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RESEARCH ARTICLE

DESIGN AND ANALYSIS OF AUTOMOTIVE CHASSIS CONSIDERING CROSS-SECTION AND MATERIAL

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ABSTRACT

The automotive chassis serves as a frame work for supporting the body and different parts of the automobile. Also, it has to withstand the shock, twist, vibration and other stresses caused due to sudden breaking, acceleration, shocking road condition, centrifugal force while cornering and forces induced by its components. The chassis acts as the backbone of a heavy vehicle which carries the maximum load for all designed operating conditions. This paper describes design and analysis of heavy vehicle chassis as the prime objective of any automobile industries in today's fast changing world. In the present paper, the pertinent information of an existing heavy vehicle chassis of EICHER is taken for modeling and analysis by considering polymer composite materials namely, S-Glass Epoxy, and cross-sections like C, I and Box type subjected to the identical load as that of a steel chassis. The numerical results are validated with analytical calculation considering the stress distribution and deformation.

INTRODUCTION

Automotive chassis is a skeletal frame on which mechanical parts like engine, axle assemblies, brakes, steering etc, are fastened. Automotive chassis or automobile chassis helps to keep an automobile rigid, stiff and unbending. Chassis ensures low levels of noise, vibrations and harshness throughout the automobile. 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. 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. It is usually made of a steel frame, which holds the body and engine of an automotive vehicle. It provides strength needed for supporting vehicular components and payload placed upon it. At the time of manufacturing, the body of a vehicle is flexibly molded according to the structure of chassis. It provides strength needed for supporting vehicular components and payload placed upon it. Automobile chassis is usually made of light sheet metal or composite plastics. This paper describes the design and analysis of heavy vehicle chassis considering weight reduction as the prime objective of any automobile industries in today's fast changing world.

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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-ratio of these composite materials are markedly superior to those of metallic materials. The fatigue strength weight ratio as well as fatigue damage tolerances of many composite laminates are excellent. For these reasons, fiber composite have emerged as a major class of structural material and are either used or being considered as substitutions for metal in many weight-critical components in aerospace, automotive and other industries. High damping capacity of composite materials can be beneficial in many automotive applications in which noise, vibration, and hardness is a critical issue for passenger comfort. In the present work, the pertinent information of an existing heavy vehicle chassis of EICHER is taken for design and analysis with different cross sections for different materials like steel and S-Glass Epoxy composite. The model of steel and polymeric composite heavy vehicle chassis was created in Pro-E and analysed with ANSYS for same load conditions. After analysis a comparison is made between existing conventional steel chassis and S-Glass Epoxy in terms of deflections and stresses, to select the best one.

Literature Survey

Considering C, I and Box type cross sections, is analyzed by employing a polymeric composite heavy vehicle chassis for the same load carrying capacity, with a reduction in weight of 73% to 80% (Ravi Chandra *et al.,* 2012). The determination of the stresses in a truck chassis before manufacturing is important due to the design improvement and it is investigated (Hemant *et al.,* 2013). Analytical investigation of the truck chassis design and the weight optimization was done by sensitivity analysis. In sensitivity analysis different cross sections were used for stress analysis and achieved 17% of weight reduction in the truck chassis (Hirak Patel *et al.,* 2013). The stress analysis of chassis using finite element analysis was performed using ANSYS. The same finite element model can be used for the fatigue analysis of the chassis (Ashutosh Dubey and Vivek Dwivedi, 2003). Investigation of the structural analysis and optimization of vehicle chassis with constraints of maximum shear stress and deflection of chassis under maximum load was performed (Abhishek Singh *et al.,* 2014).

The analysis using finite element techniques, weight of chassis frame can be optimized and it is feasible to analyse the modified chassis frame before manufacturing (Anand Gosavi *et al.,* 2014). The model for vehicle that considers the elastic characteristic of frame was applied to the rear frame of articulated dump truck, it was confirmed that this analysis can be used to predict the bending and torsion stresses of frames (Haval Kamal Asker, 2012). The automotive chassis was optimized with constraints of maximum shear stress, equivalent stress and deflection of chassis under maximum load, also a sensitivity analysis is carried out for weight reduction (Monika, *et al.,* 2013). The mathematical stress analysis of a platform integrated structure mounted on vehicle chassis designed for unconventional type of loading pattern was described (Deulgaonkar, 2012). The fatigue study and life prediction on the chassis in order to verify the safety of this chassis during its operation using Finite Element Method (FEM) was discussed in detail (Kurdi, *et al.,* 2008). The modifications of existing bracket have resulted in reduction of stress values leading to safe design was investigated (Balbirsingh, *et al.,* 2013).

The structural analysis of the chassis frame is performed to check the vulnerable points having high magnitude stress at static load condition (Paul *et al.,* 2012). A detailed review was presented on the chassis design using FEA (Harshad *et al.,* 2013). The stress analysis of heavy duty truck chassis was investigated for fatigue study and life prediction of components to determine the critical point having high stress (Roslan Abd Rahman *et al.,* 2008; Goolla Murali *et al.,* 2013). The static and dynamic load characteristics using Finite Element models are performed (Rajappan and Vivekanandhan, 2013). The analysis of chassis frame was done to improve its payload by adding stiffener at maximum stress region of chassis (Sairam Kotari and Gopinath, 1998). The effective method for dynamic stress analysis of structural components of bus systems is detailed (Kim *et al.,* 2010). To determine the characteristics of a chassis using ANSYS and reinforcement technique of optimization is carried out (Sandip Godse, 2013).

The static and dynamic load characteristics of chassis were investigated using Finite Element Analysis method (Rajappan and Vivekanandhan, 2013; Tushar *et al.,* 2013). The structural analysis of chassis was investigated by replacing traditional materials with ultra light weight carbon fiber materials (Salvi Gauri Sanjay *et al.,* 2014).

Specification of Existing Heavy Vehicle Chassis

The specification of an EICHER 10.9 vehicle is exposed in the Table 1 The capacity of truck is 78480N, total load acting on the chassis including truck capacity, weight of the body and engine is 117720N. The load acting on each beam is half of the total load acting on the chassis hence load acting on single beam is 58860N

Stress $\sigma = M_{max}/Z_{xx}$ ……………..(1)

Y= wx(b-x)/24EI [x(b-x)+ b^2- 2(c^2+ a^2)- 2/b {c^2 x+ a^2 (b-x)}] ……………..(2)

Table 1. Specifications of heavy vehicle chassis

PARAMETERS	VALUE
Material of the chassis	Steel 52
Chemical composition	0.20%C, 0.50%Si, 0.9%Mn, 0.03%P and 0.025%S
Side bar of the chassis	200mm x 76 mm x 6mm
Cross bar of the chassis	180mm x 75 mm x 4mm
Front Overhang (a)	935 mm
Wheel Base (b)	3800 mm
Rear Overhang (c)	1620 mm
Young's modulus E	2×10^5 N / mm^2
Poisson Ratio	0.3
Radius of Gyration R	100 mm

Structural Analysis of Heavy Vehicle Chassis

Dimensions of polymeric composite heavy vehicle chassis (PCHVC) are taken as that of the conventional steel heavy vehicle chassis (SHVC). Width of the chassis is 80mm. Since the properties of PCHVC vary with directions of fiber, a 3-D model of chassis is needed for analysis. The loading conditions are assumed to be static. The element has six degrees of freedom at each node translations in the nodal x, y, and z directions and rotations about the nodal x, y, and z-axes. The finite element analysis is carried out on steel chassis as well as different types of polymeric composite heavy vehicle chassis. From the analysis the stress distribution (Von-mises stress) and deformations were carried out. The total load of chassis of magnitude 58860N is applied on each side of beam and the gravitational force of 9806.6N is also considered.

RESULTS AND DISCUSSION

Deformation Plot of C - Channel Section

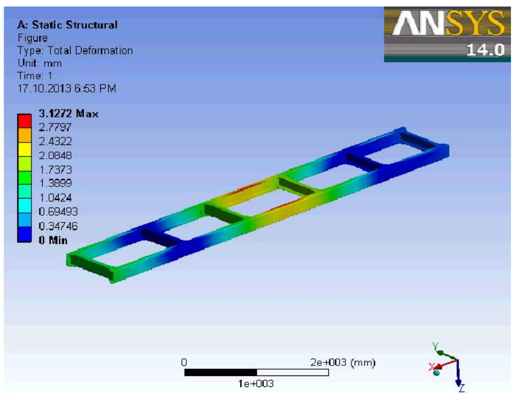

Fig. 1. Deformation pattern for steel chassis channel

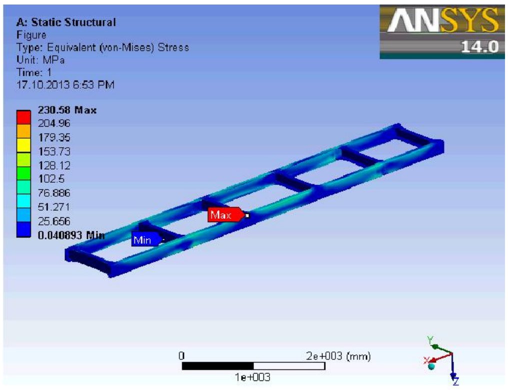

Fig. 2. Stress distribution for steel chassis

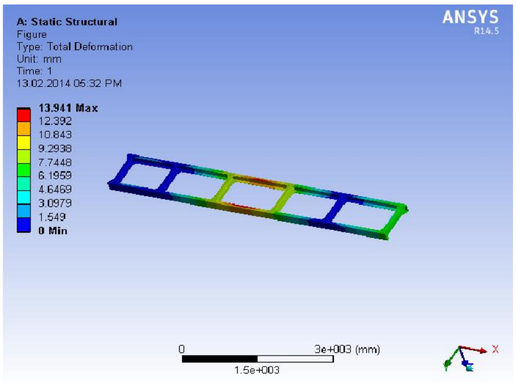

Fig. 3. Deformation pattern for S-Glass epoxy chassis

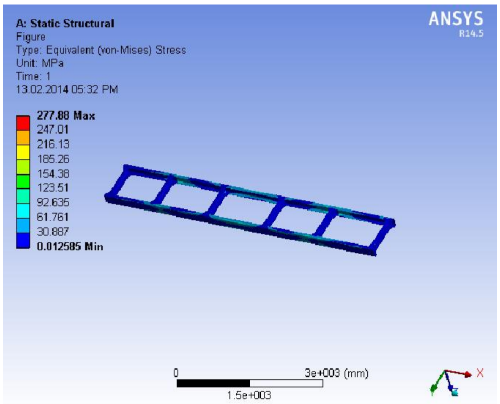

Fig. 4. Stress distribution for S-Glass epoxy chassis

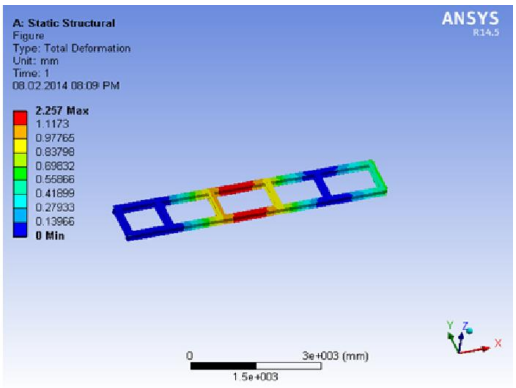

Fig. 5. Deformation pattern for steel chassis

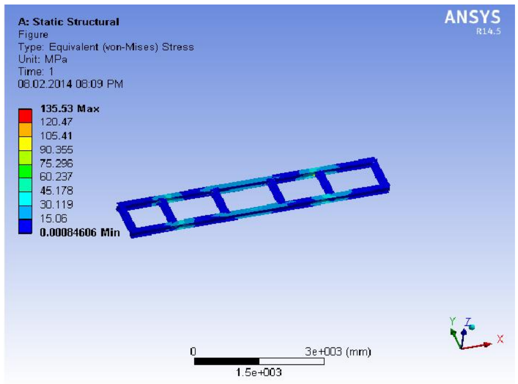

Fig. 6. Stress distribution for steel chassis

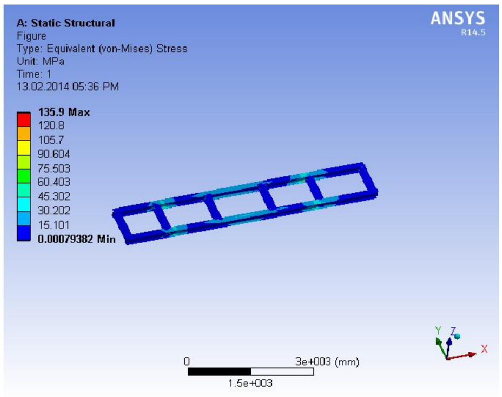

Fig 7. Stress distribution for S-Glass epoxy chassis

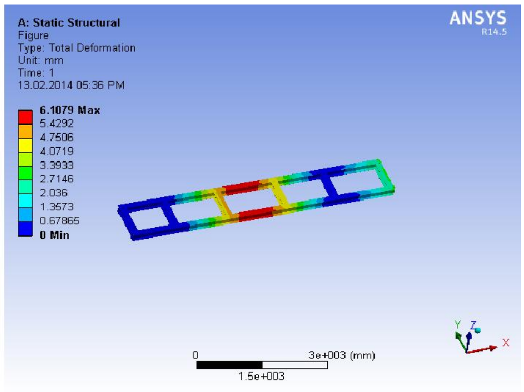

Fig. 8. Deformation pattern for S-Glass epoxy chassis

Structural Analysis of Box Channel Section

Fig 1 to 4 illustrates the deformation and stress distribution pattern for the C-channel cross section. Fig 1,3 represents the deformation plot for the C-channel cross section for the different materials. Fig 2,4 represents the stress distribution for the C-channel cross section for the different materials. The deformation and stress distribution pattern for the I- Cross section is depicted in the Fig 5 to 8. Figures 5,8 represents the deformation plot for the I-channel cross section for the different materials. Fig 6,7 represents the stress distribution for the I-channel cross section for the different materials. The deformation and stress distribution pattern for the Box- Cross section is depicted in the Fig 9 to 12. The deformation plot for the Box- cross section for the different materials is shown in fig 9,11.

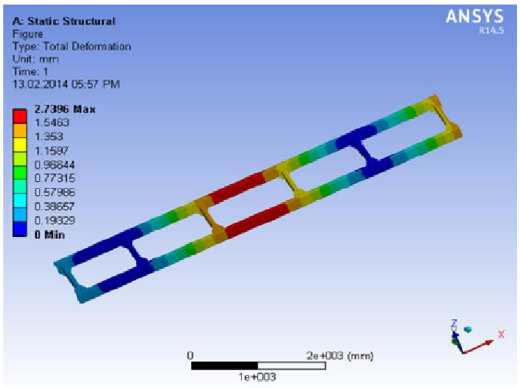

Fig. 9. Deformation pattern for steel chassis

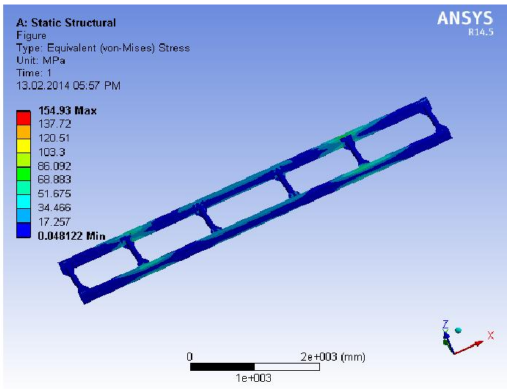

Fig. 10. Stress distribution for steel chassis

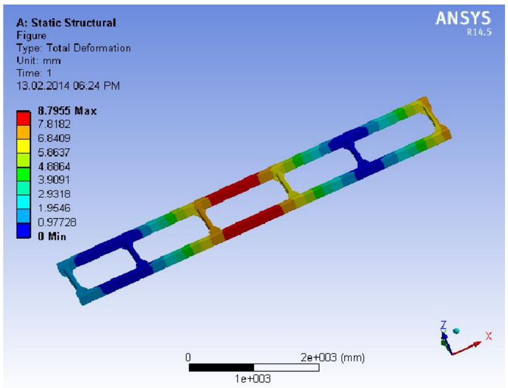

Fig. 11. Deformation pattern for S-Glass epoxy chassis

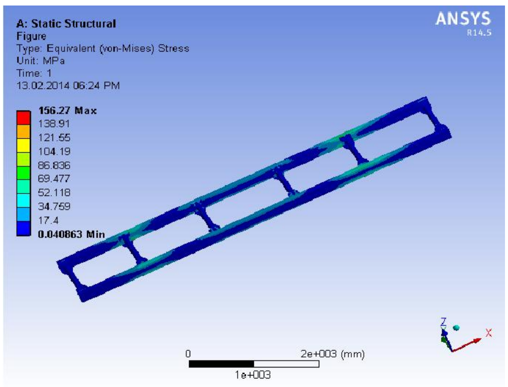

Fig. 12. Stress distribution for S-Glass epoxy chassis

The stress distribution for the Box-cross section for the different materials is shown in Fig 10,12 The analytical results of stress distribution and deformation computed using equation 1 and 2 tabulated in the Table 2. Table 2 shows the stress distribution and deformation values for materials and cross section of different materials and compared with the analytical values. It can be inferred from the tabulation that the magnitudes of the deformation and stress are very closer to analytical results in comparison with the numerical results.

Table 2. Deformation and Stress Distribution Values

Cross Section	Material Type	Stress DISTRIBUTION		Deformation (mm)	
		Numerical	Analytical	Numerical	Analytical
C	Steel	230.58	235.0789	3.1272	3.214
	S-Glass Epoxy	277.88	235.0789	13.941	13.561
I	Steel	135.53	133.64	2.2570	2.349
	S-Glass Epoxy	135.9	133.64	6.1079	6.530
BOX	Steel	154.93	155.06	2.7396	2.833
	S-Glass Epoxy	156.27	155.06	8.7955	8.912

The magnitude of stress and deformation of steel are greater when compared to other polymer composites. When compared with C and Box cross sections the I cross section induces very low stress and deformation. S-Glass Epoxy material of C and BOX cross section as high stress and deformation when compare to I cross section. Fig 13 and 14 indicates the deformation and stress distribution curve for the analysis performed on various cross sections with different materials like steel and S-Glass Epoxy composite. From the above curve it is clear that S-Glass Epoxy polymeric composite induces high level of deformation and stress distribution when compared with steel. I-Cross section provides low deformation and stress distribution when compared to other cross sections like C and Box.

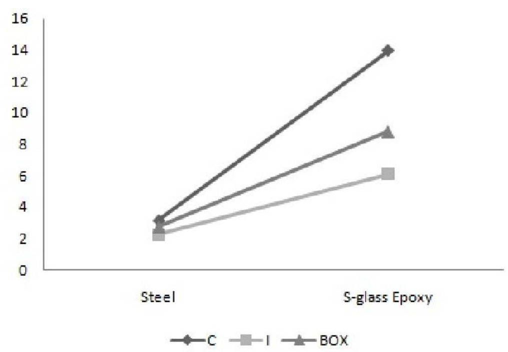

Fig. 13. Deformation curve

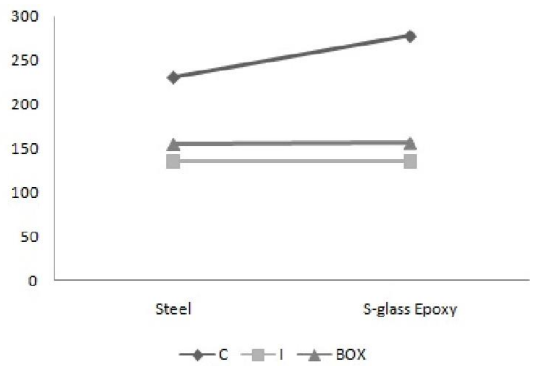

Fig. 14. Stress distribution curve

Conclusion

The existing heavy vehicle chassis of EICHER is considered for design and analysis with different cross sections for different materials like S-Glass Epoxy composites is performed. The model of the chassis was created in Pro-E and analysed with ANSYS for same load conditions. After analysis a comparison is made between existing conventional steel chassis and S-Glass Epoxy composite materials in terms of deformation and stresses, to select the best one. The results of the steel and polymeric composites material with cross section C, I, and Box are performed. It is inferred that by employing a S-Glass Epoxy composites heavy vehicle chassis for same load carrying capacity, there is a reduction in weight when compared to steel but main downside is S-Glass Epoxy induces high deformation and stress distribution when compared to steel except in 'I' section. Based on the results it was inferred that steel with 'I' section has superior strength to withstand high load and induced low deformation and stress distribution when compared to S-Glass Epoxy composites material.

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