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Design and Analysis of Chassis for Green and Light Vehicle Using Composite Material.

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ABSTRACT

Nowadays, transportation industry plays major role in the economy of modern developing and industrialized countries. Weight reduction is now the main issue in automobile industries. The chassis frame is an important part in automobiles. The main function of the auto mobile chassis is to carry the goods and pay load placed uponit. So it must be strong enough to resist the shock, wist, vibration and other stresses. In the present work, the dimensions of an existing light vehicle chassis of a TOYOTA (LJ150-GKMEE) vehicle is taken for modeling and analysis of a vehicle chassis with composite materials namely S-GLASS epoxy and HSLA Steel, subjected to the same load as that of a steel chassis. Reduction of weight of various parts of a vehicle can improve the performance and efficiency of the automobile. The composite materials provide a good strength-to-weight ratio, which could be re placed for the conventional materials. This paper deals with the structural analysis of a frontend crossbar which is replaced with s-glass Fiber Reinforced Polymer composite material. Maximum stress and maximum deflection are important criteria for design of the chassis. The objective of present is to determine the maximum stress, maximum deflection. For validation the design is done by applying the vertical loads acting horizontally in the existing cross sections. To do this research I use The FE analysis for a light modeling by utilizing commercial finite element analysis software packages like CATIA and ANSYS. Then I contribute light and high strength chassis for light and green vehicle.

INTRODUCTION

Transportation industry plays a major role in the economy of modern industrialized and developing countries. The purpose of this is to design and structural analysis of chassis for light and green vehicle using composite material.

Various loads acting on the frame:

Various loads acting on the frame area1.Momentary duration Load -While taking curve.2.Short duration Load -While crossing a broken patch3. 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. Short duration Load – crossing a broken patch.

Problem Statement:

Automobiles that uses gasoline or diesel fuels affect the environment and the country economy specially the developing country like Ethiopia. So it is necessary to build green and light vehicle. We can solve this problem by reducing the size and the weight of automobile by using light weight material such as aluminum, composite like metal metrics composite and polymer composites. When the vehicle number increases, the usage of petrol (fuel) also increases. At the same time, the emission from the vehicles increases the air pollution. Reducing the weight of the vehicle which can reduce the usage of petrol. If the chassis is designed in an optimal material usage then it will save the amount of material consumed for single time also the reduction in fuel cost will also be economical for customer.

LITERATURE REVIEW

The function of this chapter is to survey different journals, scholarly articles, books and other sources related to my title. Light vehicle chassis is a major component in an on road vehicle system. This research work contains modeling, design and structural analysis of light vehicle chassis. The FE analysis have been done for a light vehicle chassis model by utilizing commercial finite element analysis software packages like CATIA and ANSYS.

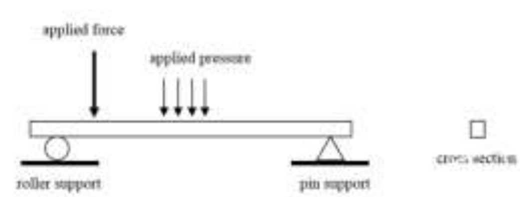
Green vehicle:

There are two main objectives, which involves on the development of automobile chassis. Firstly, the appropriate static and dynamic characteristics of the existing chassis have to be determined. Secondly, structural development process in order to achieve high quality of the product. [13] But today the research must be become to select a material used to manufacture light weight chassis for green and light vehicle. Green vehicle technologies are a promising technology for drastically reducing the environmental burden of road transport. More than a decade ago and also more recently, they were advocated by various actors as an important element in reducing CO_2 emissions of particularly passenger cars and light commercial vehicles as well as emissions of pollutants and noise. By green vehicle we can reduce also the foreign currency and maximize the country economic development because the usage of fuel is reduced and the vehicle uses alternative energy such as electrical, solar energy and other sources. This will happen by reducing the weight of chassis.

Design calculation and Static Analysis of Chassis Frame: Here in static analysis a typical ladder frame chassis is considered. The different load considerations are taken for analysis. The chassis is designed analytically by varying materials in rectangular cross section of beam. There is different kind of cross section in automobile chassis. There are:- Rectangular Section**,** Square Section**,** Tube Section.

According to my literature rectangular cross section is essential for light automobile comparing to others type because of its strength and stiffness.

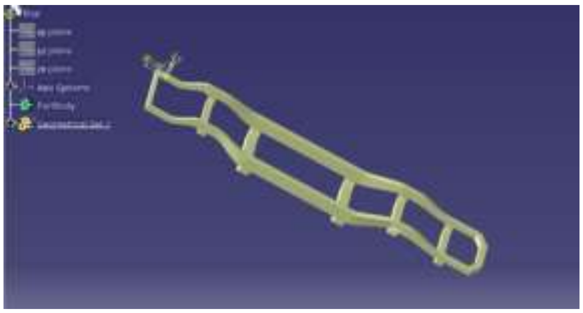
During static condition the chassis frame is only subjected to bending loads due to the weight of the members over here. By considering the equation of bending the cross sections are decided. Then the same cross sections are analyzed by using FEM.



Creating a Solid Model:

It is the process of developing a mathematical representation of any three-dimensional surface of object via specialized software. The product is called a 3D model

A Three Dimensional solid Toyota model of Ladder chassis is created on the computer using CATIA. This 3D Model is exported to Ansys for performing Finite Element Analysis.



Design of chassis frame using catia

Structural Analysis:

It is the methodology of determining the effects of loads on physical structures and their components. Structures subject to this type of analysis include buildings, bridges, vehicles, machinery, furniture, attire, soil strata, prostheses and biological tissue. Structural analysis incorporates the fields of applied mechanics, materials science and applied mathematics to compute a structure's deformations, internal forces, stresses, support reactions, accelerations, and stability. The results of the analysis are used to verify a structure's fitness for use, often saving physical tests. Structural Analysis is thus a key part of the engineering design of structures. The present frame model is converted into IGES format and it is then imported to ANSYS Workbench 18.2.There are various steps that are to be followed in analyzing a component structurally. They are:-

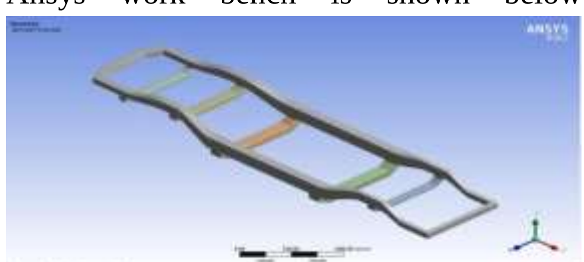
1. Mesh generation
2. Fixed supports
3. Application of loads
4. Evaluating result.

Finite Element Analysis:

In this step there are three main steps, namely: pre-processing, solution and post processing. In pre-processing (model definition) includes: define the geometric domain of the problem, the element type(s) to be used, the material properties of the elements, the geometric properties of the elements (length, area, and the like), the element connectivity (mesh the model), the physical constraints (boundary conditions) and the loadings.

In solution phase, the governing algebraic equations in matrix form are assembled and the unknown values of the primary field variable(s) are computed. The computed results are then used by back substitution to determine additional, derived variables, such as reaction forces, element stresses and heat flow. Actually, the features in this step such as matrix manipulation, numerical integration and equation solving are carried out automatically by commercial software. In post processing, the analysis and evaluation of the result is conducted in this step.

Finite element analysis of chassis using ansys workbench: ThemodelofchassisissavedinIGESformatwhichcanbedirectlyimportedintoANSYSworkbench. The model imported to Ansys work bench is shown below



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Imported Model in Ansys Workbench

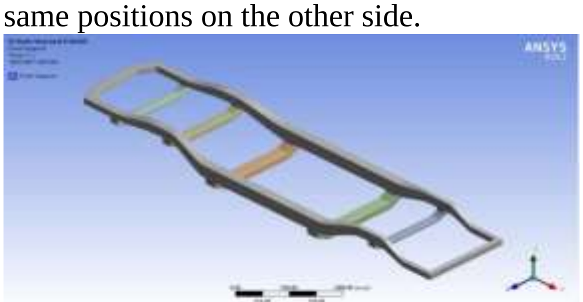
Meshing and Boundary Conditions:

The meshing is done on the model with 291662 number of nodes and 298211 numbers of elements. The Toyota chassis model is loaded by static forces from the truck body and load. For this model, the maximum loaded weight is 2700 kg. The load is assumed as a uniform distributed obtained from the maximum loaded weight divided by the total length of chassis frame. The finite element model of the chassis, applied with boundary conditions is shown in figure below. ANSYS Meshing provides a scalable solution. Quick automatic hex or hex-dominant mesh can be generated for optimal solution efficiency and accuracy**.**

Isometric View of CHASIS after Meshing

Fixed Supports:

The fixed supports for the frame are placed at the wheel positions. The total number of supports is four. The first support is placed at 1000 mm from the front end the second support is placed at 660 mm from the rear side. The other two supports are placed at same positions on the other side.

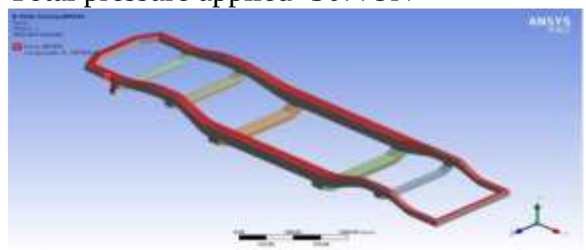


Fixed supports at Front and Rear wheel positions

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

Total pressure applied=30779N



Area on which Pressure is applied on chassis

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

= 0.0194×7800=153.66 kg

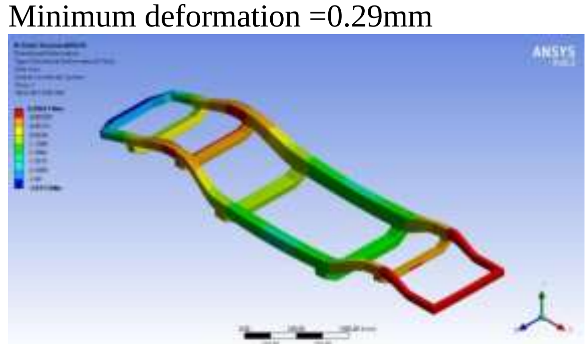
Finite element result of HSLA steel

Deformation of HSLA steel:

The values of deformation obtained in ANSYS 18.2 for structural steel are as shown in fig below is:-

Maximum deformation =3.05mm

Minimum deformation =0.29mm

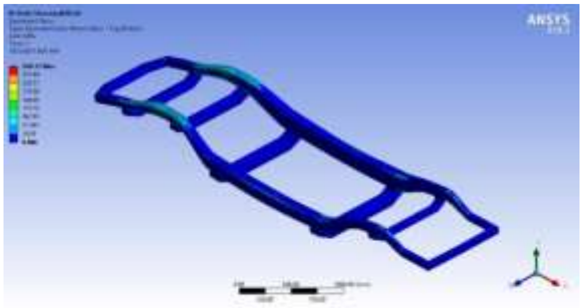


Total deformations of HSLA steel chassis

Equivalent stress:

The Equivalent stress distribution in the frame for structural steel is as shown in Fig.

3.11. From Fig. 3.11 it can be inferred that Maximum Equivalent stress = 260MPa (Approx.) Minimum Equivalent stress = 0 MPa



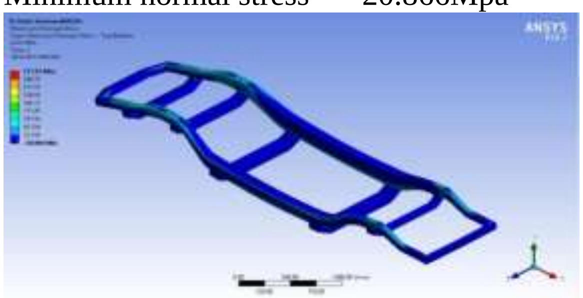
Von Mises Stress Distribution or equivalent stress of HSLA steel

Normal stress of HSLA steel:

The normal stress distribution in the frame for structural steel is as shown in Fig... From the Fig.18 it can be inferred that

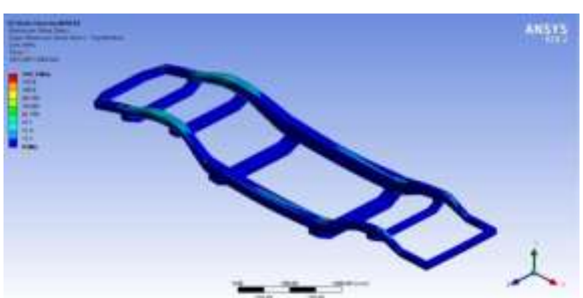
Maximum normal stress = 277.93 Mpa

Minimum normal stress = - 20.866Mpa



Maximum principal stress of HSLA steel.

Maximum Shear stress of HSLA steel:Maximum shear stress =141.3Mpa Minimum shear stress =0Mpa

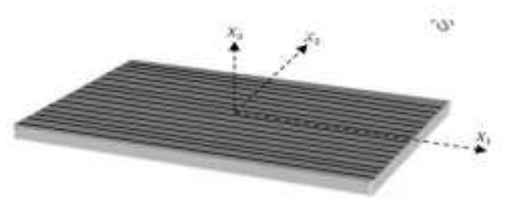


Maximum shear stress of HSLA steel.

Finite element result of s-glass epoxy composite material

Engineering constants of s-glass unidirectional composite lamina

Unlike isotropic materials that have similar properties in all directions, a uniax- ial lamina is orthotropic, with distinct properties along the fiber, transverse, and through-the-thickness directions, as seen in Figure 20. Isotropic materials have only two independent engineering constants, which are Young's modulus of elastic- ity (E) and Poisson's ratio (ν). Conversely, orthotropic laminas have nine distinct engineering parameters, including three Young's moduli along the three principal materials directions (E 1 , E 2 , E 3), three independent Poisson's ratios (ν 12 , ν 13 , ν 23), and three shear moduli (G 12 , G 13 , G 23). The generalized 3-D compliance relationship of an orthotropic sheet is [36]



FRPlaminawiththeprincipalmaterialdirections.

Massofs-glassepoxychassis:

Mass = Volume × Density= 0.0194×2000= 38.8kg

Directionaldeformationofs-glassepoxy:

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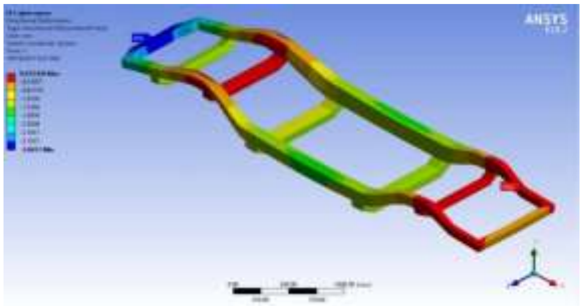
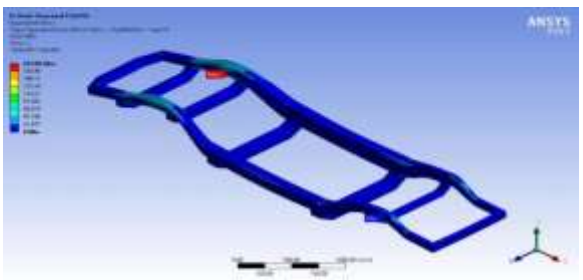


Total deformation ofs-glassepoxy

Maximumdeformation=3.06mm

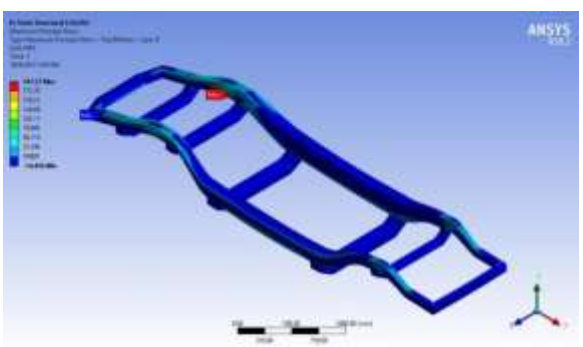
Minimumdeformation=0.012mm

Equivalentstressofs-glassepoxy:



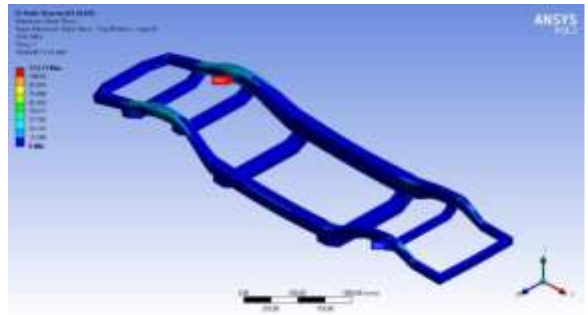
Maximum equivalent stress =205.86 Mpa Minimum equivalent stress =0Mpa

Normal (principal stress) of s-glass epoxy:



Normal (principal stress) of s-glass epoxy:

Maximum principal stress =197.27Mpa Minimum principal stress =-14.456Mpa**Shear stress of s-glass epoxy material:**



Materials and ceramics: Each class of engineering materials – metals, high polymers and ceramics – has its distinct and Outstanding properties as well as limitations. However, very stringent requirements of supersonic aircraft, gas turbines, high temperature reactors, missiles and spacecraft, have forced the technologists to think of such combinations of materials that weak points of one are covered by the other. Composite materials made artificially are called man made composites. Nature also produces composites materials. Some of the examples of natural composites are wood, bamboo and bone. Wood and bamboo consist of cellulose and lignin whereas; bone consists of collagen and apatite.

In spite of the fact that no definition will be completely satisfactory, one may define a composite material as a materials system which consists of a mixture or combination

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of two or more micro constituents mutually insoluble and differing in form and / or material composition. The components form distinct phases. The combination not only has its own distinctive properties but its strength or some other desirable property is superior to either of the components or different from either of them.

RESULTS & DISCUSSIONS

Microstructure analysis:

The samples of unreinforced alloy and composites were polished using emery papers of P600 and P1200 grit sizes followed by cloth polishing and then the samples were cleaned using etching solution prepared from 5ml of hydro fluoric acid and 95ml of water. The pictures show the uniform distribution of the reinforcement in the matrix and no evident agglomeration of SiC can be found.

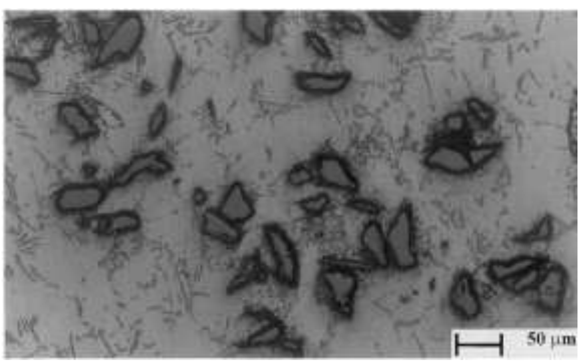

Fig: 2. Optical Micrograph of reinforced Al: 5% SiC

DAMPING MEASUREMENTS:

Damping measurements were carried out using a GABO Eplexor DMA.

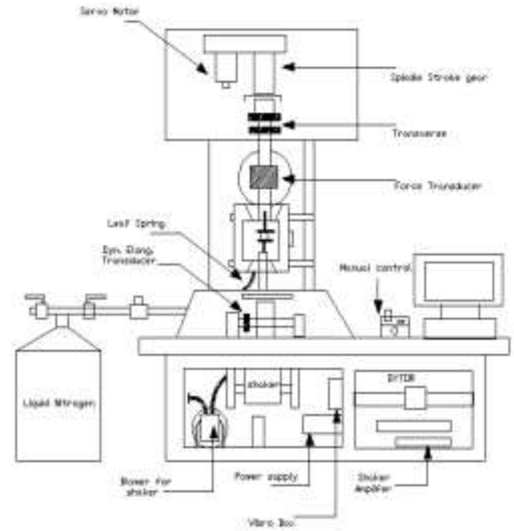

Fig .3. Schematic diagram of GABO Eplexor DMA

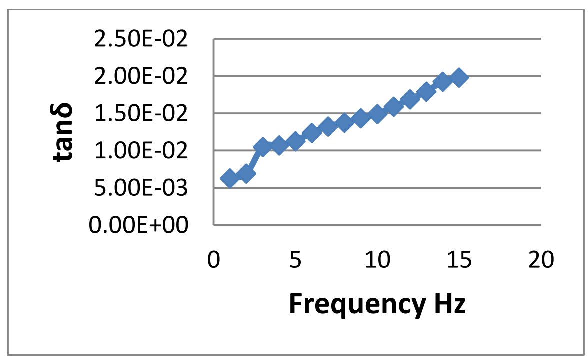

Fig .4 .variation of damping with frequency of 5% SiC reinforced composites

DISCUSSION

Experiments were conducted to find out the damping capacity at different frequencies of unreinforced Al and composites. Results show that composites exhibit higher damping capacities than the unreinforced Al at all frequencies. The improved damping capacity of the composites is a result of SiC reinforcement in the matrix. The damping capacity of the 15%SiC reinforced composites have same magnitude for the frequencies ranging from 12 to 15Hz. The addition of SiC particles in the alloy also increases the storage modulus and is independent of frequency.

CONCLUSIONS

Damping capacities of unreinforced Al and Al/SiC composites prepared by stir casting or compo casting technique were studied. From the analysis it is observed that:

1. Uniform distribution of SiC particles in the unreinforced alloy can be obtained through stir casting technique.

2. Good interfacial bonding is observed from the microscopic analysis.

3. Composites show higher damping characteristics than the unreinforced alloy at room temperature of 25^0C and a dynamic load of 40N.

4. The damping capacity increases with increase in frequency which ranges from 1Hz to 15Hz at room temperature of 25^0C.

5. Storage modulus increases with the increase in weight percentage of SiC particles.

6. Storage modulus is constant and is independent of the frequency at room temperature of 25^0C and increases with weight percentage of SiC particles.

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