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Analysis of Composite Material Light Weight Chassis

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Abstract - In this research work, suitable lightweight material is found for chassis frame by analyzing chassis with different materials like structural steel, aluminum alloy and Epoxy E-Glass UD composite materials. The selected material should have the sufficient strength to carry the load coming on to the chassis when it is supporting the vehicle. With reduction in the weight of the chassis, reduces the overall weight of the vehicle, which leads to the reduction in fuel. Thus, the usage of lightweight materials in manufacturing of chassis frame has the advantages. The materials used should help in reducing the weight of the vehicle while maintaining the necessary strength for supporting the expected load acting on the frame under various operating conditions. ANSYS finite element software is used to analyze the performance of the chassis with different materials. The 3D model of the chassis frame is developed by SOLIDWORKS software and numerical analysis is carried out by ANSYS. The model of the ladder frame is developed using generic specifications. The FEM analysis was done on chassis frame for its deformation and stresses by applying maximum load. The von-misses stresses, strain and deformations of the chassis with structural steel, aluminum alloy and composite materials are compared. Composite materials are observed to be better with less weight with similar performance. It is found that composite (E-glass) is more preferable material for chassis frame.

Keywords Aluminum alloy, Composite materials, Chassis, FEM, Structural steel.

INTRODUCTION

Transpiration became one of the necessary component of the day today life in these days. Automobile manufacturers are producing vehicle with different designs in accordance with the performance requirements. The key players of automotive industry are competing with each other with ever growing level of completion in producing high performance vehicles. Fuel economy, luxury, high power and torque are some of the criteria used in producing the vehicles. Reducing the weight of the vehicle is the major path being followed by vehicle manufacturers in maintaining the fuel economy of the vehicle. Aluminum is used widely for reducing the weight of the vehicle [7]. Lighter frame causes higher intensity of vibrations which causes discomfort to the users. This problem has to be studied before using the lighter materials [11]. The prime part of the vehicle structure is referred as chassis, which is adopted from French term. The chassis frame is a key part of the vehicle like a backbone for living beings. When upper body of the vehicle is removed, remaining part is a chassis. Many functional components like wheels, axles, tires and functional systems like braking system, transmission system, steering system, suspension system and also various electronic and electrical controlling systems are mounted on the chassis frame. Chassis frame is like a carrying unit, because all systems including body are mounted on it [15].

Synthetic object consists of a load bearing chassis frame work which supports it article structurally and helps in construction and better functionality. Chassis, while supporting the load, provides appropriate location for mounting and positioning various components of the vehicle. The vehicle chassis frame hat to be as lighter as possible for maintaining better fuel economy and it is strong enough to be able to withstand the rated loads without undergoing much deformation. It has to be rigid to protect all components and systems mounted on it without undergoing deformation [9].

Since chassis is a large part of the vehicle structure, it became a more important and significant part considered foremost in automotive industry. The chassis frame is able to withstand vibrations, shocks, twist and different types of other stresses while accommodating and holding other components. For better handling, having adequate stiffness in bending is necessary. So the maximum deflection, maximum equivalent stress, maximum stress are treated as critical criteria in designing the chassis of a vehicle. Minimizing the injuries caused to the occupants, by transmitting less impact energy and absorbing higher fraction of impact energy is a major necessity of the vehicle structure [14]. Chassis being a significant part of the vehicle structure has the greater scope of weight reduction of the vehicle [13]. One can observe, the chassis of a commercial vehicle rolling on the road with all essential functional components without body [4].

The loading situations, the vehicle chassis experience are like fatigue, torsion, bending in different directions etc. Also choosing the shapes depending on the requirements and shape of cross sections for better strength and lighter weight is a necessity. Reinforcement of the chassis with cross members, side members fastening with appropriate joining methods is also to be critically considered. The fatigue life of the structure is also crucial. All the parameters which hae great influence on fatigue life of vehicle structure are like geometry, residual stresses, size, material type, cyclic stress, material type, internal defects distribution, grain size, and the direction of loading etc., are to be analyzed carefully. Many researchers od automotive industry are exerting their effort in improving the manufacturing processes of automotive structure [13]. Specifications of the existing vehicle are given in Table 1.

TABLE 1. CHASSIS SPECIFICATION OF EXISTING VEHICLE

Parameter	Value
Width (mm)	1539
Front Overhang (mm)	900
Rear Overhang (mm)	1160
Wheelbase (mm)	2800
Length (mm)	4330
Applied weight (N)	32000

Materials for Chassis Frame

High resilience, good fatigue strength, better ductility and higher creep resistance are the requirements to be possessed by the materials of the vehicle chassis. Materials selected for chassis frame analysis are composite material (E-Glass/Epoxy Material), structural steel and aluminum alloy. Properties of materials are given in Table 2.

TABLE 2. PROPERTIES OF MATERIALS

Material selected	Structural chassis frame	E- glass	Aluminum alloy
Young's Modulus, (E)	2e+005 MPa	73000 MPa	7.1e+010 Pa
Poisson's Ratio	0.3	0.22	0.33
Bulk modulus	1.6667e+005 MPa	34553 MPa	6.9608e+010 Pa
Density	7.85e-006 kg mm^{-3}	2000 kg m^{-3}	2770 kg m^{-3}
Shear Modulus	76923 MPa	29918 MPa	2.6692e+010 Pa
Behavior	Isotropic	Orthotropic	Isotropic

Properties of structural steel

Wide ranges of characteristics are to be considered for the selection of the materials. In addition to durability, easy manufacturability many other parameters like mechanical, chemical and thermal resistances are to be considered. Steel, possessing all the characteristics is the first preference material for vehicle body. For the past few years, lot of improvement registered in manufacturing and material technology in making the material less weight, stiffer, stronger while improving other performance requirements. Improvement of material also important in case of IC Engines, wheels, body and many other parts. For vast majority of vehicles, low cost materials like iron and steel became important elements of vehicle structure. Due to inbuilt characteristics of steel absorbing impact energy during vehicle collisions, the steel is primarily used in vehicle structure.

Properties of composite material (E-Glass Material)

Due to low cost and high specific strength, glass fiber is more predominantly used in many engineering and science applications. E-glass is the commercially available form of glass fibers which is of electrical grade. ECR glass an improved form of E-glass with higher acid resistance and high strength and S-2® glass are the widely used general purpose composite reinforcements.

Properties of aluminum alloy

The strength of aluminum can be improved by using alloying elements like zinc, nickel, silicon, copper, magnesium, manganese et,. By appropriate alloying and treatment, aluminum alloys are available in a variety of strengths. Aluminum alloys possess high specific strength, good manufacturability and good thermal conductivity. Alluminum alloys are used in construction of light weight structiures, in application of light weight vehicles in transportation and other reinforcement of structures [17].

METHODOLOGY

The methodology followed is shown in the form of a flowchart in Figure 1.

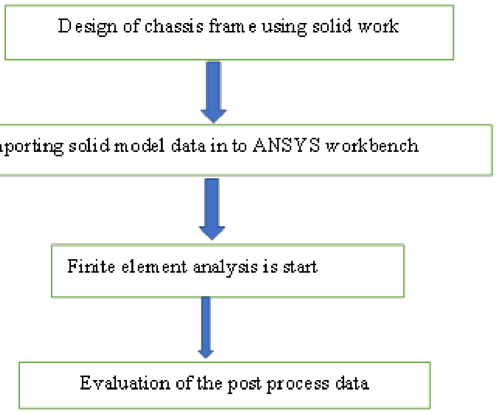


FIGURE 1. METHODOLOGY

Analysis of Chassis Frame

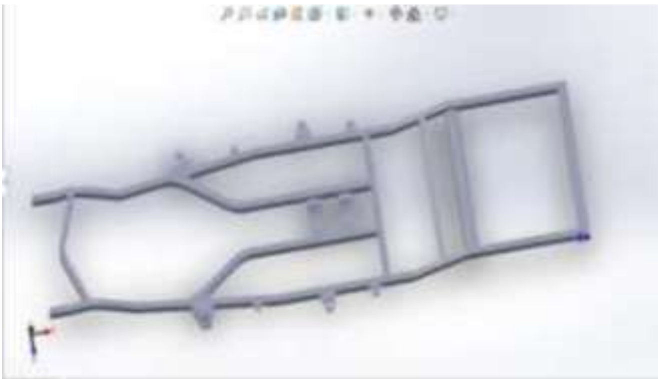


FIGURE 2. 3D MODEL OF CHASSIS FRAME

The model is created by modeling in SOLIDWORKS 2017 and it is imported into the ANSYS software. In FEM, finite elements are used to discretize, continuous physical system and solving a system of equations. Discretisation is a process of dividing domain into small and simple shapes called finite elements. A commercial finite element analysis software package is used to carry out the finite element analysis. Design of chassis frame: model geometry is defined in a primary stage of the process. This is often done by prepare a 3D solid modeling by using SOLIDWORKS. The 3D model is shown in Figure 2.

Importing Solid Model Data into ANSYS Workbench and Generation of Mesh

Mesh: Discretizing of model into the small sections called as elements. Mesh element selected for this analysis is tetrahedron. The meshed frame is shown in Figure 3.

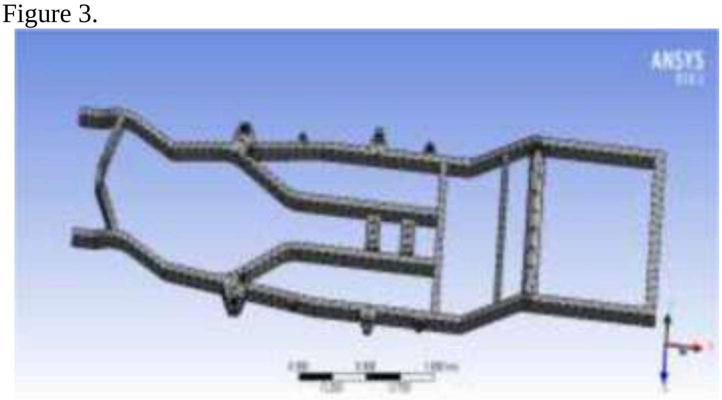
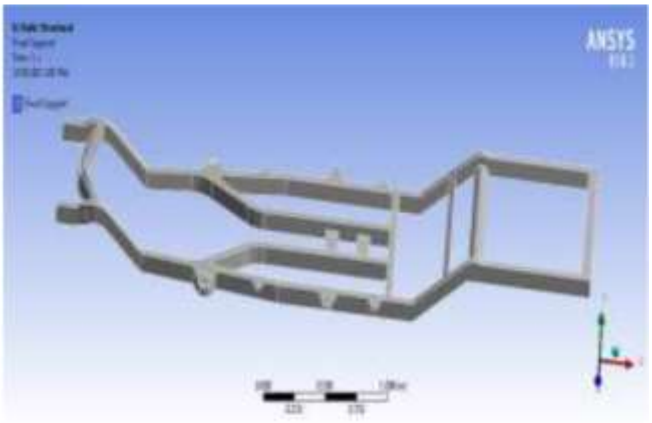


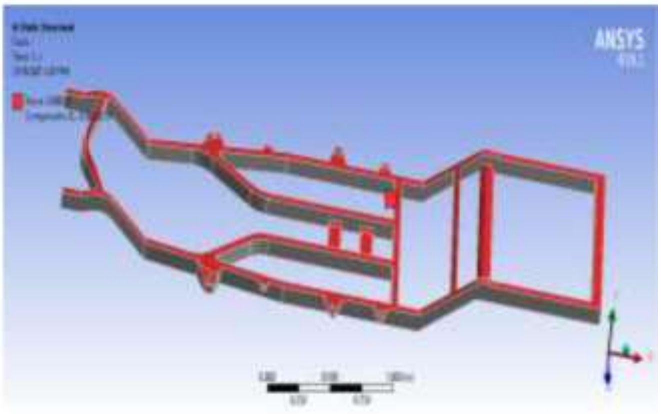
FIGURE 3. MESH ELEMENT

Loads and Boundary Conditions

For a vehicle to simulate on realistic driving conditions, loads and boundary conditions are to be defined to create realistic testing parameters and loading conditions. Highest possible tolerable loads which don't cause permanent damage to the structure are to be determined [2]. These highest tolerable loads should take care of all applicable loads like torsion, bending, lateral loads, fatigue etc., and coming on vehicle structure. In general these loading scenarios are being simulated by dividing the vehicle with fast cornering, very high acceleration, panic braking, driving on bumpy roads and on potholes etc. The particular loading case has to be connected to the vehicle components which depend on constraints of the model [2]. The applied boundary conditions are shown in Figure 4 a. The total load applied to the model is 32000 N (Figure 4 b).



(a)



(b)

FIGURE 4. (a) BOUNDARY CONDITIONS (b) LOADING CONDITION

RESULTS AND DISCUSSION

Total Deformation

The deformation of chassis frame under the application of 32000 N load is shown in Figure 5.

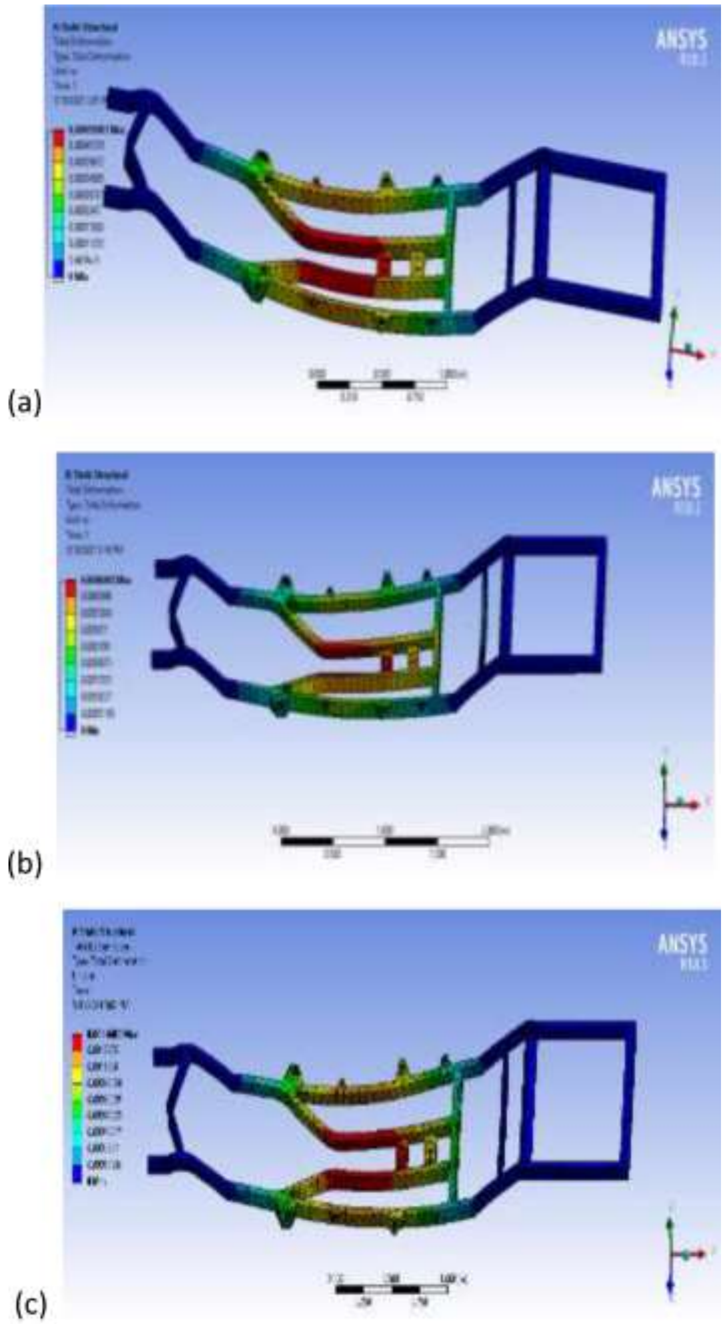


FIGURE 5. TOTAL DEFORMATION (a) STRUCTURAL STEEL CHASSIS FRAME (b) E-GLASS CHASSIS FRAME AND (c) ALUMINUM ALLOY CHASSIS FRAME

Equivalent (von-Mises) Stress

The equivalent von-Mises stress induced in chassis frame under the load of 32000 N load is shown in Figure 6.

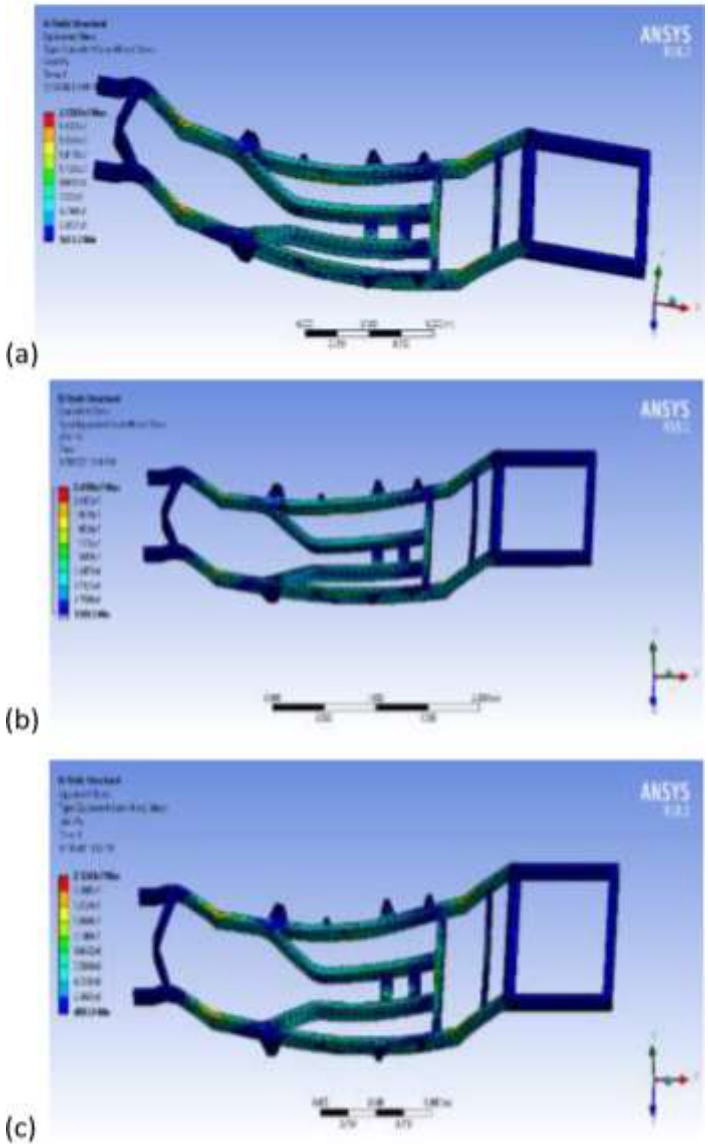


FIGURE 6 . EQUIVALENT VON-MISES STRESS INDUCED (A) STRUCTURAL STEEL CHASSIS FRAME, (B) E-GLASS CHASSIS FRAME, (C) ALUMINUM ALLOY CHASSIS FRAME

Equivalent (von-Mises) Strain

The equivalent von-Mises strain induced in chassis frame under the load of 32000 N load is shown in Figure.7.

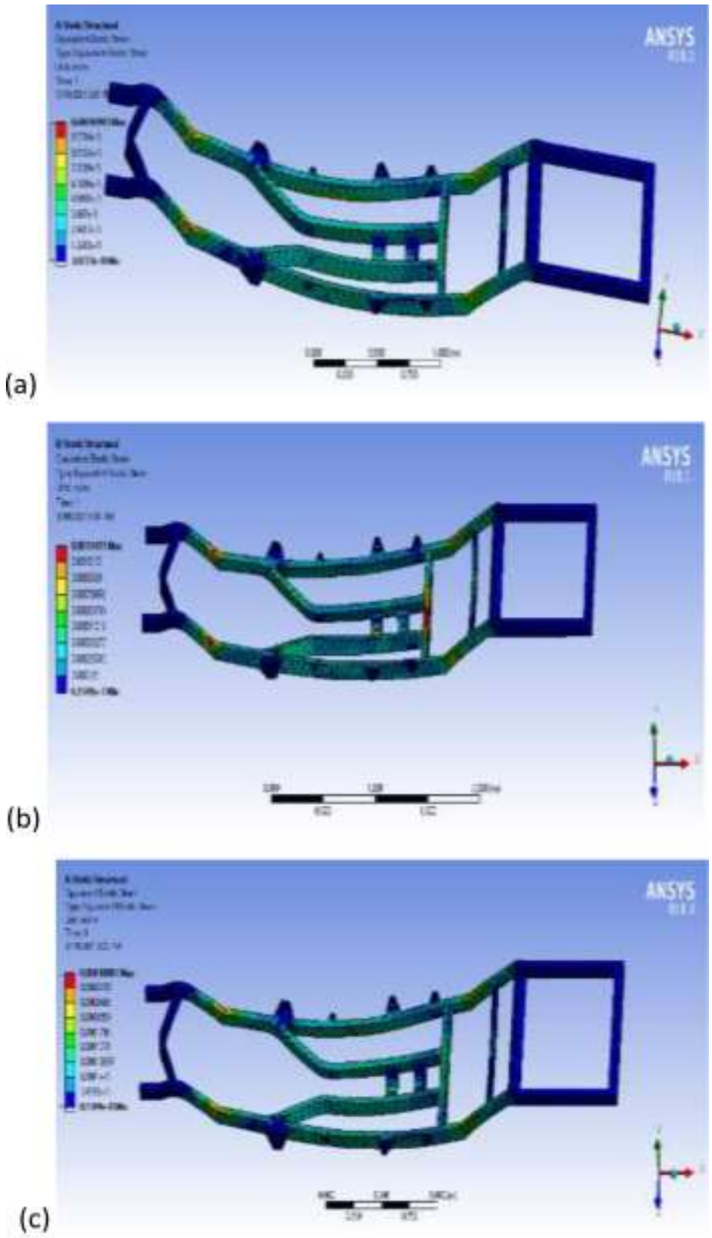


FIGURE 7. EQUIVALENT VON-MISES STRAIN (A) STRUCTURAL STEEL CHASSIS FRAME, (B) E-GLASS CHASSIS FRAME (C) AND ALUMINUM ALLOY CHASSIS FRAME

The results obtained are given in Table 3.

TABLE 3. TOTAL DEFORMATION, VON-MISES STRESS AND STRAIN RESULTS

Material	Max. total deformation (m)	Max. Equivalent (von-Mises) strain (m/m)	Max. Equivalent (von-Mises) stress (Pa)
Structural steel	5.1007e-004	1.0995e-004	2.1287e+007
Composite material(E-glass)	4.6065e-003	1.1471e-003	2.4786e+007
Aluminum alloy	1.4405e-003	3.0881e-004	2.1243e+007

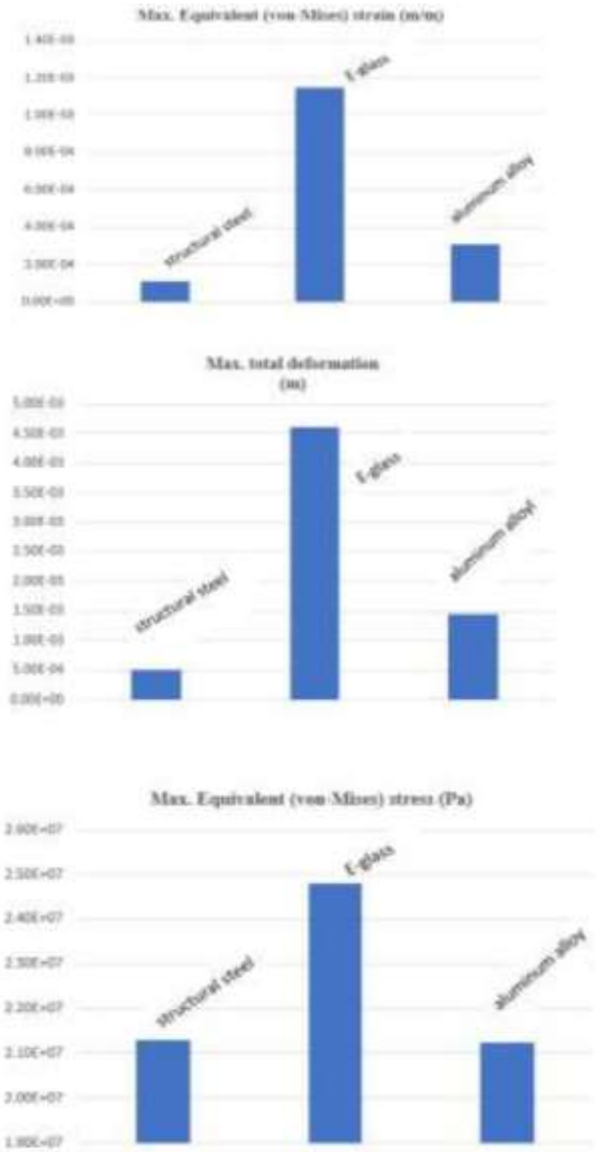


FIGURE 8. MAXIMUM DEFORMATION, VON- MISES STRAIN AND STRESS OF CHASSIS FRAME

Maximum deformation and maximum equivalent strain of structural steel is lower than composite material and aluminum alloy chassis frame. And von-Moises stress of aluminum alloy is lower than the other materials (Figure 8). The calculated mass of chassis frame with different materials is given in Table 4. Therefore, composite material chassis frame is lighter than structural and aluminum alloy chassis frame

TABLE 4. MASS OF CHASSIS FRAME

Material	Mass (kg)
Structural steel	732.37
Composite material(E-glass)	186.59
Aluminum alloy	258.43

CONCLUSIONS

3D model is developed by using SOLIDWORKS 2017. Deformation, strain, stress analysis of both structural steel aluminum alloy and composite material (E-Glass) chassis frame is done by using ANSYS 2018 simulation software. The maximum deformation value is occurred at the center of the chassis frame and maximum stress and strain is induced near the center of the chassis frame. Maximum value of deformation, stress and strain are indicated by red color, and the area of minimum value of deformation, strain and stress are indicated by blue color. It observed that maximum deformation and von-Mises strain of structural steel chassis frame is lower than the other chassis frame. And composite material chassis frame is lighter as compared to structural steel and aluminum alloy chassis frame. Therefore, composite (E-glass) is the preferable material for chassis frame.

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