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Analysis of LCV Chassis for Optimizing Weight by Using FEM

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***Abstract*- Chassis is the component of an automobile that acts as the frame to support the vehicle body. This study main objective of the study reduce the overall weight of the chassis with help of FEA method. Increase the overall strength of the chassis. Calculated the stress and deformations at different loading conditions. Proposed the best suitable material for chassis design. This results are the total weight of the chassis reduce up to 37 kg. And total deformation and equivalent stress was 26.285mm and10.441mpa. The FEA Analysis Of Tata Ace Chassis design is built with low density carbon fiber (1298Kg/m3) since it is a less weight and has an excellent strength weight ratio and shows good bending and torsion stiffness comparing with other material hence FEA Analysis Of Tata Ace Chassis with carbon fiber material is a best alternative design for the light weight chassis design.**

***Keywords*- chassis, FEA, LCV, Carbon Fiber.**

I. INTRODUCTION

Chassis is the component of an automobile that acts as the frame to support the vehicle body. It offers strength and stability to the vehicle when it is subjected to different conditions. It held together the engine part, cab, transmission, axles, suspension system and other cassis component. Ladder chassis is taken into account to be one of the oldest styles of automotive chassis. As the ladder chassis possess superior load carrying capacity, they are employed in most of the SUVs as well as in heavy commercial vehicles. Higher load carrying capacity of the chassis provides good driving dynamics and high ride comfort. Hence, ladder chassis are widely preferred over unibody and backbone frames.

Ladder chassis frame comprises of longitudinal members called as side bars attached with cross members. Ladder frames also consists of brackets to support body and dumb iron to act as bearing for spring shackles. The chassis components are connected by riveted joints, weld joints or bolts. The ladder frame is made upswept at front and rear to accommodate the springing action of suspension system. The frame is narrowed at front to have better steering lock. The various cross sections used in frame construction includes channel, box, hat, double channel and I-section. Stress analysis is carried out on the chassis to find the critical point having maximum stress. Critical point is the crucial element that causes fatigue failure of the chassis frame. Thus, life span of the fire truck chassis completely depends on the magnitude of stress. In this modal and static structural analysis is carried out on ladder chassis.

II. LITERATURE REVIEW

Sanchit Shrivastava et al. [1] Chassis is a French term and was first of all used to indicate the body elements or basic Structure of the automobile. It is the spine of the vehicle. The fundamental role of the chassis body is to safely deliver the most load for all designed working situations. A perfect built chassis improves the crashworthiness, passenger safety, and weight efficiency.

LKiran et al. [2] The automobile chassis is the backbone for the entire vehicle. A good chassis is one which absorb all the sudden loads, twist loads, shock loads without damaging the other parts which is placed on the chassis and provide the best ride and handling for the driver. Now the Indian automobile market is growing and so the demand for the light commercial vehicles. Small yet dynamic and reliable Commercial vehicles of about 1 ton load capacity are in demand. In general steel ladder type chassis is considered. It is found that there is sufficiently large value of stress and considerable amount of deformation is observed in the chassis structure and since there is a growth in demand for alternative materials to withstand such loads.

A. Benjamin Asirdason et al. [3] the automotive industries are advancing various systems of a vehicle with innovative technologies. It is more essential to improve the vehicle performance at low manufacturing cost. Reduction of weight of various parts of a vehicle can improve the performance and efficiency of the automobile. This paper deals with the structural analysis of a frontend cross bar which is replaced with Carbon Fiber Reinforced Polymer composite material.

Chintada, Vinnod babu et al. [4] automotive chassis is an important part of an automobile. The chassis serves as a frame work for supporting the body and different parts of the automobile. The chassis frame has to withstand the stresses developed within a limit. Along with strength, an important consideration in chassis design is to have adequate bending stiffness for better handling characteristics. So, strength and stiffness are two important criteria for the design of the chassis.

III. Objective

- The main objective of the study reduce the overall weight of the chassis with help of FEA method.
- Increase the overall strength of the chassis.
- Calculated the stress and deformations at different loading conditions.
- Proposed the best suitable material for chassis design.

IV. Methodology

A. Design Strategy

TATA Ace model ref for analysis

Table 1. Dimension details of LCV chassis concept-1

Parts	Dimensions
Total length of Chassis	3700 mm
Height of chassis	450 mm
Type of cross section	Rectangular Tubular and Rectangular Cross section

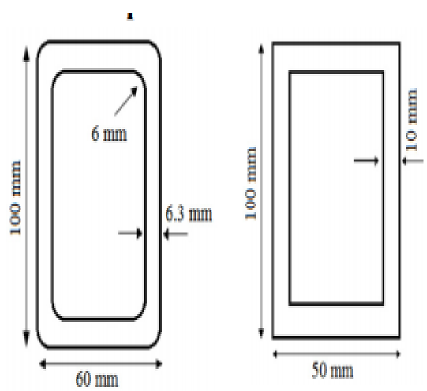


Fig. 1: (a) Rectangular Tubular Cross section; (b) Rectangular Cross section

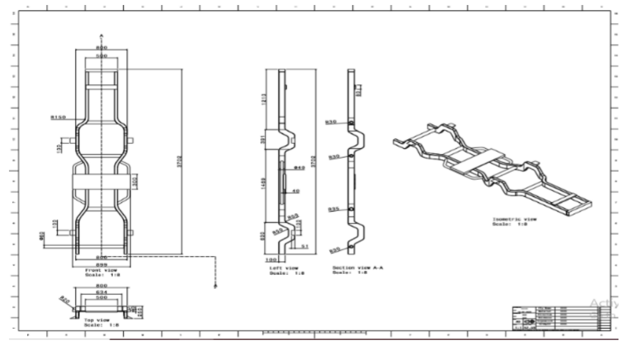


Fig. 2. Dimension of chassis part

B. Dimension

Side bar = 100 × 50 × 10

Front overhang = 1400mm

Rear overhang = 200mm

Wheel base = 2100mm

Width = 800mm

Young modules = 113 Gpa

Poisson ration = 0.32

Capacity = 1000 × 9.81 =9810N

Capacity with 1.25% = 12262 N

Weight of body and engine = 6000N (600kg)

Kerb weight = 920 kg

Gross weight = 1630 kg

Total load = 162690 N

Load acting on single bar of chassis = 81345 N

Reaction forces :-

We are assuming side rail as a simply supported beam with uniformly distributed load acting on beam = 81345N

Length of beam = 3700 mm

Uniformly distributed load = $\frac{81345}{3700}$ = 21.98 N/mm^2

$\sum M = 81326 \times 450 - R_2 \times 2100 = 0$

$R_2 = 17427$ N

$\sum V = R_1 + R_2 - 81326 = 0$

$R_1 = 63899$ N

Shear force

D = 0 N

C' = 21.98 × 200 = 4396 N

C = 21.98 × 200 – 17427 = - 13031 N

B' = 21.98 × 2300 – 17427 = 33127 N

B = 21.98 × 2300 – 17427 – 63899 = - 30772 N

A' = 0 N

A = 0 N

Bending moment:

D =0

C' = -(21.98 × 200) × 100 = -439600 N-mm

C = -(21.98 × 200) × 100 = 439600 N –mm

SF = 0 – (21.98 × 792.85) × 396.425 + 17427 × 592.85 = 3423160.714N -mm

B' = - (21.98 × 2300) × 1150 + 17427 × 2100 = - 21540400 N -mm

B = - (21.98 × 2300) × 1150 + 17427 × 2100 = - 21540400 N -mm

A' = 0

A = 0

- $(21.98 \times y) \times \frac{y}{2} + 17427 \times (y - 200) = 0$
- $10.99\, y^2 + 17427 \times y – 3485400 = 0$

$10.99\, y^2 - 17427 \times y + 3485400 = 0$

Y = 1350.96071 mm

Y_1 = 234.75 mm

Bending stress:

$\frac{M}{I} = \frac{\sigma\, b}{y}$

$\sigma\, b = \frac{M}{I}\, y$

$\sigma\, b = \frac{3423160.714}{2886666.66} \times 50$ = 59.29 N/mm²

Shear stress

$Y = F \times \frac{A \times y}{I \times b}$

$Y = 33127 \times \frac{1300 \times 25}{2886666.66 \times 50}$

Y = 7.45 N/mm²

Von – misses stress:

= Vm-misses stress:-

$= \sqrt{\sigma_b^2 + 3z^2}$

$= \sqrt{59.29^2 + 3 \times 7.45}$

= 11.87 N/mm²

Principal Stress:-

$$\sigma_1, \sigma_2 = \frac{1}{2}\left[(\sigma_x + \sigma_y) \pm \sqrt{(\sigma_{x-}^2\sigma_y^2)} + 4z^2xy\right]$$

$$= \frac{1}{2}\left[59.29 \pm \sqrt{59.29} + 4 \times 11.87^2\right]$$

$= \frac{1}{2}[59.29 \pm 14.613]$

σ_1= 36.95 N/mm²

σ_2= 22.33 N/mm²

Max shear stress :

$\frac{\sigma 1 - \sigma 2}{2}$

$= \frac{36.95+22.33}{2}$

= 29.64 N/mm²

Total deflation

EI = 113Gpa × 2886666.66 = 3.261 ×10^{12} N-mm²

$\delta = \frac{Wl3}{48EI} = \frac{81345 \times 3700\ 3}{48 \times 3.261 \times 1012}$

δ = 26.323 mm

C. *Case-1 Cad Model Developed In Catia*

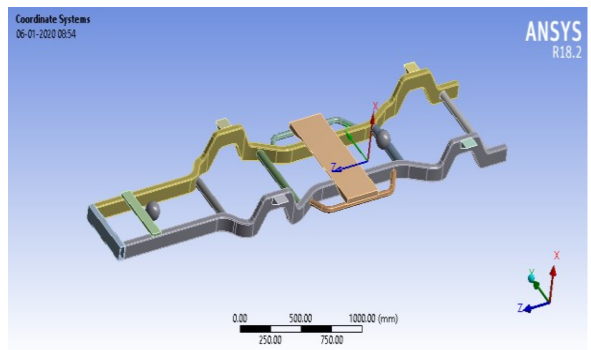


Fig. 3. (a). Cad Model Developed In Catia

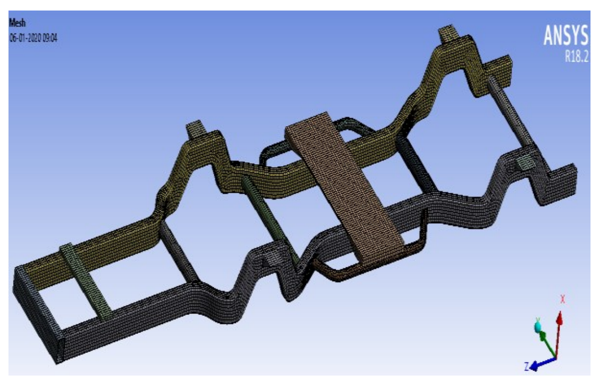


Fig. 3 (b). Mesh model

D. *Case-2 Cad Model Developed In Catia*

Cross section view of LCV Chassis Concept-2

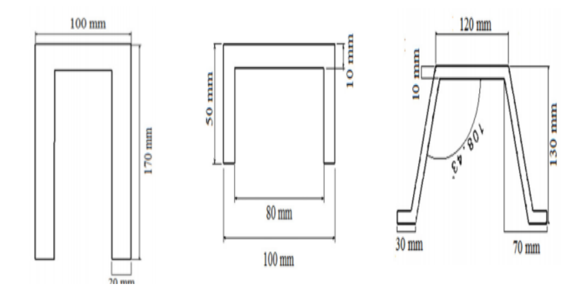


Fig. 4: (a), (b), (c) Cross sections for LCV chassis concept-2

Table 2. Dimension details of LCV chassis concept-2

Parts	Dimensions
Total length of Chassis	3600 mm
Height of chassis	1200 mm
Type of cross section	Inverted Tubular section

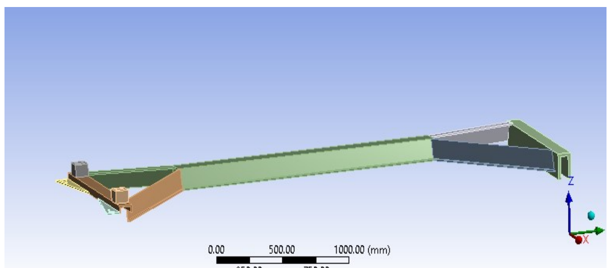


Fig. 5. Model

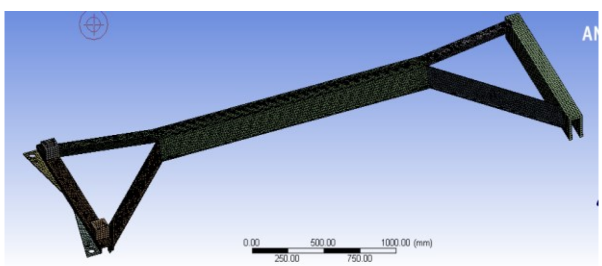


Fig. 6. Meshing

E. Defining Material Properties

Carbon Fiber Material:-

Table 3. Mechanical property of Carbon Fiber material

Material Property	Carbon Fiber (0-45)
Density	1650 Kg/m3
Young's modulus	135 GPa
Poisson's ratio	0.3
Tensile Yield strength	400 MPa

Low Density Carbon Fiber Material:-

Table 4. Mechanical property of low density Carbon Fiber material

Material Property	Properties
Density	1298 Kg/m3
Young's modulus	113 GPa
Poisson's ratio	0.32

F. Defining Boundary Condition

Case-1 Boundary Conditions

Fixed support: - There are two boundary conditions which includes fixing the front and the rear suspension location as shown in figure

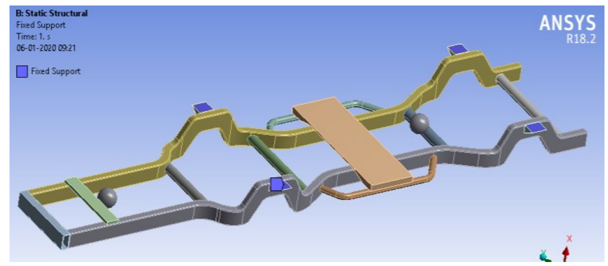


Fig. 7. Fixed support

UDL Load:- Load is applied in the form of UDL pressure of magnitude 0.50 MPa.

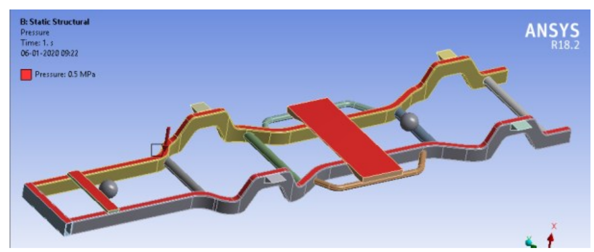


Fig. 8. UDL Load

Mass Distribution:-

Total 1000 kg uniform load is applied to the payload area. Engine weight, driver weight, 1 passenger, and other accessories etc. 600 kg was considered and applied front side of the chassis.

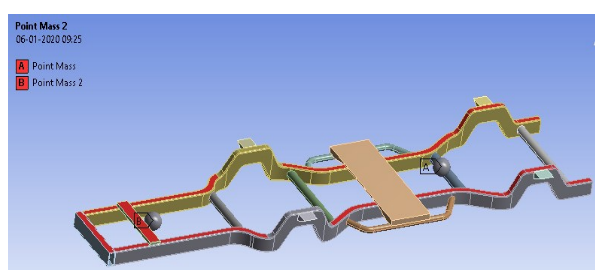


Fig. 9. Mass Distribution

G. Case-2 Boundary Conditions

Fixed support:

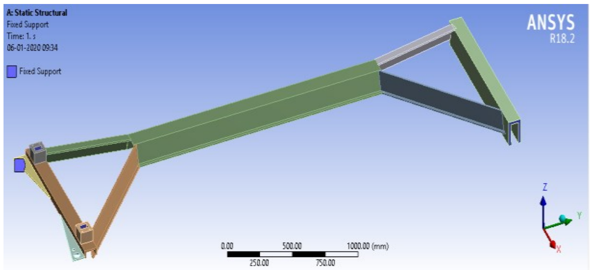


Fig. 10. Fixed Support

Loading condition for bending

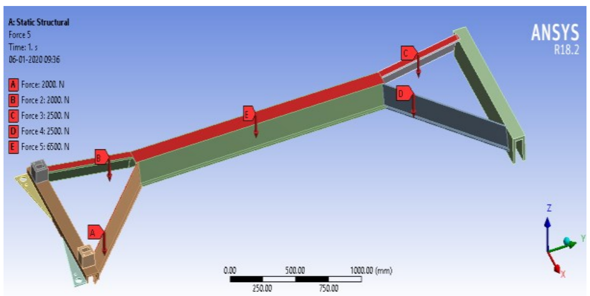


Fig. 11. Loading condition for bending

H. Case-1 result using Carbon fiber (Density:-1650kg/m3)

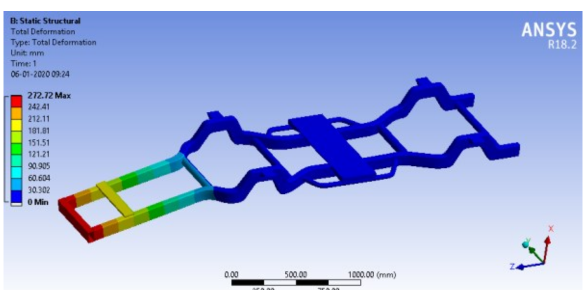


Fig. 12. Total deformation (Validation)

result using Carbon fiber (Density:-1650kg/m3)

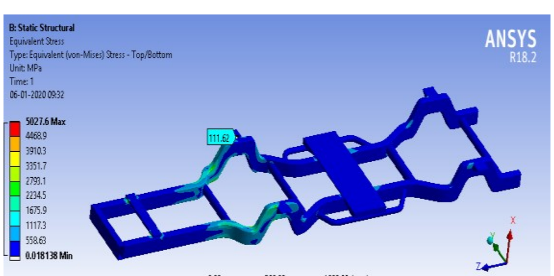


Fig. 13. Equivalent stress (Validation)

result using New Carbon fiber (Density:-1298kg/m3)

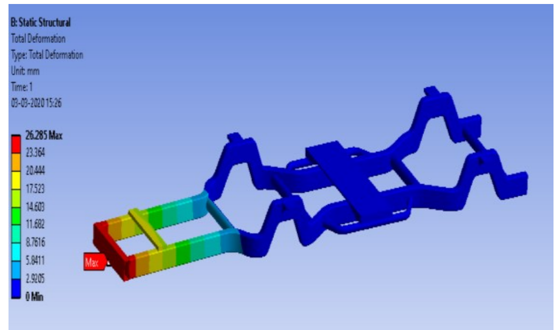


Fig. 14. Total deformation new material

result using New Carbon fiber (Density:-1298kg/m3)

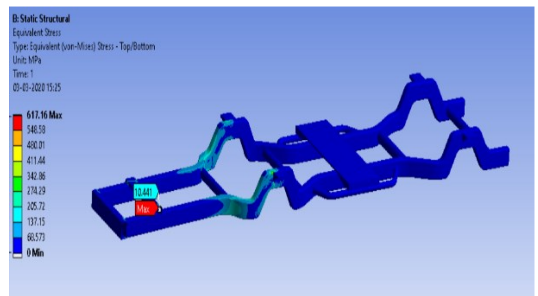


Fig. 15. Equivalent stress new material

I. Case-2 Self-Weight Analysis

Validations

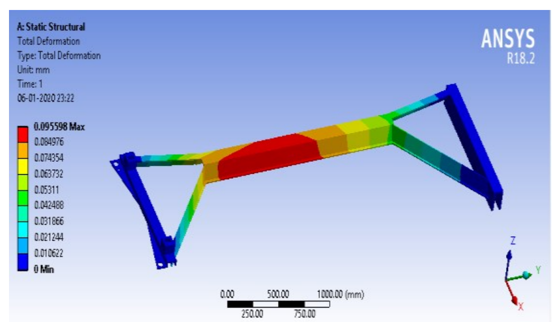


Fig. 16. Total deformation (Validation)

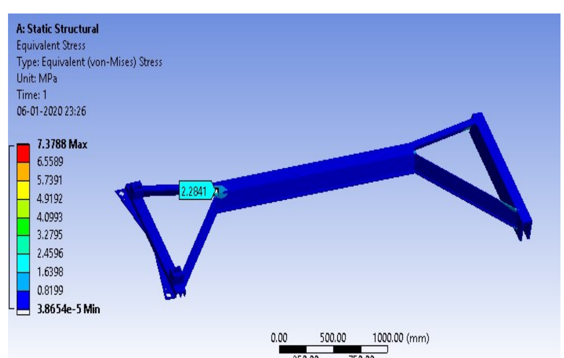


Fig. 17. Equivalent stress (Validation)

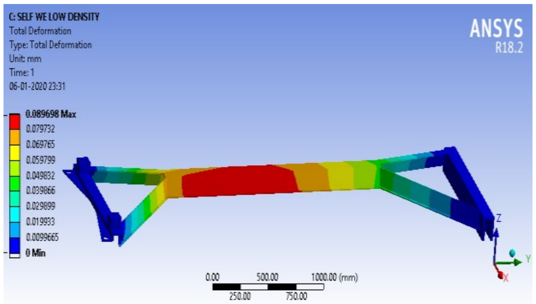


Fig. 18. Total deformation new material

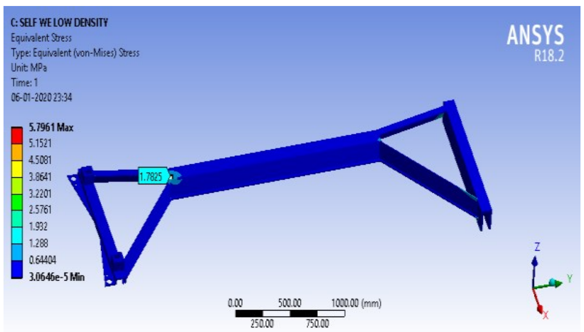


Fig. 19. Equivalent stress new material

J. *Case-2 Bending test analysis*

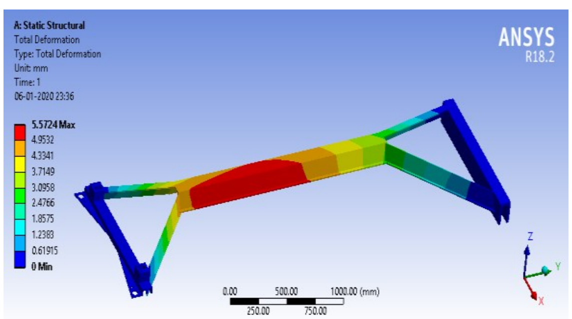


Fig. 20. Total deformation (Validation)

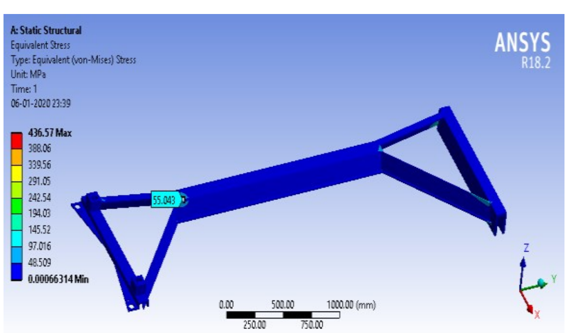


Fig. 21. Equivalent stress (Validation)

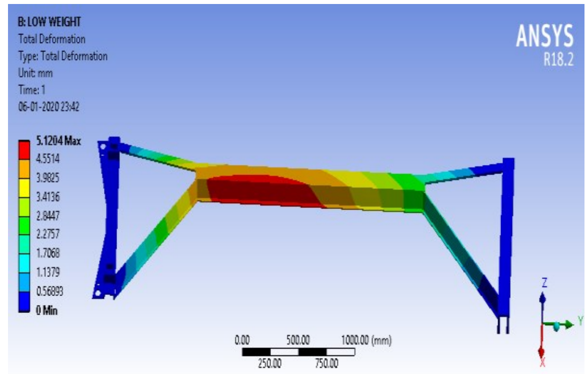


Fig. 22. Total deformation new material

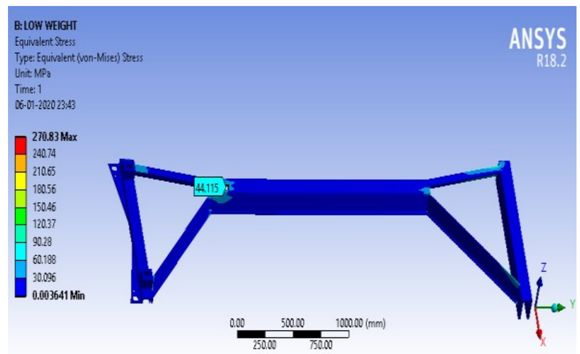


Fig. 23. Equivalent stress new material

K. *Case-2 torsional test analysis*

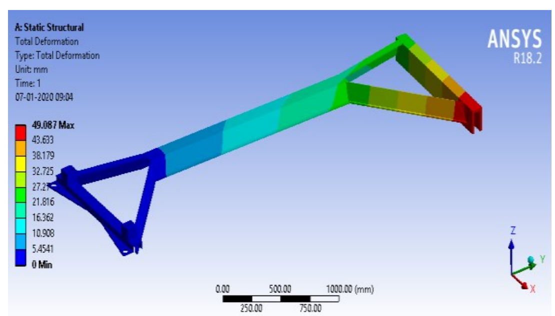


Fig. 24. Total deformation (Validation)

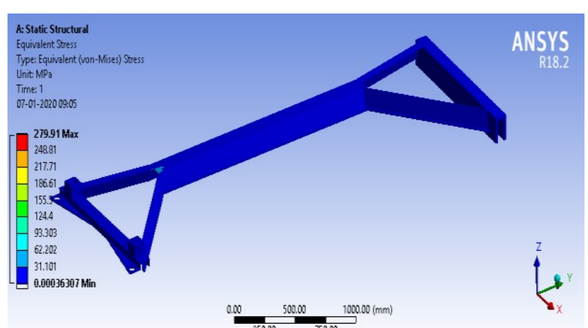


Fig. 25. Equivalent stress (Validation)

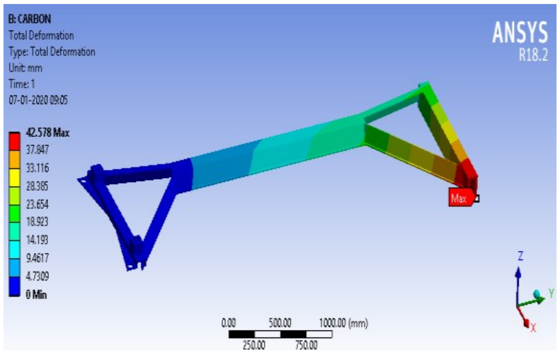


Fig. 26. Total deformation new material

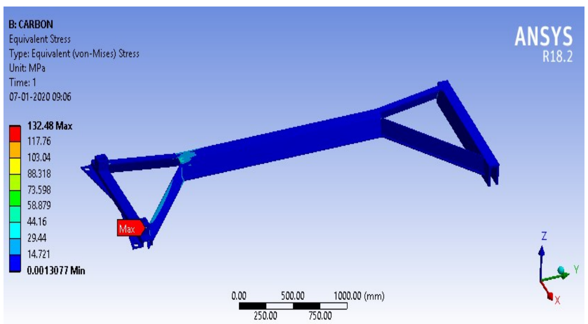


Fig. 27. Equivalent stress New material

L. Case-2 model analysis old material

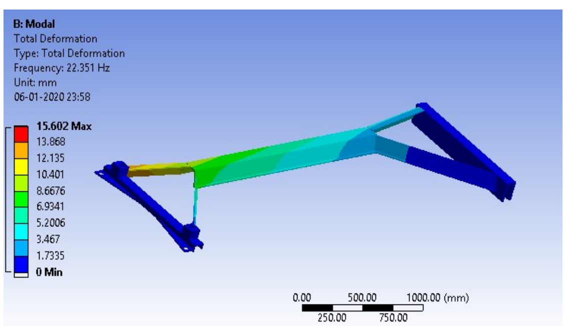


Fig. 28. Mode shape-1

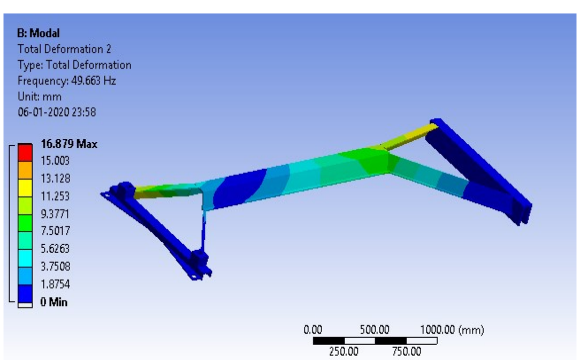


Fig. 29. Mode shape-2

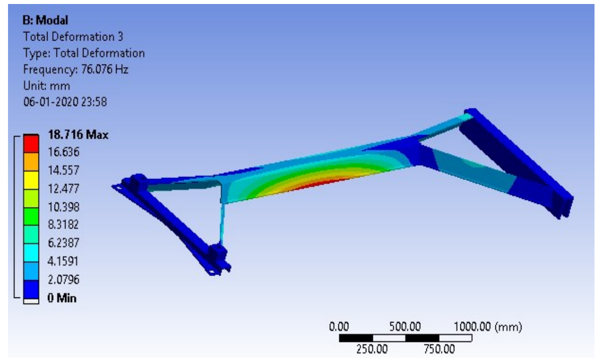


Fig. 30. Mode shape-3

M. Case-2 model analysis New material

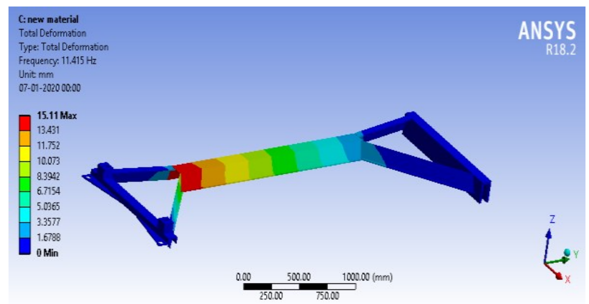


Fig. 31. Mode shape-1

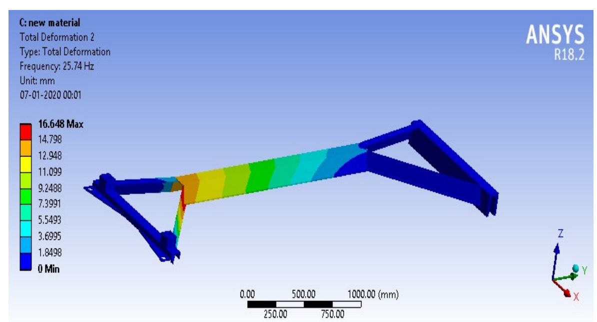


Fig. 32. Mode shape-2

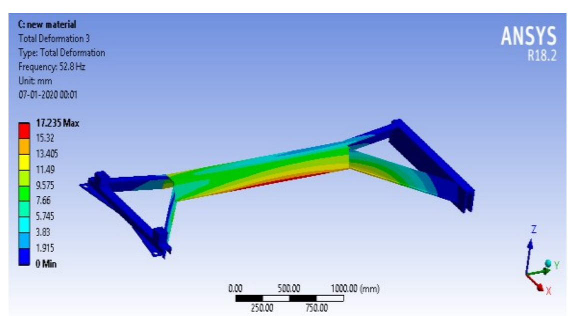
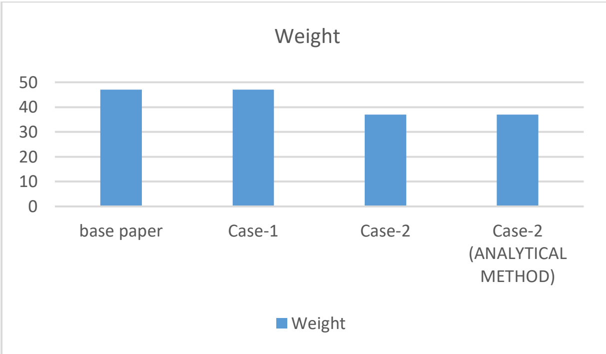


Fig. 33. Mode shape-3

V. RESULTS

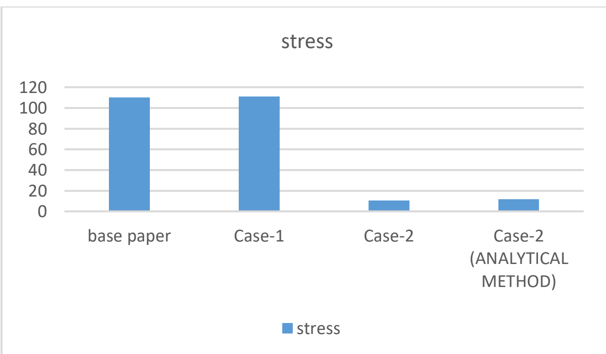
A. FEA Analysis of Tata Ace Chassis (Case-1)

Weight Graph of Tata ACE CHASSIS (CASE-1):-



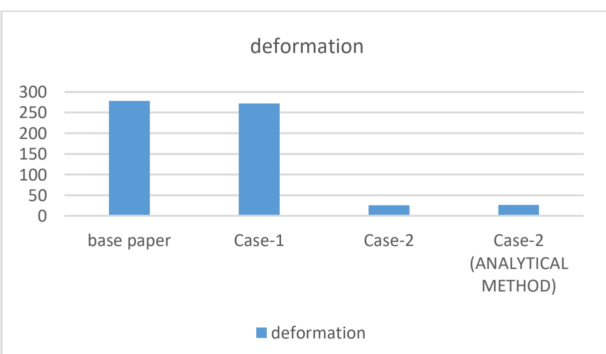
Graph. 1. Weight graph

B. Equivalent stress Graph of Tata ACE CHASSIS (CASE-1):-



Graph. 2. Stress graph

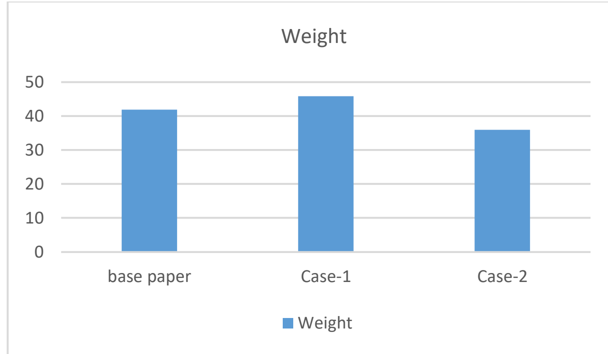
C. Total Deformation Graph of Tata ACE CHASSIS (CASE-1):-



Graph. 3. Deformation graph

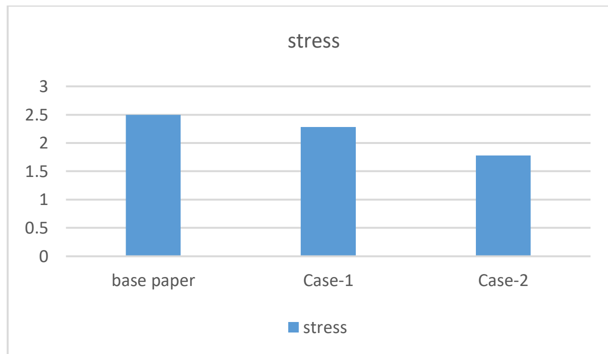
D. FEA Analysis Of Tata Ace Chassis (CASE-2)

A. SELF-WEIGHT ANALYSIS



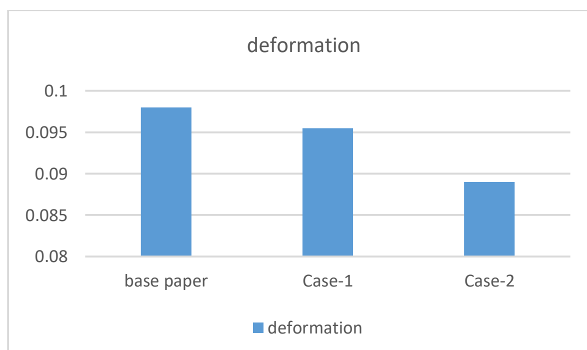
Graph. 4. Self-Weight Analysis graph

E. Stress Graph of Tata ACE CHASSIS (CASE-2):-



Graph. 5. Self-Weight ANALYSIS graph

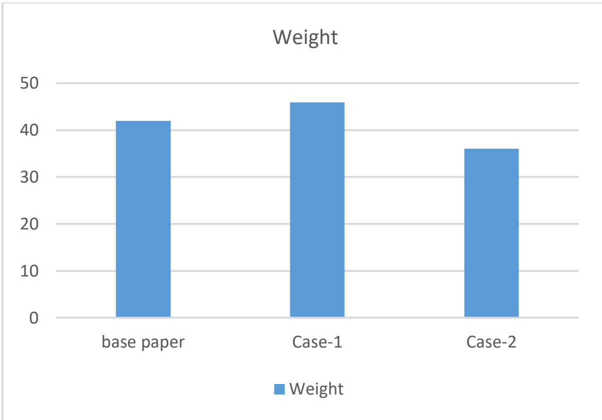
F. Total deformation Graph of Tata ACE CHASSIS (CASE-2):-



Graph. 6. Self-Weight ANALYSIS graph

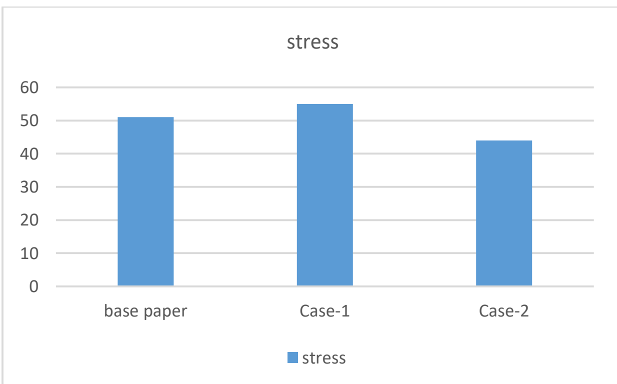
A. Bending Test ANALYSIS

G. Graph of Tata ACE CHASSIS (CASE-2):-



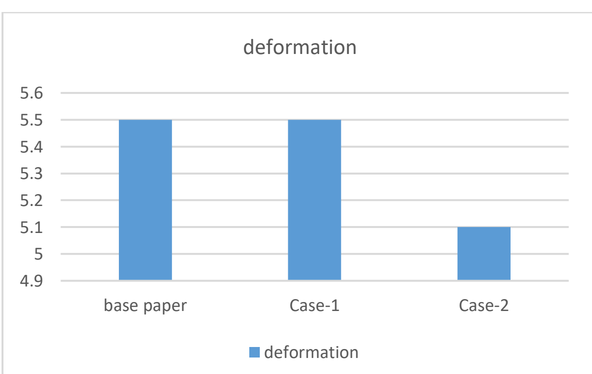
Graph. 7. Bending Test ANALYSIS graph

H. Stress Graph of Tata ACE CHASSIS (CASE-2):-



Graph. 8. Bending Test ANALYSIS

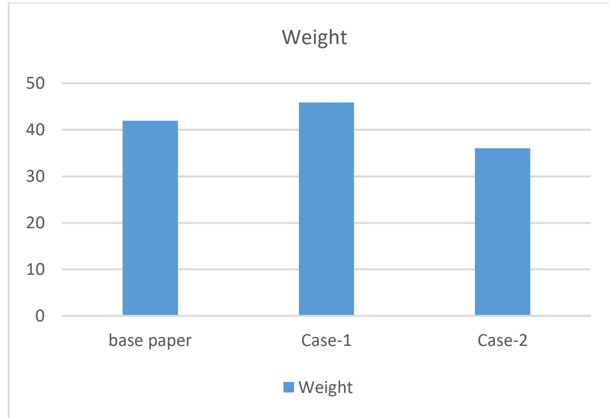
I. Total deformation Graph of Tata ACE CHASSIS (CASE-2):-



Graph. 9. Bending Test ANALYSIS

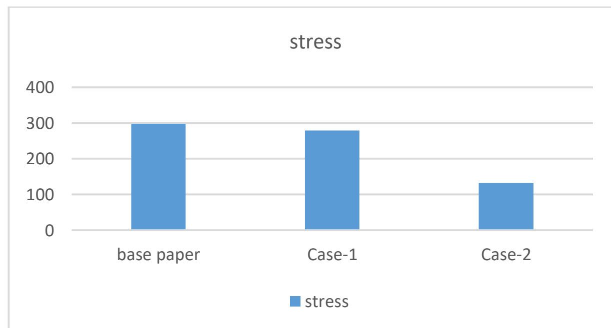
J. Torsional Test ANALYSIS

I. *Graph of Tata ACE CHASSIS (CASE-2):-*



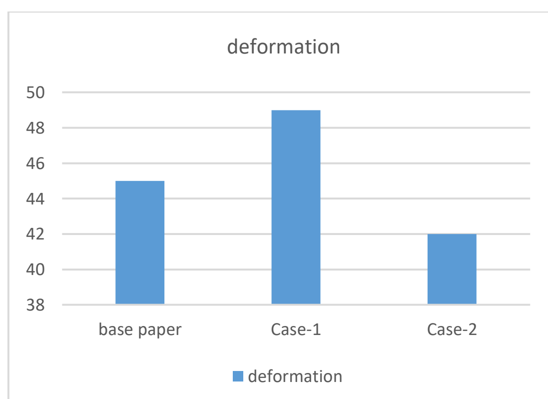
Graph. 10. Torsional Test ANALYSIS graph

II. *Stress Graph of Tata ACE CHASSIS (CASE-2):-*



Graph. 11. Torsional Test ANALYSIS graph

III. *Total deformation Graph of Tata ACE CHASSIS (CASE-2):-*



Graph. 12. Torsional Test ANALYSIS graph

VI. CONCLUSION

- In this test TATA Ace chassis is analyzed with three different materials in the concept-1 and the concept-2.

- The LCV chassis analysis of both concept 1 and concept-2 with material Carbon fiber and low density carbon fiber.
- The total weight of the chassis reduce upto 37 kg.And total deformation and equivalent stress was 26.285mm and10.441mpa.
- The Case-2 design is built with low density carbon fiber (1298Kg/m3) since it is a less weight and has a excellent strength weight ratio and shows good bending and torsion stiffness comparing with other material hence Case-2 with carbon fiber material is a best alternative design for the light weight chassis design.

VII. Future scope

Current study only static conditions was applied. For future study dynamic force will also consider for calculated deformations and stress by using dynamic analysis method.

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