Chassis Stress Analysis and optimization by using ANSYS

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Abstract— The main advantage of Ansys is that it helps to reduce the cost of production and the time it will take to complete it. At the same time they help to ensure that the products come out with higher quality and better durability. Designs with Ansys will also help design and engineering teams manage performance implications and risks of their design. Also, designers can make use of computer based simulations to refine and evaluate their designs instead of relying on money and time consuming physical prototype testing. With the use of Ansys products data and processes can be stored in a server to be accessible by designers and engineers in different areas so they can all work together in creating a masterpiece without necessarily coming into physical contacts with one another. Design changes are one of the major factors that make product design and manufacturing cash intensive. Ansys allow engineers and designers to make changes to their design especially at the early stages. When properly integrated into the design and development process, Ansys help manufacturers detect faults with the product on time, so problems can get solutions without delay.

Key words: Design and Static Analysis, Finite Element Analysis, ANSYS

I. Introduction

The Finite Element Analysis (FEA) is becoming increasingly popular among design engineers using it as one of many product design tools. It has been used for the solution of many types of problems. FEA has become an integral part of design process in automotive, aviation, civil construction and various consumer and industrial goods industries, cut throat competition in the market puts tremendous pressure on the corporations to launch reasonably priced products in short time, making them to rely more on virtual tools (CAD/CAE) accelerate the design and development of products . FEA is used to predict multiple types of static and dynamic structural responses. For example, companies in the automotive industry use it to predict, stress, strain, deformations, and failure of many different types of components. FEA reduces the need for costly experiments and allows engineers to optimize parts before they are built and implemented. The wide and most common commercial finite element packages are (ANSYS, ABAQUS, COMSOL, HYPERVIEW, LS DYNA, NASTRAN etc.). The advent of faster computers and robust FEA software allows design engineers to build larger, more refined and complex models resulting in timely, cost-effective, accurate, and informative solutions to customer problems.

A. Reduced Weight and Improved Fuel Consumption

Weight reductions were implemented in chassis components that accounted for 65 % of cab-and-chassis weight and in the tank mounted on the chassis. Also, super-single tires, whose rolling resistance is 10% lower than that of conventional tires, were specified for improved fuel consumption. [Main weight-reduction items]

- Adoption of aluminum alloys chassis frame (weight reduction achieved: 320 kg)
- Adoption of super-single tires with aluminium wheels as well as other aluminum parts including fuel tank (weight reduction achieved: 200 kg). [ref.6]
- Adoption of aluminum alloys bulk tank.

These measures reduced weight by approximately 250 kg in total, allowing the payload to be increased by the same amount and concurrently realizing a 3% improvement in fuel consumption.

Many types of pollution such as water pollution, noise pollution, thermal pollution and air pollution. Air pollution can be considered as one of the main hazard to the health of human being. The air pollution is due to the increasing number of vehicle use by human. When the number of vehicle increase, the usage of the petrol increase respectively. The lack of the source of the petrol makes the price increase by time to time. The emission from the vehicle makes the environment faces the air pollution that in critical level. Many steps need to reduce the number of the vehicle in other side to reduce the price of the petrol. Besides that also use to reduce the air pollution. The big number of vehicles in each country makes the prevention to reduce the number of vehicle difficult. So, the other prevention is increase the efficiency of the vehicle's engine. When the engine at the efficient level, the emission is at the low level and the most important is the usage of petrol is low. The prevention is reducing the weight of the body and chassis of each vehicle. This project focused to reduce the usage of petrol by design and analysis the chassis to reduce the weight of the chassis of vehicle. At the same time, the global usage of the petrol also reduced.

B. Engineering Aspects of a Long Member in a Truck Chassis

Chassis frame consist of two channel shaped side member / long members, which are held apart by series of cross members (Figure.1). Cross members are positioned at points of high stress and are cold riveted to side member. The depth of the channel must be sufficient to minimize the deflection. Since the load at each point of the frame varies, a weight reduction can be achieved by either reducing the depth of the channel, or having a series of holes positioned along the neutral axis in the regions where the load is not so high.[Ref.7]

During movement of a vehicle over normal road surfaces, the chassis frame is subjected to both bending and torsional distortion. The open-channel sections exhibit excellent resistance to bending, but have very little resistance to twist. Therefore, both side and cross-members of the chassis must be designed to resist torsional distortion along their length. Generally for heavy commercial vehicle channel section is preferred over hollow tube due to high torsional stiffness. The chassis frame, however, is not designed for complete rigidity, but for the combination of both strength and flexibility to some degree. .[Ref.7]

The chassis frame supports the various components and the body, and keeps them in correct positions. The frame must be light, but sufficiently strong to withstand the weight and rated load of the vehicle without having appreciable distortion. It must also be rigid enough to safeguard the components against the action of different forces. The chassis design includes the selection of suitable shapes and cross-section of chassis-members. .[Ref.7]

Moreover, the design should consider the reinforcement of the chassis side- and cross member joints, and the various methods of fastening them together.

The design of an automobile chassis requires prior understanding of the kind of conditions the chassis is likely to face on the road. The chassis generally experiences four major loading situations, that include[Ref.7]

- Vertical Bending
- Longitudinal Torsion
- Lateral Bending,
- Horizontal Lozenging.

In addition there is torsion loading and fatigue loading.

Hence the material selected for this member must with stand the high bending loads, torsional loads and fatigue. In addition corrosion resistance is also important. Apart from chemical and mechanical properties, the critical requirements of this product are:

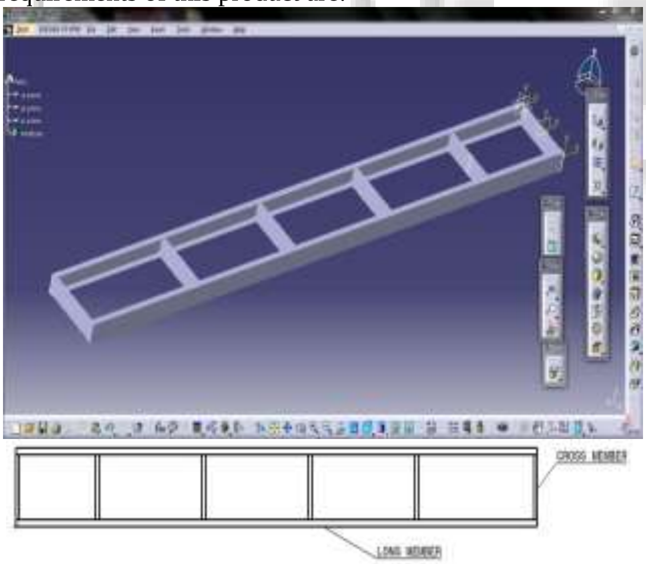


Fig. 1: Truck Chassis frame

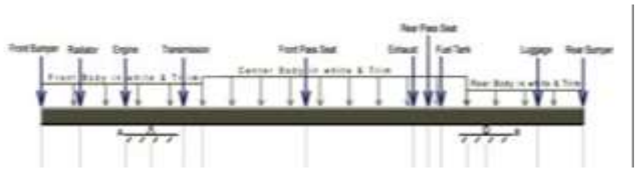
1) *Chassis*

- Thickness Tolerance – No negative thickness and narrow band thickness
- Camber – Max camber spec is 1mm/meter – can effect flange height of C channel
- Length & Width Tolerance – No negative in length and width.
- Grain Size 7 or Finer
- Micro alloying element should not exceed 0.20
- Material should be free from sliver, lamination, scabs and deep rolling marks.[Ref.7]

C. *Loads on Chassis*

The chassis of an automobile consists of following components suitably mounted:

- Engine and the radiator.
- Transmission system, consisting of the clutch, gear box, propeller shaft and the rear axle.
- Suspension system.
- Road wheels.
- Steering system.
- Brakes.
- Fuel tank



D. *Meshing*

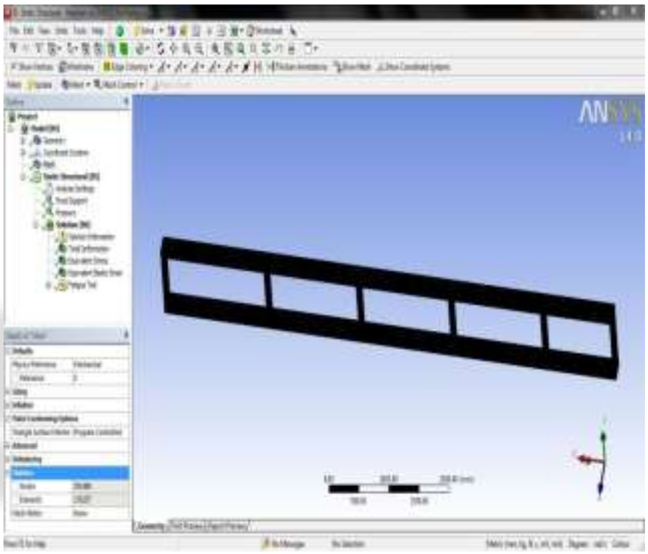


Fig. 2: Chassis mesh

E. *Types of Mesh*

Details of "Mesh"	
Defaults	
Physics Preference	Mechanical
Relevance	0
Sizing	
Use Advanced Size Fun...	Off
Relevance Center	Fine
Element Size	10.0 mm
Initial Size Seed	Active Assembly
Smoothing	Medium
Transition	Fast
Span Angle Center	Coarse
Minimum Edge Length	2.30 mm
Inflation	
Patch Conforming Options	
Triangle Surface Mesher	Program Controlled
Advanced	
Defeaturing	
Statistics	
Nodes	351489
Elements	170257
Mesh Metric	None

1) *Tetrahedral Meshing*

- Number of Node -351489
- Number of Element -170257

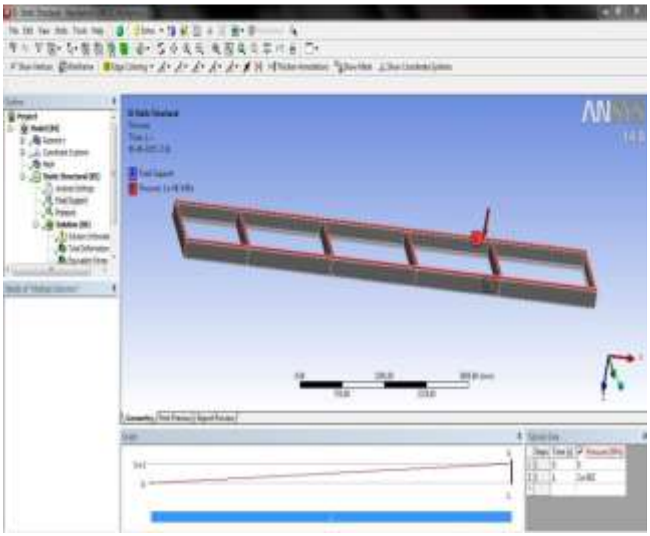


Fig. 3: Load Over the chassis

F. *Numerical Method*

1) *Chassis Calculation*

Model No. = SE1613 Turbo Truck (TATA)
Specification of chassis as per the IS 9435 for the wheel base 4565mm as mentioned as under
Front wheel = 1933mm
Rear wheel = 1809mm
Overall length of chassis = 7720mm
Weight of the chassis as per the IS 9211 for the wheel base 4726 mm as mentioned as under:.
chassis kerb weight = 4235 Kg.
Bare chassis kerb weight with cowl = 4045 Kg.
Max. Permissible gross vehicle weight = 16200 Kg.
Weight of the Engine = 413 Kg.
Total weight acted on the chassis = 20000 Kg.
Capacity of Truck = 20 ton
=20000*9.81
= 196200 N
Capacity of Truck with 1.25% = 196200 x 1.25 N = 245250N
Total Load on the Chassis =245250 N

All parts of the chassis are made from "C" Channels with 230.2 mm x 76.20mm Each Truck chassis has two beam. So load acting on each beam is half of the Total load acting on the chassis. = Total load acting on the chassis/2 = 245250 N/Beam = 122650 N/ Beam

2) *Find a Reaction on supports:*

Beam is simply clamp with Shock Absorber and Leaf Spring. So Beam is a Simply Supported Beam with uniformly distributed load. Load acting on Entire span of the beam is 122650 N. Length of the Beam is 7720 mm.

Uniformly Distributed Load is 122650 N/ 7720 = 15.88N / mm

Now taking the reaction around the support A. According to loading condition of the beam, beams has a support of three axle means by three wheel axles but among these three wheels one wheel / axle are working as a supporting only. Total load reaction generated on the beam is as under:

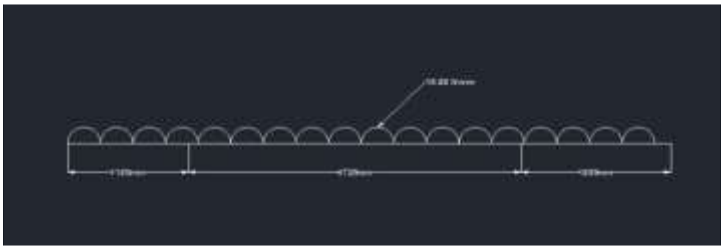
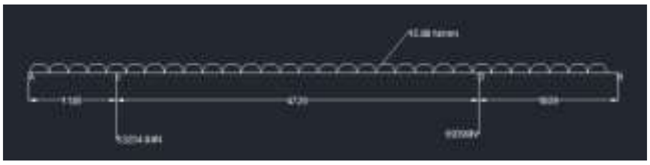


Fig. 4: Total load generated on the beam

For getting the load at reaction C and D, taking the moment about C and we get the reaction load generate at the support D.
Calculation of the moment are as under.
Momentum about C
15.88x1185x1185/2 = [15.88x4726x4726/2]-4726xD+15.88x1809x5630.50
11149546.5 = 177340503.44-4726xD+161746923.06
D = 69390.15N
Total Load acting on the Beam =122625 N
C =122625N-69390N
C =53234.84N



Reactions

3) *Find Shear Force Diagram and Bending Moment Diagram:*

Shear Force Diagram:-
F_A=0N
F_C = -15.88 x 1185 + 53234.84
= -18817.8 + 5323.84
= -34417.04N
F_D = -15.88 x 59911+53234.84+69390
= -93866.63+122624.84N
= 28758.16N
F_B = -15.88 x 7720+53234.84+69390
= 0N
Bending Moment Diagram:-
$M_A = 0$
$M = -\frac{WL2}{2}$
$M_C = -\frac{15.88\ X\ 1185X1185}{2}$
M_C = - 11149546.5
$M_D = -\frac{15.88\ X\ 5911X5911}{2} + 53234.84 \text{ x } 4726$
M_D = - 25835118.9N/mm
M_B= 0

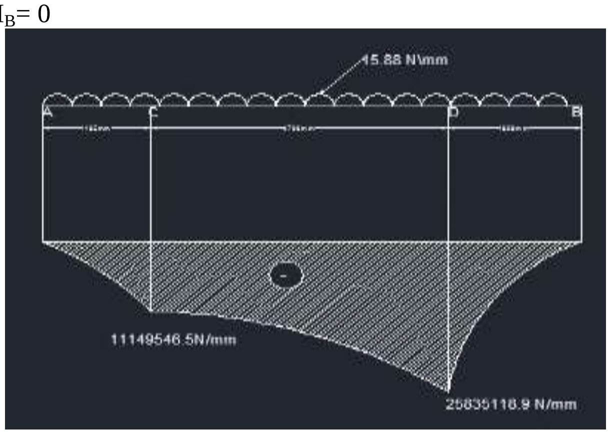


Fig. 5: Bending Moment Diagram

4) Calculation of Deformation:-

Material of the chassis is as per IS stander

UTS:-450 Mpa

Density :- 8.7 g/cm^2

Yield stress :- 250Mpa

Elasticity :- 2E5 Mpa

Radius Of gyration R =(230.20/2)=115.1mm

$I_{xx}=bh^3[b_1h_1^3]/12$

$=76.8x230.20^3-[70.8x218.2^3]/12$

$I_{xx}=16778354.54mm^3$

Section of Modules around X-X axis :-

$Z_{xx}=bh^3-[b_{1h1}^3]/6h$

$=76.8x230.20^3-[70.8x218.2^3]/6x230.20$

$Z_{xx}=145771.97mm^3$

Bending equations are as per:-

$(M/I)=(\sigma/y)=(E/R)$

Maximum Bending Moment acting on Beam

$M_{max}=25835118.9$

$I \quad =16778354.54mm^3$

$Y \quad =115.1mm$

Stress Produced on the Beam is

σ =M/Z

= 25835118.9/145771.97

= 177.22 N/mm^2

Maximum Deflection Produced on Beam

$Y=[WxX_2]/12EI \; xL^3-2LX^3_1+X^3_2$

$=[15.88x1809] / 12 \times 2 \times 10^5 \times 16778354.54 \times 7720^3-2 \times 7720 \times 1185^3+1809^3$

= 3.2 mm

G. Results and Discussion

The location of maximum Von Misses stress is at opening of chassis which is contacted with bolt as shown in Fig. The stress magnitude of critical point is 157MPa. This critical point is located at element 86104 and node 16045. The internal surface of opening of chassis was contacted with the very stiff bolt. The BC 3 is also a fixed constraint, thus it cause a high stress on it. Based on static safety factor theory, the magnitude of safety factor for this structure is 1.43. The formula of Safety Factor (SF) is defined by :

$$SF = \frac{\text{significant strength of material}}{\text{Corresponding significant stress from normal load}}$$

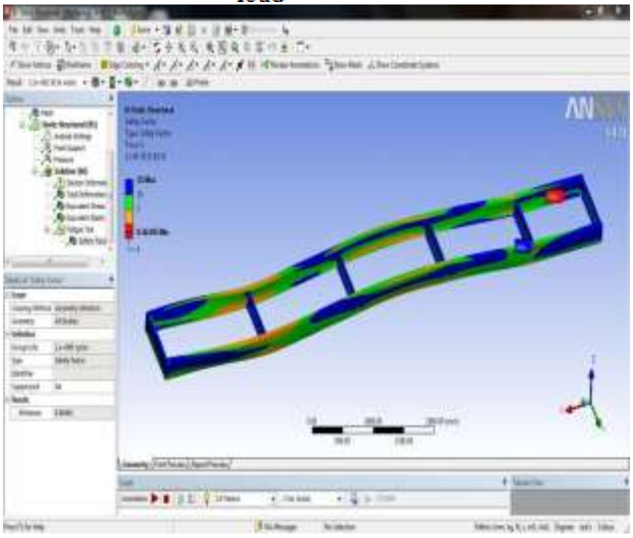
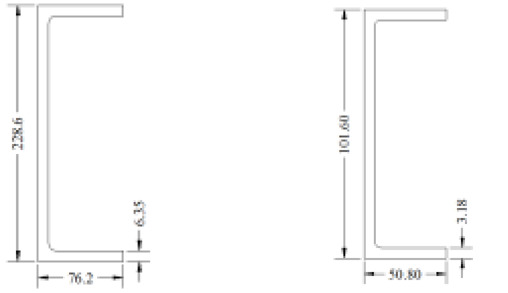


Fig. 6: Safety factor

1) Before Modification when



Long Member [Ref.12] Cross Member[Ref 12]

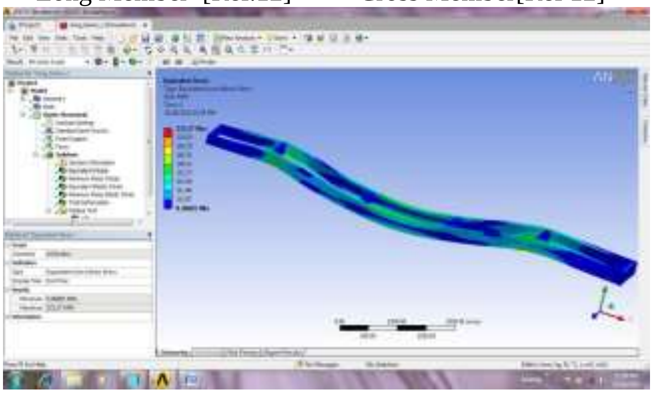


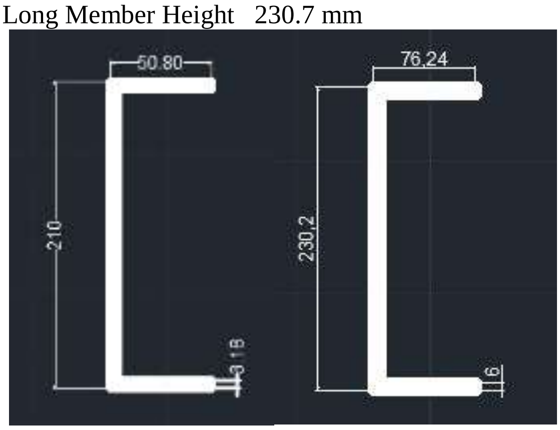
Fig. 7: Von maises stress [Ref 12]

Max. Stress von maises stress is 252Mpa under the loading point The above shown result plot represents the stress in the chassis. Max. Deflection = 7.97 mm / Location = just under the loading point The above shown result plot represents the total deformation in the chassis From the above stress and deformation contour, stress induced in the frame is224.99 Mpa and deformation is 7.97mm. It is more than the yield strength of the material. So it is necessary to increase the strength of the chassis frame incorporating suitable design changes.

2) After Modification of chassis

The strength of the chassis was increased to the safety level by adding stiffeners. Six no of stiffeners was introduced in the maximum stress induced areas which is coming in the center of the rear chassis frame. The various result plots for different thickness are shown below. For Stiffener thickness of 6 mm:6mm thickness stiffeners was introduced in the chassis frame and static analysis was carried out and the stress and deflection contours are shown below

For Long Member Height 230.7 mm



Cross Member Long Member

Instead of For Long Member Height 230.7 mm was introduced in the chassis frame, static analysis was carried out, and the stress and deflection contours are shown below,

Details of "Part 1"

Graphics Properties	
Definition	
Suppressed	No
Stiffness Behavior	Flexible
Coordinate System	Default Coordinate System
Reference Temperature	By Environment
Material	
Assignment	Structural Steel
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Length X	7720. mm
Length Y	900. mm
Length Z	230.2 mm
Properties	
Volume	3.997e+007 mm^3
Mass	313.77 kg
Centroid X	3828.7 mm
Centroid Y	450. mm
Centroid Z	-67.283 mm
Moment of Inertia Ip1	5.5996e+007 kg·mm^2
Moment of Inertia Ip2	1.6369e+009 kg·mm^2
Moment of Inertia Ip3	1.6884e+009 kg·mm^2
Statistics	

Fig. 8: Geometry of truck chassis

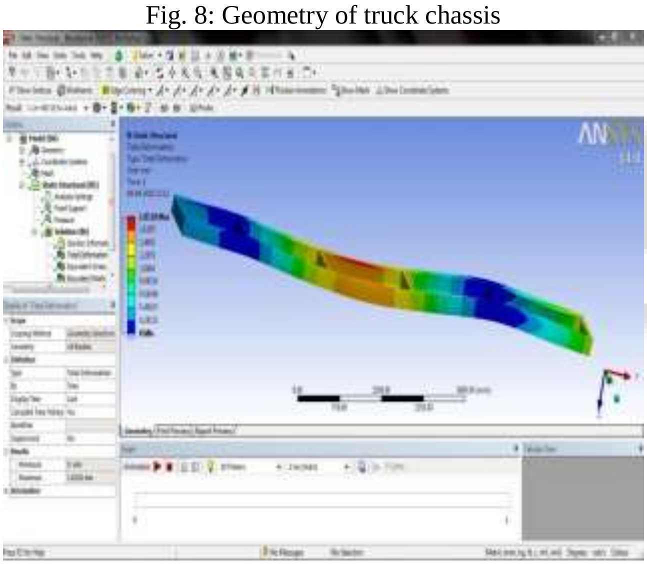


Fig. 9: Deformation

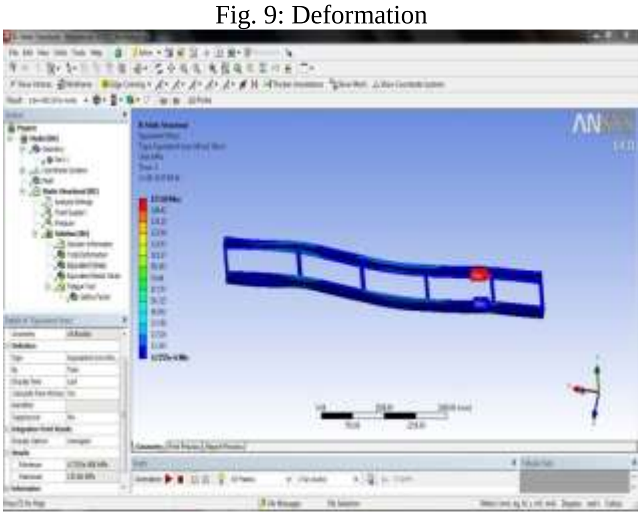


Fig. 10: Von-mises stress

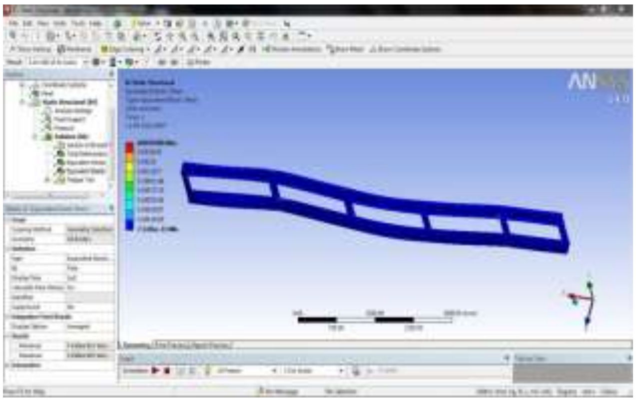


Fig. 11: Elastic strain

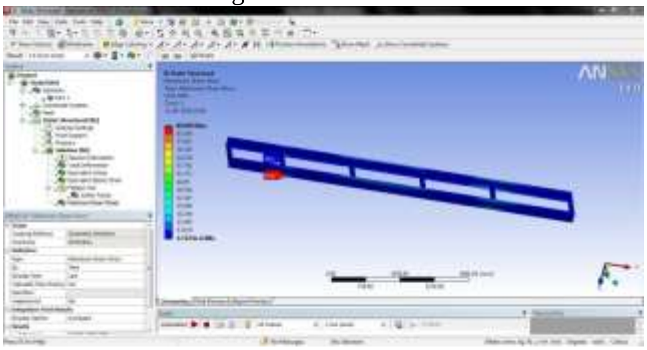


Fig. 12: Maximum shear stress produced in model

II. Conclusions

By using the CAE and CAD we can fine the stress and create a model as shown in fig. when before modification applying loading condition we can find the stress over the chassis is 252Mpa in this condition chassis will failed. after modification in catia v5we can find von misses stress is 155 mpa and Maximum shear stress is143.11Mpa ansd von misses strain is produced 0.0012mm and Equivalent stress is 155Mpa. Maximum shear strain 0.001758

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