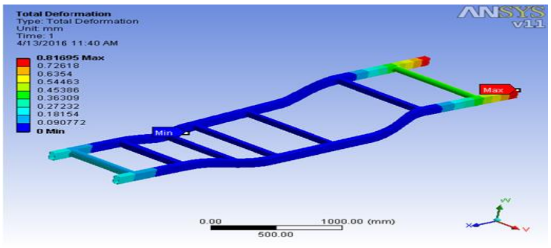


Fig -5: Total deformation for Rectangular section chassis frame

Carbon

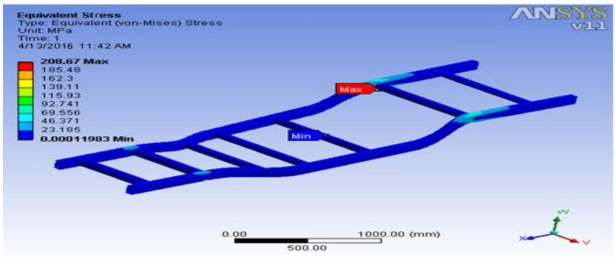


Fig -6: Equivalent stress for Rectangular section chassis frame- Carbon epoxy

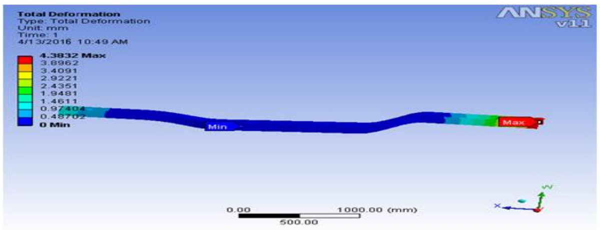


Fig -7: Total deformation for Rectangular section chassis frame-E-Glass fiber

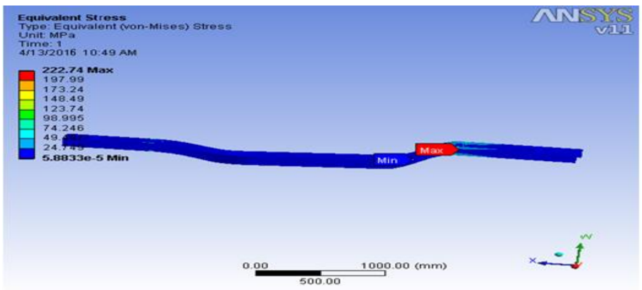


Fig -8: Equivalent stress for Rectangular section chassis frame-E-Glass fiber

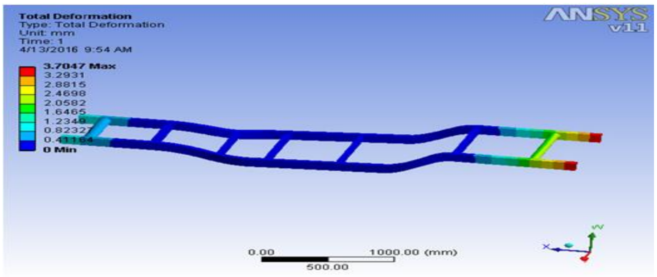


Fig -9: Total deformation for Rectangular section chassis frame-S-Glass fiber

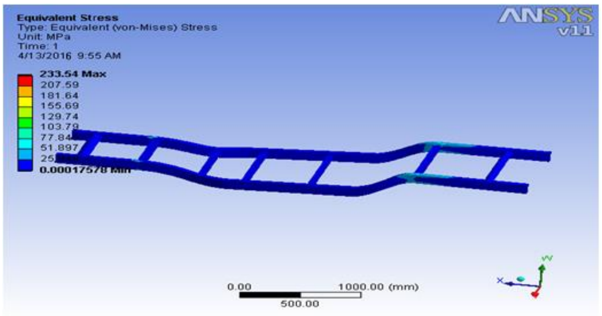


Fig -10: Equivalent stress for Rectangular section chassis frame-S-Glass fiber

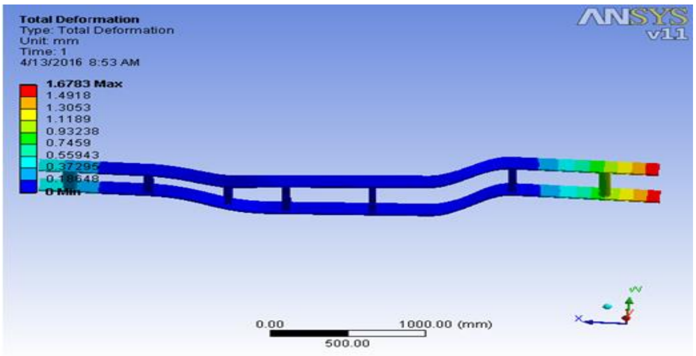


Fig -11: Total deformation for Rectangular section chassis frame-Stainless steel-Glass fiber

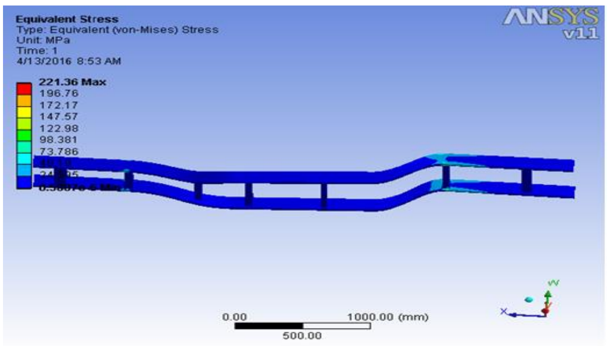


Fig -12: equivalent stress for rectangular-section chassis frame stainless-steel glass-fiber

5. structural analysis of c-section chassis frame

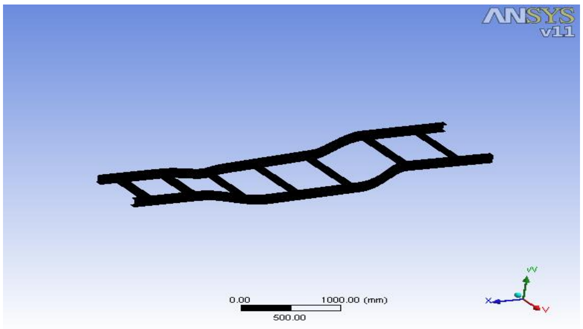


Fig -13: mesh gearation of c-section chaisiss frame

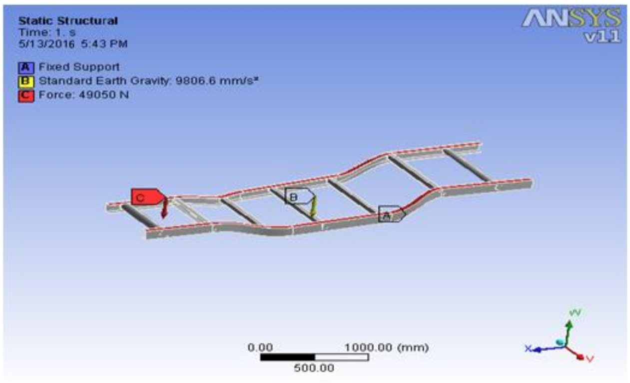


Fig -14: Fixed support and force application on C- section chassis frame

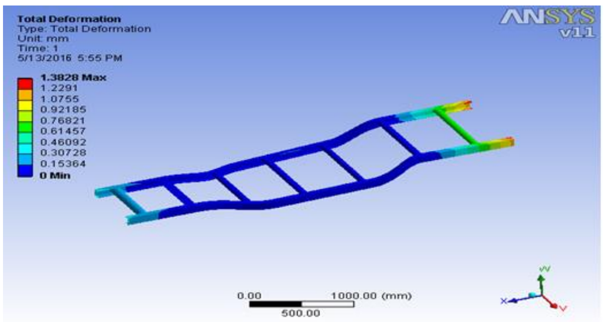


Fig -15: total deformation of c-section chassis frame-carbon epoxy

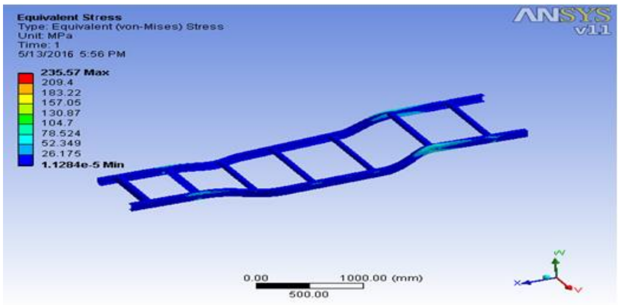


Fig -16: equivalent stress for c-section chassis frame carbon epoxy

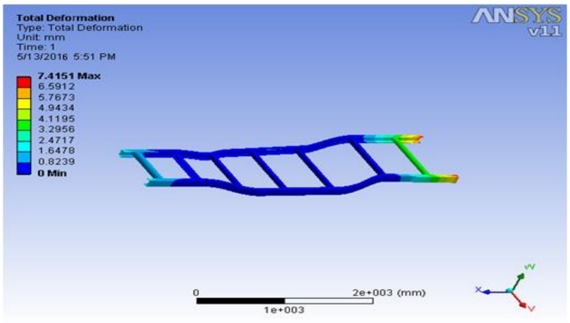


Fig -17: Total deformation for C- section chassis frame-E-Glass fiber

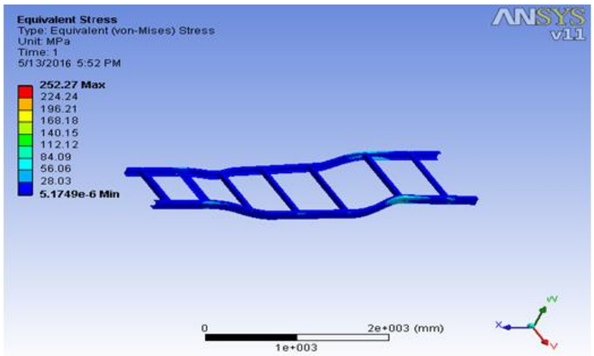


Fig -18: Equivalent stress for C section chassis frame-E-Glass fiber

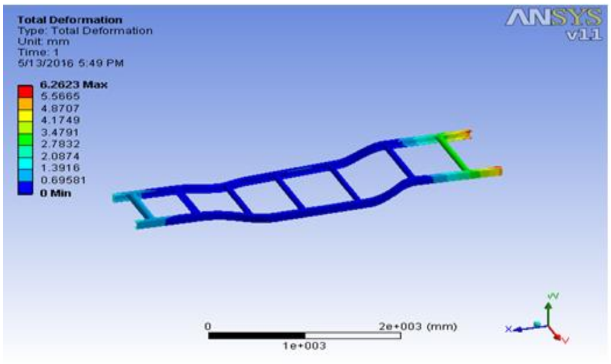


Fig -19: total deformation of c-section chassis frame s-glass fiber

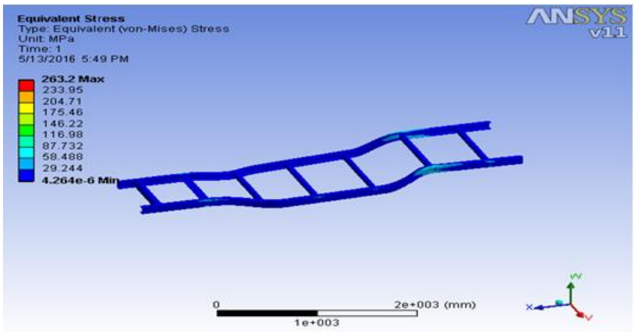


Fig -20: Equivalent stress for C section chassis frame-S-Glass fiber

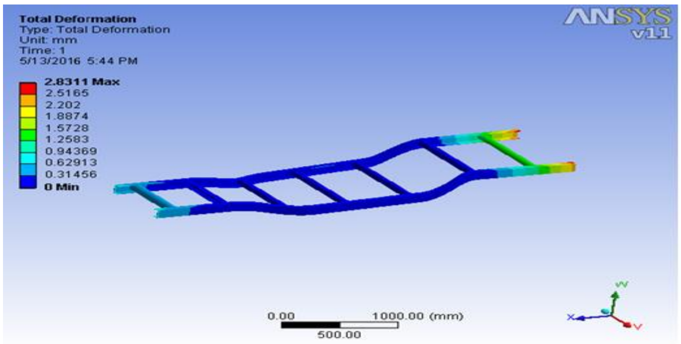


Fig -21: total deformation of c-section chassis frame stainless steel glass fiber

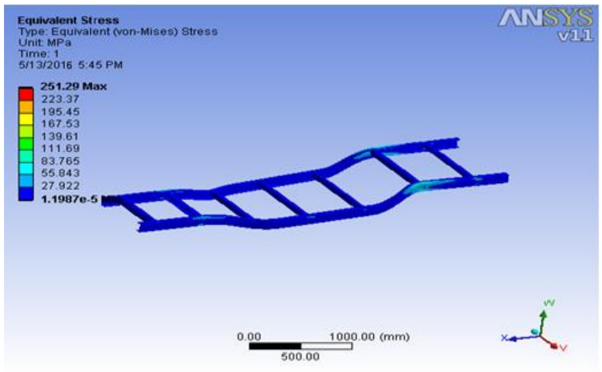


Fig -22: equivalent stress of c-section chassis frame stainless steel glass fiber

6.structural analysis of I-section chassis frame

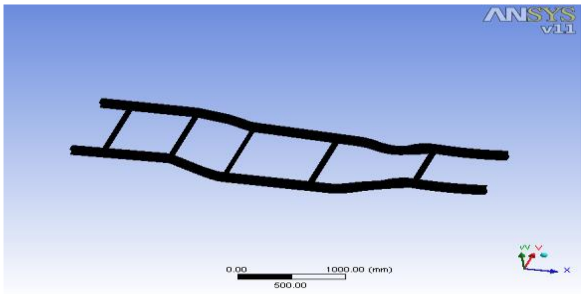


Fig -23: mesh genaration on I-section chasiss frame

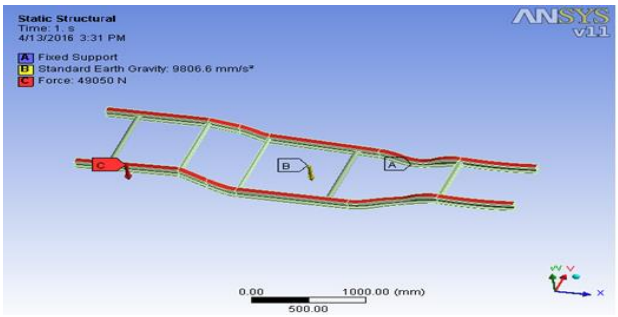


Fig -24: Fixed support and force application on I- section chassis frame

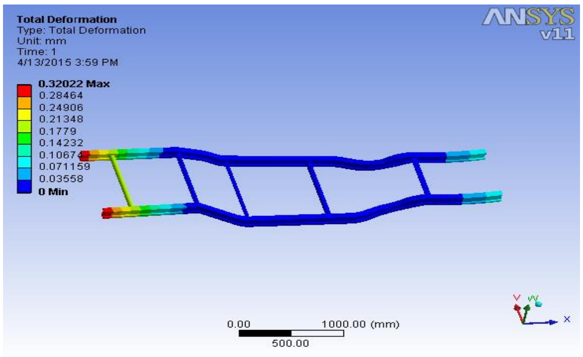


Fig -25: Total deformation for I- section chassis frame-Carbon epoxy

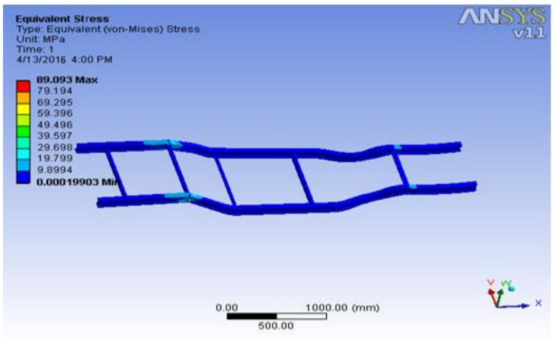


Fig -26: equivalent stress for I-section chassis frame carbon epoxy

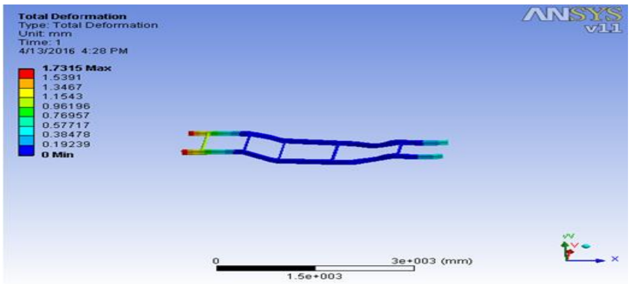


Fig -27: Total deformation for I- section chassis frame-E-Glass fiber

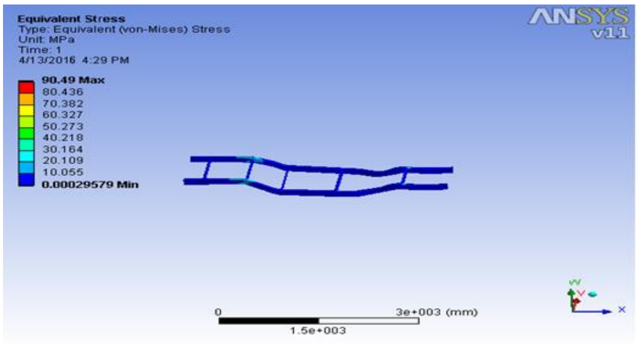


Fig -28: equivalent Stress for I- section chassis frame-E-Glass fiber

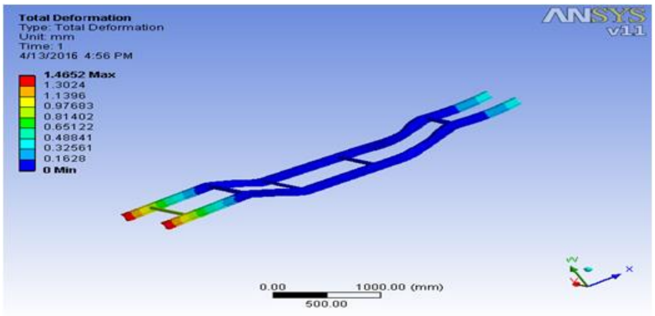


Fig -29: Total deformation for I- section chassis frame S-Glass fiber

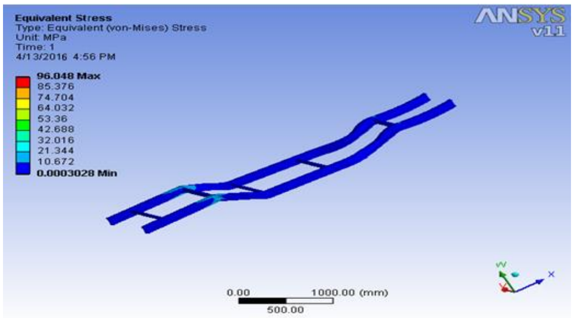


Fig -30: equivalent stress for I-section chassis frame S-glass fiber

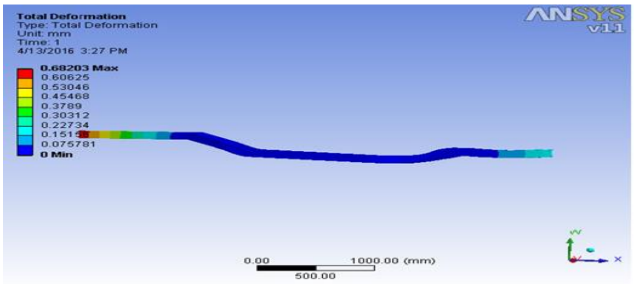


Fig -31: Total deformation for I- section chassis frame

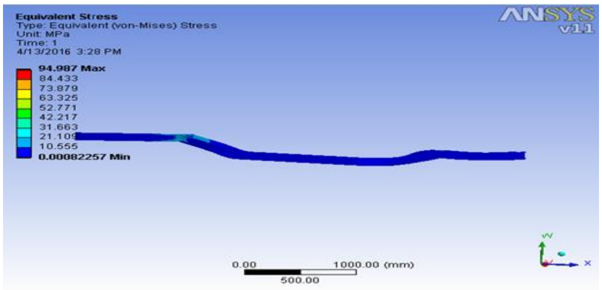


Fig -32: Equivalent Stress for I- section chassis frame

7.ANANLYASIS OF RESULT

Material	Stainless steel	
Shape	Total deformation(mm)	Equivalent stress(Mpa)
Box	1.6783	221.36
C-Section	2.8311	251.29
I-section	0.68203	94.987

Table -2: analysis result for stainless steel

Material	Carbon epoxy	
Shape	Total deformation(mm)	Equivalent stress(Mpa)
Box	0.81695	208.67
C-section	1.3828	235.27
I-section	0.32022	89.093

Table -3: analysis result for carbon epoxy

Material	E-Glass	
Shape	Total deformation(mm)	Equivalent stress(Mpa)
Box	4.3834	222.74
C-section	7.4151	252.27
I-section	1.7315	90.49

Table -4: analysis result for E-glass

Material	S-glass	
Shape	Total deformation(mm)	Equivalent stress(mpa)
Box	3.7.47	233.54
C-Section	6.2623	263.2
I-section	1.4652	96.048

Table -5: analysis result for S-glass

8.CONCLUSION

[1] From the structural Analysis it is concluded that Equivalent stresses and total deformations are more in C type Cross section and less in I type cross section where as Box type cross section offers moderate total deformation and equivalent stresses.

[2] Considering 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 vehicle chassis with I-SECTION has superior strength and stiffness and lesser in weight compared to steel and other polymeric composite materials mentioned.

[3] From the results, it is concluded that the polymeric composite vehicle chassis is lighter and more economical than the conventional steel chassis with similar design specifications.

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