Design & Analysis of a Chassis Frame by using Carbon Fiber, Graphene, Steel & Epoxy as Composite Material: A Comparative Study

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Abstract - *In Automobile the word chassis Frame means the part of automobile that hold all the important part of vehicle like Engine, Steering Systems, Suspension Systematic and all the components constitute together to form a chassis. The conventional chassis is very heavy and bulky in nature due to that it contributes in higher emission and less efficiency of vehicle. In this paper firstly the chassis frame is modeled in CAD software and the further analysis is done in ANSYS by using the composite material like Carbon Fibre, Graphene, Steel and Glass Epoxy . Analysis is done to find out areas with maximum stress. The weight of chassis with different materials is also found out. Furthermore Front impact and Side impact is also done.*

Key Words: **Chassis Design, Composite Material, Graphene, Carbon Fiber, Front impact, Side impact.**

1. INTRODUCTION

In modern world on Road vehicles have changed drastically based on the design and other functional aspects. Market demands the faster and higher transportation in a short span. In order to meet this market demand, vehicle manufacturers are designing heavy load carrying vehicles. These heavy load carrying vehicles gives an advantage of faster, heavy transportation in a short span. On the other side the safety of the heavy load carrying vehicle has to be ensured. Based on the historical data Chassis/body is responsible for only 7% of the failure types. However, failures of chassis are catastrophic with serious consequences. In some cases, a consequence of these in-service failures results in the recall of all affected vehicles with heavy costs and bad publicity. Every vehicle has a body, which has to carry both the loads and its own weight. Vehicle body consists of two parts; chassis and bodywork or superstructure. The conventional chassis frame, which is made of pressed steel members, can be considered structurally as grillages. The chassis frame includes cross-members located at critical stress points along the side members. To provide a rigid, box-like structure, the cross-members secure the two main rails in a parallel position. The cross members are usually attached to the side members by connection plates. The joint is riveted or bolted in trucks and is welded in trailers. Chassis is the backbone of any vehicle. If any failure occurs in chassis it will leads to the collapse of a whole vehicle system. Also chassis is not a component that can be replaced easily. If any failure occurs at chassis, either have to replace the chassis totally or require the cost and effort similar to the new vehicle assembly. Chassis design should be cost effective, lesser weight, maximum payload, ensures vehicle safety by withstanding the worst loading conditions. Automotive chassis is a skeletal frame on which various mechanical parts like engine, tires, axle assemblies, brakes, steering etc. are bolted. It is the most crucial element that gives strength and stability to the vehicle under different conditions.

2. LITRETURE SURVEY

Kenji KARITA, Yoichiro KOHIYAMA, Toshihiko KOBIKI, Kiyoshi OOSHIMA, Mamoru HASHIMOTO (2003) had developed a chassis made by Aluminium. The material selected for the frame is 6061-T6. They used the Variable section extrusion method for making the chassis. It's developed with the help of computer Aided Engineering. Aluminium material gives an advantage of weight reduction. From this study authors found that the Aluminium chassis meets the target of weight reduction, strength and rigidity. Also they concluded that the remaining technical issues will be addressed to enable commercial adoption of the aluminum frame. M.

Ravichandra, S. Srinivasalu, Syed altaf Hussain (2012) studied the alternate material for chassis. They studied and analyzed Carbon/Epoxy, Eglass/Epoxy and S-glass/Epoxy as chassis material in various cross sections like C, I and Box Section. So, after studying this survey we will find the weakest and strongest section of chassis frame then will select suitable composite for particular section then will analyze the result.

Roslan Abd Rahman, Mohd Nasir Tamin, Ojo Kurdi (2008) used FEM stress analysis as a preliminary data for fatigue life prediction. They used ABAQUS software for simulation and analysis and also taken ASTM Low Alloy steel A710 (C) for study. Primary objective was to find the high stressed area where the Fatigue Failure will start. It's found that the chassis opening area having contact with bolt experiences high stress. N.V.Dhandapani, G Mohan kumar, K.K.Debnath (2012) have used Finite element methods to study the effect of various stress distribution using Ansys software. To investigate the field failure of 100Ton dumper they introduced gussets in failure area. After modification the chassis structure was validated by linear static analysis and found that the modified chassis was safe. Teo Han Fui, Roslan Abd. Rahman (2007) have studied the 4.5 Ton truck chassis against road roughness and excitations. Vibration induced by Road Roughness and excitation by the vibrating components mounted on chassis were studied. Chassis responses were examined by stress distribution and displacements. Mode shape results determine the suitable mounting locations of components like engine and suspension systems. 429 IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 1 Issue 7, September 2014. www.ijiset.com ISSN 2348 – 7968 Analysis results reveal that the road excitation was a main disturbance to the chassis. S.S Sane, Ghanashyam Jadhav, H. Ananadaraj (2008) analyzed the light Commercial Vehicle chassis using FEM and simulated the failure during testing. Hyper mesh and Opti-struct software were used for analysis and simulation. During the study they introduced local stiffeners to reduce the magnitude of the stress. The modified chassis stress values were reduced by 44%.

3. OBJECTIVE

- By doing this project chassis manufacturing company can save time and effort because of easy manufacturing method.
- Reduced fuel economy.
- Low weight of chassis with composites.
- To carry load of the passengers or goods carried in body.
- To support the load of the body, engine, gear box, etc.
- To withstand centrifugal force while cornering.
- To withstand the stresses caused due to the sudden braking or acceleration.

4. DETAILS OF CHASSIS FRAME

State	Fully defined
Length X	1574.8mm
Length Y	360.11mm
Length Z	660.4mm
Volume	$1.9898*10^{7}$ mm^{3}
Surface area (approx.)	$5.6851*10^{6}$ mm^{2}
Analysis type	3D
Mass	$2.9847*10^{-2}$ t

5. MATERIAL SELECTION

Table-1: Material properties

Sr. no	Properties	Units	Steel	Carbon fiber	E-glass	Graphene
1	Density	*Kg/mm³*	$7.85*10^{-9}$	$1.5*10^{-9}$	$2*10^{-19}$	$2.267*10^{-9}$
2	Young's modulus	*Mpa*	$2*10^{5}$	$1.55*10^{5}$	73000	$1*10^{6}$
3	Poisson's ratio	-	0.29	0.38	0.32	0.456
4	Ultimate strength	*Mpa*	650	600	1280	$1.3*10^{5}$
5	Yield strength	*Mpa*	440	1000	$7*10^{-4}$	14000
6	Bulk modulus	*Mpa*	$1.5873*10^{5}$	$2.1528*10^{5}$	67593	$3.7879*10^{6}$
7	Shear modulus	*Mpa*	77519	56159	27652	$3.434*10^{5}$

The loads acting on the chassis frame are as follow:-

1. Stationary loads namely the loads of permanent attachment like all the parts of the chassis, body etc.
2. Short duration loads while turning, braking etc.
3. Momentary loads while quick acceleration, sudden braking etc.
4. Loads applied while crossing roads of irregular and uneven surfaces
5. Loads caused by sudden accidents, head on collusions etc.
6. Loads caused by irregular and overloading of vehicle.

6. DETAILS OF SOFTWARE

While appealing at first glance as a simple hunk of the metal, frames encounter greater amounts of stress are built accordingly. The first issue addressed is beam height or the height of the vertical side of the frame. The taller the frame the better it is able to resist vertical flex when force is applied to the top of the frame. This is the reason to make proper model on 3D software before we used for analyses the situations. Hence, the modeling of chassis frame using 3D software like SolidWorks, ANSYS.

6.1 INTRODUCTION TO SOLIDWORKS

Solid works mechanical design automation software is feature based, parametric solid modeling design tool which advantage of easy to learn windows graphical user interface. We can create fully associated 3S solid models with or without while utilizing automatic or user defined relations to capture design intent. Solidworks is used modeled frames chassis body as shown below;-

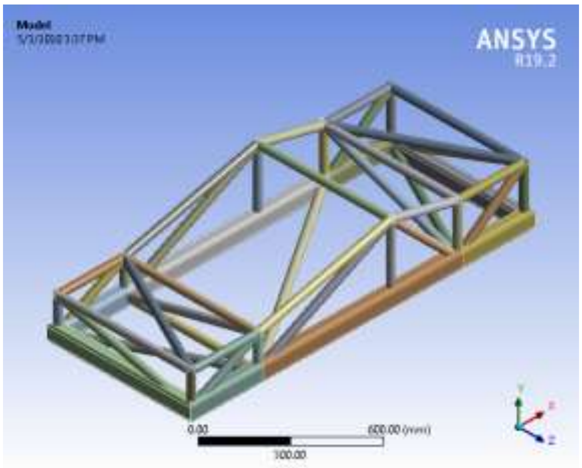


Figure -1: CAD Model of frame

6.2 MESHING OF CHASSIS FRAME

The finite element method (FEM) is a numerical technique for finding approximate solutions to boundary value problems FEM subdivides a large problem into smaller, simpler, parts, called finite elements Meshing of chassis frame is done in Ansys R 14.5 and method used for meshing is tetrahedrons surface mesher .The size of elements is kept as minimum as possible to get the accurate results and at some points the finer meshing is also done to get better results.

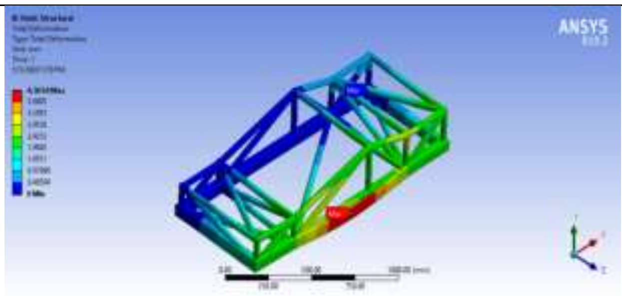
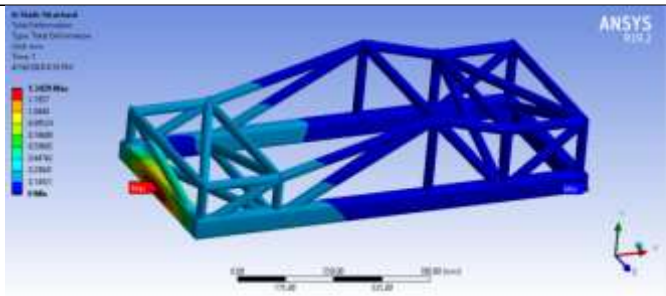
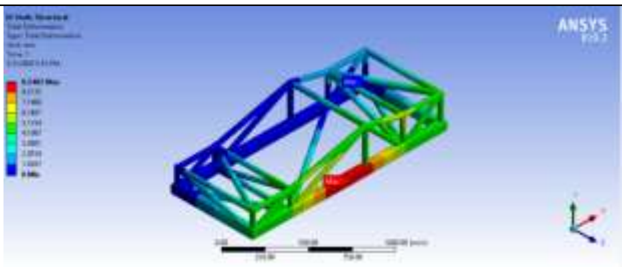
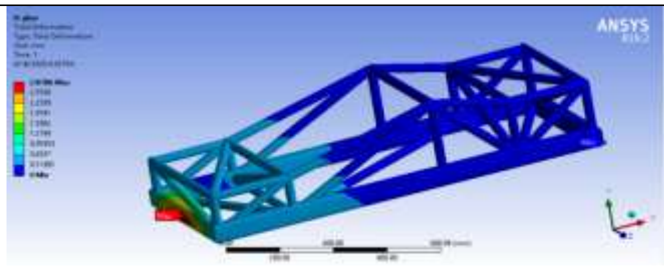
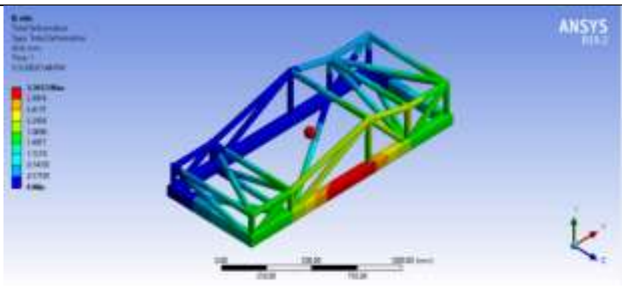
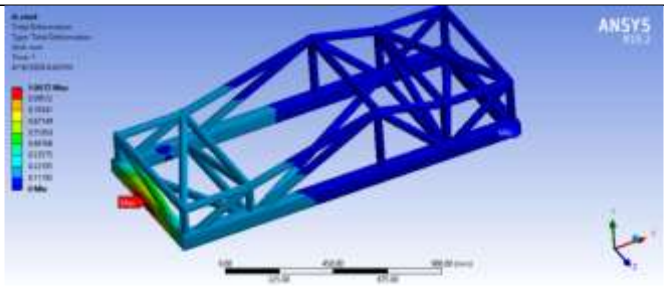
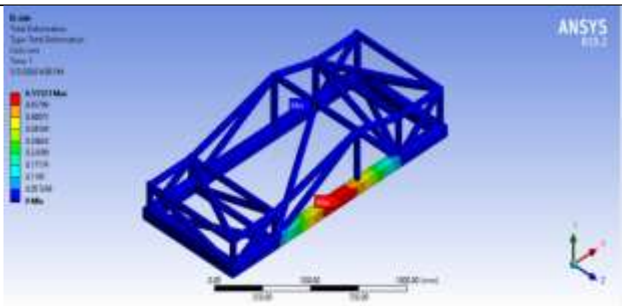
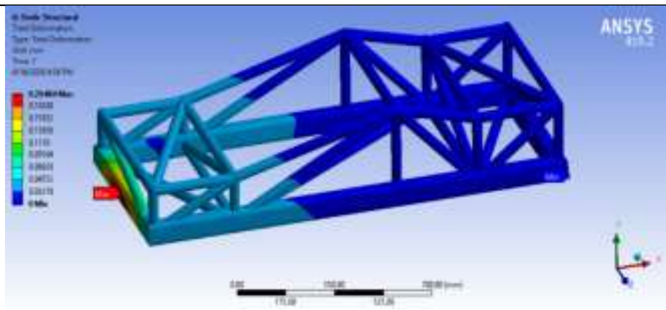
6.3 BOUNDARY CONDITIONS FOR STATIC ANALYSIS:

While doing software based analysis there is need to apply boundary conditions. The Boundary Conditions are as follows:

1. Rear Part of chassis is fixed and load is applied to Front Part
2. Right part of chassis is fixed and load is applied to Left part.

6.4 INTRODUCTION TO STATIC ANALYSIS

The Static and Dynamic analysis of mechanical parts plays a very important role for the efficiency and precision of the work performed by any engineer, including product development engineers, QA engineers, reliability engineers, design engineers, among others. In the past, these analyses were performed through tests that were carried out on prototypes of the product, which meant an increase on the time needed to develop the product, as well as an increase on the related costs. However, technological advancements have allowed developers and engineers to depend upon computational tools to carry out these tests virtually via the Finite Elements Method (FEM), which is also referred to as Finite Element Analysis (FEA).The static analysis of mechanical parts is intended to calculate the effects of constant loads on the structure ignoring the effects of inertia and shock that are commonly found when the applied loads change rapidly.

Comparison of Impacts on chassis body		
Material	**Side impact of chassis**	**Front impact of chassis**
Carbon Fibre		
Epoxy		
Carbon Steel		
Graphene		

7. RESULT & DISSCUSSION

7.1 Table consist of result of side impact;-

Material		Deformation	Equivalent stress
Carbon fiber	**Minimum**	0 mm	0 Mpa
	Maximum	4.3654 mm	369.73 Mpa
	Average	1.2555 mm	24.92 Mpa
E-glass/Epoxy	**Minimum**	0 mm	0 Mpa

	Maximum	9.2402 mm	366.67 Mpa
	Average	2.6541 mm	24.905 Mpa
Graphene	**Minimum**	0 mm	0 Mpa
	Maximum	0.51523 mm	406.01 Mpa
	Average	$2.7897*10^{-2}$ mm	13.305 Mpa
Steel	**Minimum**	0 mm	0 Mpa
	Maximum	3.3653 mm	359.04 Mpa
	Average	0.98496 mm	24.377 Mpa

7.2 Table consist result for front impact:-

Material		**Deformation**	**Equivalent stress**
Carbon fiber	**Minimum**	0 mm	0 Mpa
	Maximum	1.3429 mm	281.8 Mpa
	Average	0.15042 mm	12.674 Mpa
E-glass/Epoxy	**Minimum**	0 mm	0 Mpa
	Maximum	2.878 mm	281.9 Mpa
	Average	0.31917 mm	12.678 Mpa
Graphene	**Minimum**	0 mm	0 Mpa
	Maximum	0.20484 mm	282.77 Mpa
	Average	2.3283810^{-2} mm	12.645 Mpa
Steel	**Minimum**	0 mm	0 Mpa
	Maximum	1.0072 mm	269.7 Mpa
	Average	0.11173 mm	9.5933 Mpa

7.3 Table consist result for chassis weight:-

Sr. no	**Material**	**Weight (Kg)**
1	Carbon fiber	30Kg
2	Steel	156.2 Kg
3	E-glass/Epoxy	39.795 Kg
4	Graphene	45 Kg

8. CONCLUSIONS

1. From table 6.1, Maximum deformation of 9.2404mm is observed in chassis made out of Glass Epoxy. An important observation is made in case of chassis made out of Graphene where the deformation is only 0.515mm. Whereas, equivalent stress is maximum in case of Graphene having a value of 406.01 Mpa and minimum in case of Steel having a value of 359.04 Mpa.
2. A similar trend is observed in Table 6.2 where peak deformation of 2.878mm is observed in Glass Epoxy, and Graphene shows a deformation of 0.204mm. The equivalent stress is more or less the same for all materials ranging from 270-282Mpa.
3. It is noted that chassis made out of Carbon Fibre weighed the least (30Kg), followed by E-Glass(40Kg) and Graphene (45Kg). Steel chassis weighed 520% more than that of Carbon Fibre.

4. Even though cost of fabricating a chassis solely made out of Graphene is costly, we can use Graphene as a replacement in those areas which is more prone to failure.

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