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Design & Analysis of Ladder Frame I Section Chassis

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Abstract: This Chassis frame is the basic frame work of an automobile. It supports all the parts of an automobile which are attached to it. With the increase in the weight of the chassis, load on the engine increases thus performance of vehicle decreases. Thus, to improve the efficiency of vehicle the reduction of weight of the chassis is needed. In this work, we have considered ASTM A710C Steel as the material for the chassis. This material properties are applied on a ladder chassis and is analyzed under maximum load conditions. The ladder chassis is designed with I shaped cross section for long members and C shaped cross section for cross members and further material is removed from the cross members, so as to reduce the weight. Chassis is modeled in SOLID WORKS with appropriate dimensions. Static Structural analysis is done in ANSYS Workbench. Results are compared with the existing chassis model values.
Keywords: Chassis, SolidWorks, Ansys

I. INTRODUCTION

A. Hari kumar, V. Deepanjali, et al.[1] has presented the design and analysis of automobile chassis. The best material and most suitable cross-section for an Eicher E2 TATA Truck ladder chassis with the constraints of maximum shear stress, equivalent stress and deflection of the chassis under maximum load condition. In present the Ladder chassis which are uses for making buses and trucks are C and I cross-section type, which are made of Steel alloy (Austenitic). They designed chassis with high strength cross-section is to minimize the failures including factor of safety in design.In the present work, they have taken strength as the main concern. The dimensions of an existing vehicle chassis of a TATA Eicher E2 (Model no.11.10) Truck is taken for analysis with materials namely ASTM A710 Steel, ASTM A302 Alloy Steel and Aluminum Alloy 6063-T6 subjected to the same load. The different vehicle chassis have been modeled by considering three different cross-sections namely C, I and Rectangular Box (Hollow) type cross sections. The report is the work performed towards the optimization of the automobile chassis with constraints of stiffness and strength. The modeling is done using CATIA, and analysis is done using ANSYS. The overhangs of the chassis are calculated for the stresses and deflections analytically are compared with the results obtained with the analysis software. K. Someswara Rao K. Pradeep Kumar, B. Sai Kumar, et al.[2] has presented Design and Analysis of Light Weighted Chassis. In this paper , they have designed and analyzed a light weighted chassis to find the light weight material suitable for an automobile chassis. In this work, they have considered a steel alloy ASTM A710, two aluminum alloys AA 6063, AA 7075. Analysis for the different materials is done in ANSYS based on the model and theoretical calculations. The material should withstand all the load carried by the chassis. Presently materials with steel alloys are used in chassis, but they are heavy weighted. With the increase in the weight of the chassis, load on the engine increases thus performance of vehicle decreases. Thus, to improve the efficiency of vehicle light weighted materials like Aluminum alloys may be used. These material properties are applied on a ladder chassis and analyzed under maximum load conditions. The ladder chassis is designed with C cross-section so as to minimize the weight. Chassis is modelled in SolidWorks with the appropriate dimensions. Analysis for the different materials is done in ANSYS.

Abhishek Sharma, Mr. Pramod Kumar, et al.[3] has presented Structural Analysis of a Heavy Vehicle Chassis Made of Different Alloys by Different Cross-Sections. In this paper, the three material used for the chassis are grey cast iron, AISI 4130 alloy steel and ASTM A710 Steel GRADE A (Class III). There are different shapes of the cross sections that were used in this work i.e. C, I and Box type cross sections. Chassis of different cross section shapes have been analyzed, which gives the conclusion that the box channel section is best in strength and have less deformation. S.A. Karthikeyan, R. Pavendan, et al.[4] has presented Design and Analysis of Chassis in 2214 Truck. They designed chassis frame as the backbone of a vehicle. Its principle function is to safely carry the maximum load for all designed operating conditions. This paper describes design and analysis of vehicle chassis. Weight reduction is now the main issue in automobile industries. In the present work, the dimensions of an existing vehicle chassis frame of a 2214 Truck vehicle is taken for modeling and analysis of a vehicle chassis frame with three different composite materials namely, Carbon/Epoxy, E-glass/Epoxy and S-glass/Epoxy subjected to the same pressure as that of a steel chassis frame. The design constraints were stresses and deflections. The three different composite vehicle chassis frames have been modeled by considering three different cross-sections. Namely C, I and Box type cross sections. For validation the design is done by applying the vertical loads acting on the horizontal different cross sections. Software's used in this work are PRO – E for modeling, ANSYS for analysis.N. Siva Nagaraju, M.V.H. Satish Kumar, et al.[5] They have presented Modeling And Analysis of An Innova Car Chassis Frame by Varying Cross-Section. In this paper, they have observed all results to compare the rectangular and c-type cross sectional steel chassis frame from ansys. We observed that the C-type cross section will reduces the weight ,area, production time and as well as manufacturing cost.

Ahmad Zainal Taufik, Nur Rashid1, et al.[6] They has presented an electric car chassis design by using the commercial design software package, CATIA V5 R19. The design of the chassis with adequate stiffness and strength is the aim of this project. The material used is mild steel AISI 1018 with 386 MPa of yield strength and 634 MPa of ultimate strength. The result shows that the critical point of stress and displacement occurred in the middle of the side members in all loading conditions, maximum stresses are below the yield stress.P. S Madhu., T. R. Venugopal, et al.[7] In this project RADIOSS is used as solver for the analysis, they found that location of maximum Von Misses stresses and maximum shear stresses are just near the support and at the joining portion of connecting plates and side rail. These stresses can be minimized by relocating the position of the cross members and deflection of the chassis side members can be reduced considerably. K. I. Swami, Prof. S. B. Tuljapure, et al.[8] has considered Eicher 20.16 ladder chassis and they have studied the effect of varying thickness on chassis. They found that at the free end of beam highest deformation has occurred leading to lowest stresses. Deformation and stresses are directly proportional to load applied. As the thickness of cross members increases there is decrease in von misses stress and deformation. H. B. Patil, S.D. Kachave and E. R. Deore, et al.[9] have selected ladder chassis of truck. They have selected different thicknesses for cross members and side members of truck. They have suggested that in order to achieve a reduction in the magnitude of stress at critical point of the chassis frame, side member thickness, cross member thickness and position of cross member from rear end were varied. Finally they have suggested that to change the thickness of cross member at critical stress point than changing the thickness of side member and position of chassis for reduction in stress values and deflection of chassis.

Singh, V. Soni, A. Singh, et al.[10] have carried out study on ladder chassis for higher strength. The research paper describes Structural analysis & optimization of vehicle chassis with constraints of maximum shear stress and deflection of chassis under maximum load. The dimensions of an existing vehicle chassis of a TATA LP 912 Diesel BS4 bus is taken for analysis. The four different vehicle chassis have been modeled by considering four different cross-sections. Namely C, I, Rectangular Box (Hollow) and Rectangular Box (Intermediate) type cross sections. From the results, they observed that the Rectangular Box (Intermediate) section is having more strength full than the conventional steel alloy chassis with C, I and Rectangular Box (Hollow) section.Suraj B Patil1, Dinesh G Joshi, et al.[11] In this paper an effort is made to review on static structural analysis of chassis. It surveys most recent literature published within last 2 years. The review aims to provide insight into truck chassis analysis and act as a guide for researchers working on Finite Element Analysis (FEA). Truck chassis forms the structural backbone of commercial vehicle. The main function of truck chassis is to support the components and payload placed on it. There are many factors to consider while designing heavy truck chassis, material selection, strength, stiffness and weight. The present study reviewed the literature on chassis analysis and presented the findings in the subsequent sections.

II. DESIGN CONSIDERATIONS

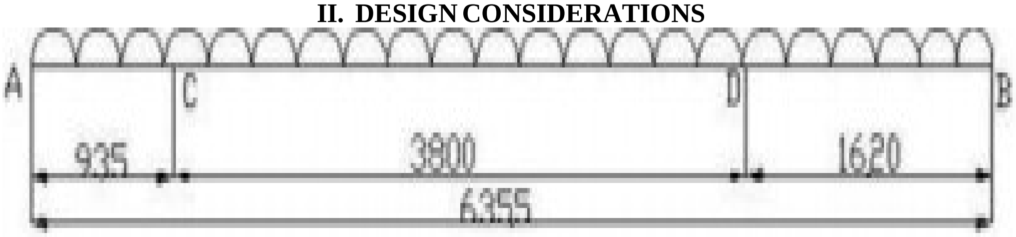

Fig.1. Geometry of Eicher E2 (Model No.11.10) Truck.

A. Specifications

Front Overhang (a) = 935 mm

Rear Overhang(c) = 1625 mm Wheel Base (b) = 3800 mm

Capacity of Truck = 8 tons = 8000 kg= 8000 × 9.81 = 78480 N

Capacity of Truck with 1.25% = 98100 N

1) *Modifications in our model:* The basic structure of a normal chassis is a completely made by C shaped cross sections. In this project the ladder chassis is designed with I shaped cross section for long members and C shaped cross section for cross members and further material is removed from cross members, so as to minimize the weight. The chassis weight is very high, so we have modified the design of a chassis by removing the material from the cross members ,which are generally used for supporting purpose. With the increase in the weight of the chassis, load on the engine increases thus performance of vehicle decreases. This can be analyzed by static analysis, combining existing theoretical knowledge and advanced analytical methods.

B. Selection of Material :ASTM Low alloy steel A 710C (Class 3)

1) Chemical composition

a) Carbon, C 0.070 %
b) Chromium, Cr 0.60 - 0.90 %
c) Copper, Cu 1.0 - 1.3 %
d) Iron, Fe 95.33 - 97.13%
e) Manganese, Mn 0.40 - 0.70 %
f) Molybdenum, Mo 0.15 - 0.25 %
g) Nickel, Ni 0.70 - 1.0 %
h) Niobium, Nb (Columbium, Cb) 0.020%
i) Phosphorous, P 0.025 %
j) Silicon, Si 0.40 %
k) Sulfur, S 0.025 %

2) Mechanical properties

Table.1. Mechanical properties for ASTM Low alloy steel A 710C Class 3

Property	Value	Units
Modulus of Elasticity, E	205×10^9	Pa
Density	7800	Kg/m^3
Poisson's ratio	0.3	---
Yield Strength	550	MPa
Tensile Strength	620	MPa

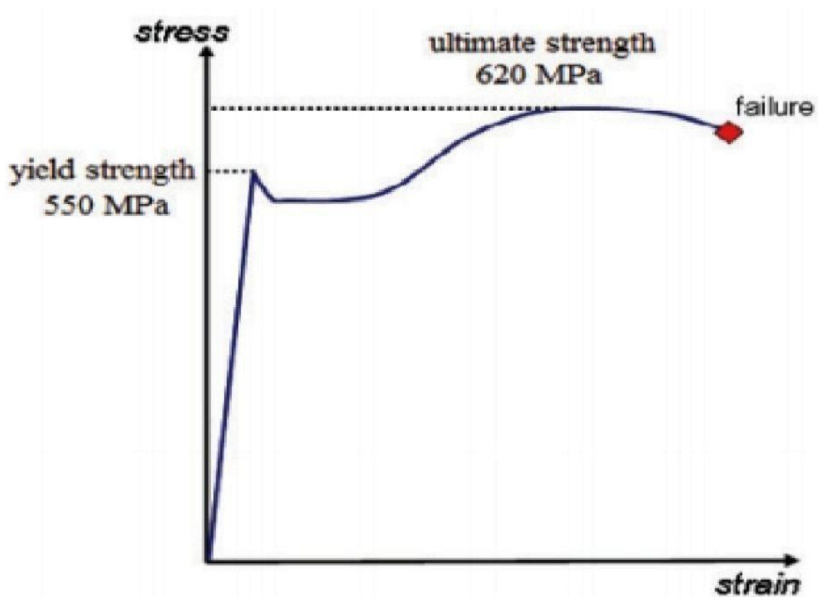

Fig. 2.Stress and Strain diagram of ASTM Low alloy steel

C. Meshing & Boundary conditions of chassis

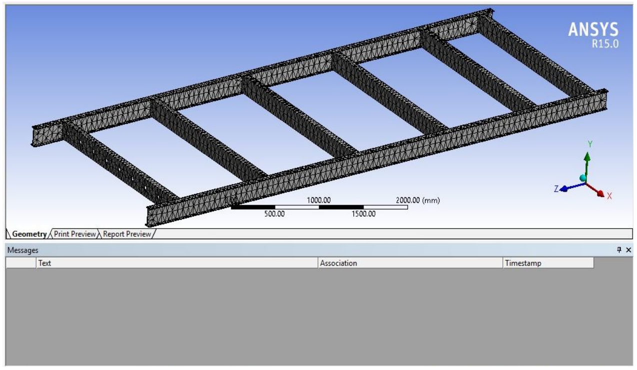

Fig.3. Meshing of the proposed model

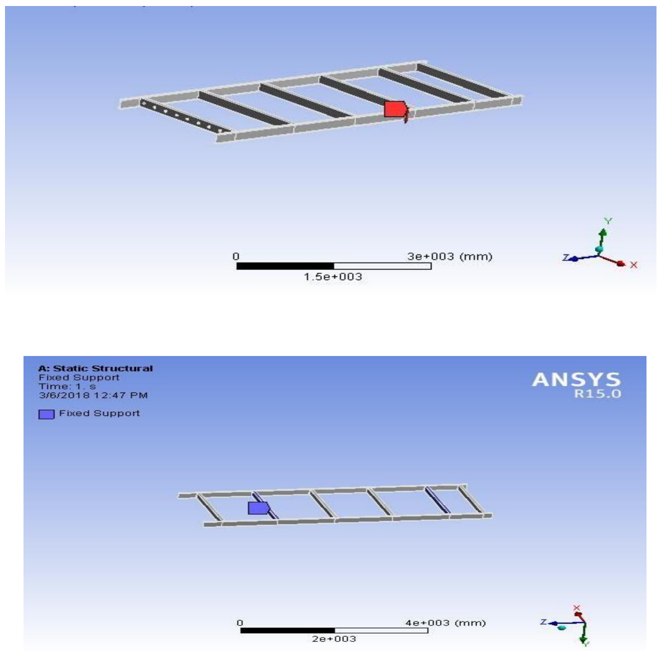

Fig.4. Boundary conditions applied on the proposed model

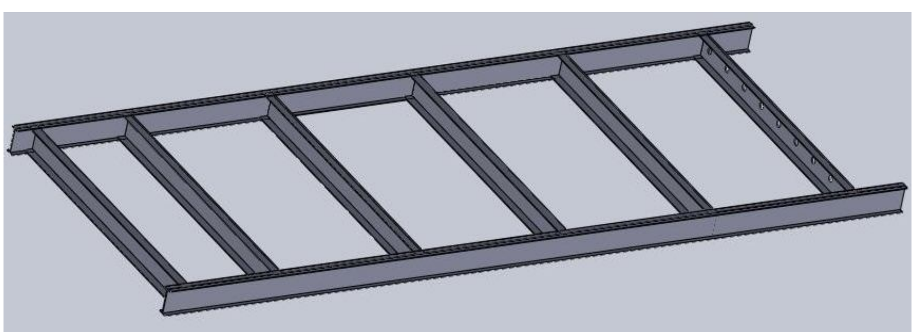

Fig.5. The proposed model of chassis

D. Design Calculations

Capacity of the Truck = 8tons = 8000 kg = 8000 × 9.81 = 78480 N

Capacity of the truck with 1.25% factor of safety = 98100 N Weight of the body and engine = 2 ton = 2000 kg = 19620 N

Total load acting on chassis = Capacity of the Chassis + Weight of body and engine = 117720 N

Chassis has two beams. So load acting on each beam is half of the Total load acting on the chassis. Load acting on the

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single frame = 117720/2= 58860 N / Beam

1) *Calculation for reaction:* Beam is simply clamp with shock absorber and leaf spring. So, beam is considered as a simply supported beam supported at C and D with uniform distributed load.

Fig.5. Load acting on chassis

Load acting on the entire span of the beam = 58860 N
Length of the beam = 6355 mm
Uniformly Distributed Load = 58860/ 6355= 9.26 N/mm
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. Let R_a, R_b, R_c, R_d be the reaction forces at A, B, C, D respectively.

2) *Moment about C:*

9.26 ×935×935/2 = (9.26×3800×3800/2) - (R_d ×3800) + (9.26 ×1620×4610) R_d = 34727.7 N
Total load acting on the beam = 58860 N
$R_c + R_d$ =58860 N R_c = 24132.3 N

3) *Calculation of bending moment*

Let M_a, M_b, M_c, M_d be the moments at A, B, C, D respectively.
M_a = 0 N-mm M_c = (-9.26×935×935)/2= -4047661.75 N-mm
M_d = [(-9.26×4735×4735)/2] + (24132.3 ×3800)= - 12102901.75 N-mm
M_b = 0 N-mm
Maximum bending moment acting on the beam, Mmax = 12102901.75 N-mm y =102 mm
Bending stress acting on the beam = 92.4 N/mm^2 Assume angle of twist 1°θ = 1° = 0.017452 rad.
By considering the whole system as a one rotational body and as per following data, when in twist from its support.
Width of the chassis = 2250 mm Length of chassis = 6355 mm
Distance between two reaction = 3800 mm
Modulus of rigidity for mild steel = 80×10 ^{3} N/mm^2
Shear stress, τ = [(80000*0.01742)/ 2250] * 210

= 130 N/mm^2 Equivalent stress = $\sqrt{(\sigma 2 + 4\tau 2)}$

= √(92.4 ^ 2 + 4 (130^2)) = 275.93 N/mm^2

Deflection of Chassis =

$$\frac{W*(b-x)}{34\,EI} * [x*(b-x)+(b)^2 - 2*((c)^2+(a)^2) - {}^2 * [(x*c)+((a)^2*(b-x))]] \quad \frac{}{b}$$

Where W = Weight of Chassis=58860 N b = wheel base=2250 mm
x = Total length/2 =3177.5 mm Deflection of Chassis = 9.51 mm

III. RESULTS AND DISCUSSION

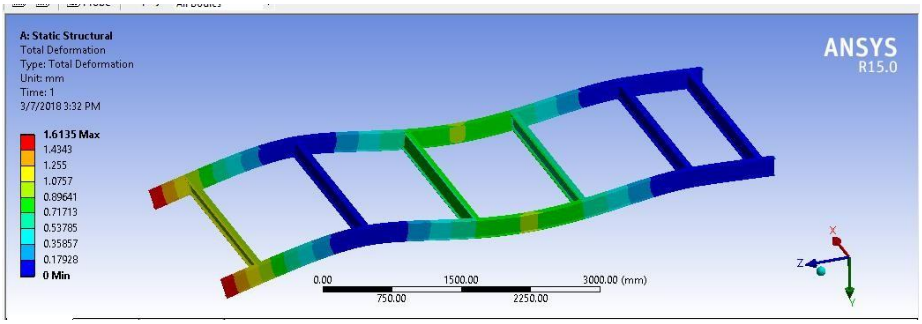

Fig. 6. Equivalent stress of chassis before creating holes

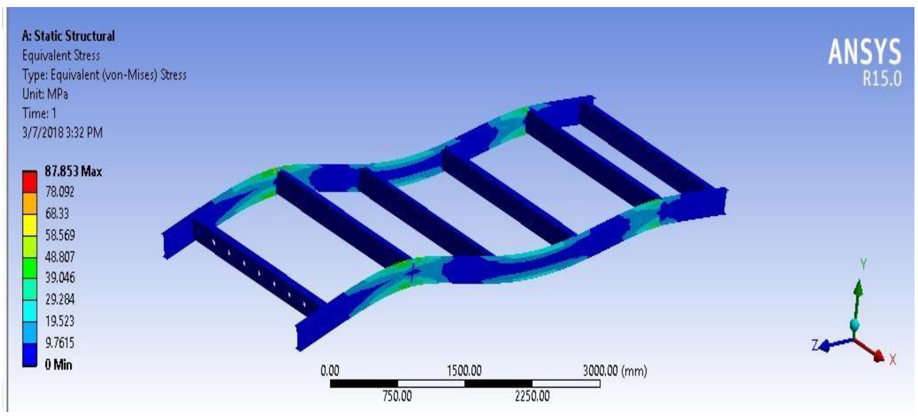

Fig. 7. Equivalent stress of chassis after creating holes

Table.2. Equivalent stress of chassis

Name	Type	Before creating holes	After creating holes
Stress	Von mises stress	83.229 MPa	87.853 MPa

A. Total deformation

The total deformation or directional deformation can be put as the displacement of the system in a particular axis or user defined direction. Total deformation is the vector sum all directional displacements of the systems.

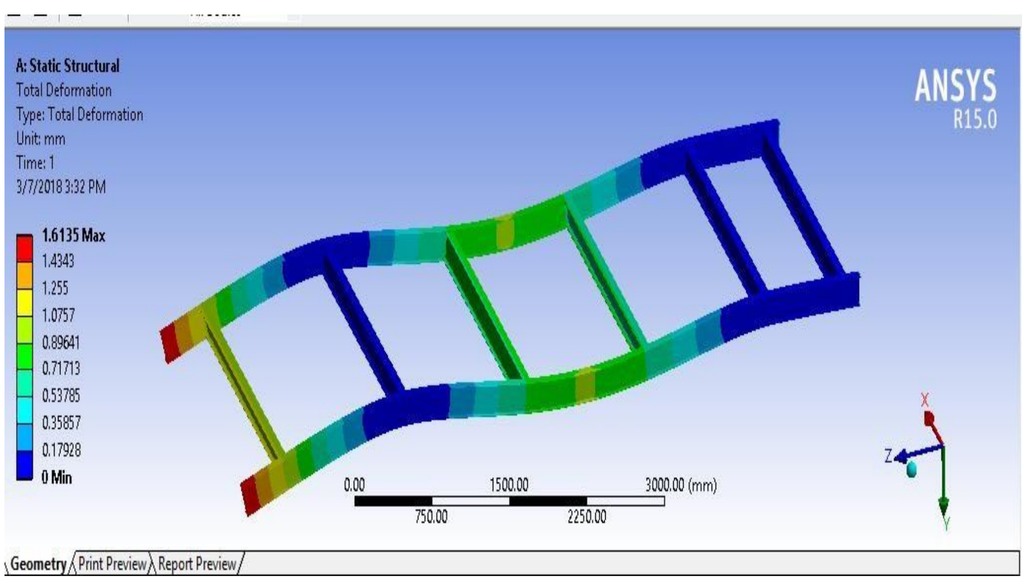

Fig. 8. Total deformation of chassis before creating holes

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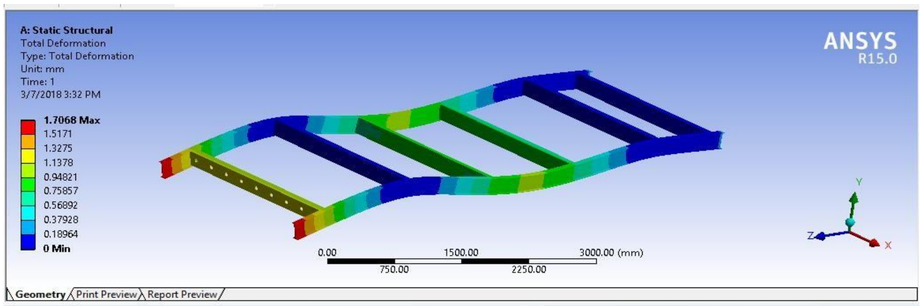

Fig. 9. Total deformation of chassis after creating holes

Table3. Total deformation of chassis

Name	Type	Before creating holes	After creating holes
Deformation(mm)	Total Deformation	1.6135	1.7068

B. Shear stress

Shearing stress is a force that causes layers or parts to slide upon each other in opposite directions. An example of shearing stress is the force of two connecting rocks rubbing in opposite directions. Shear stress is the amount of force per unit area perpendicular to the axle of the member.

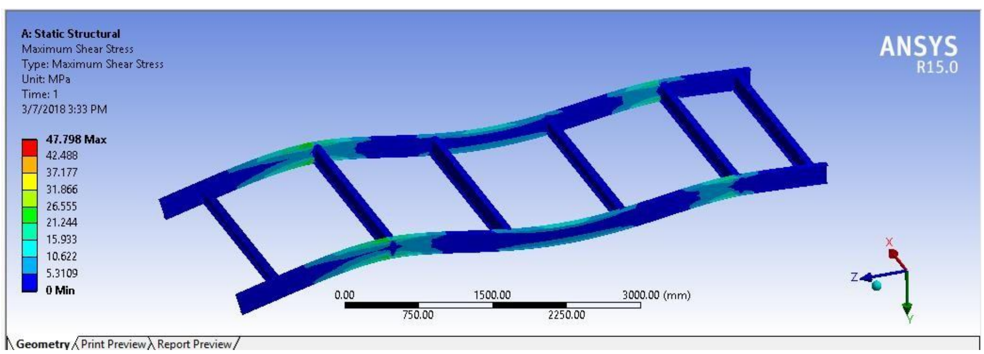

Fig. 9. Shear stress of modelled chassis before creating holes

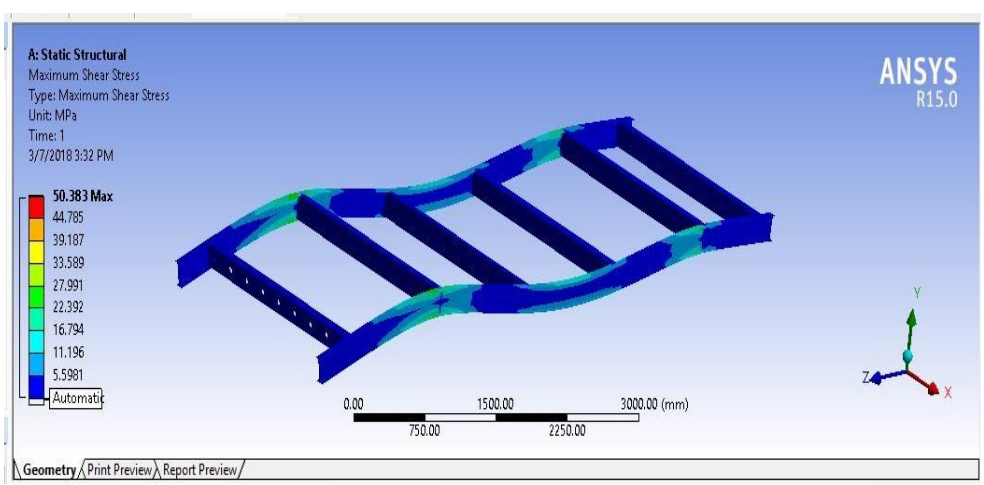

Fig. 10. Shear stress of modelled chassis after creating holes

Table4. Shear stress of modelled chassis

Name	Type	Before creating holes	After creating holes
Shear Stress	Maximum Shear stress	47.798 MPa	50.383 MPa

Table5. Analysis results of chassis

Property	Before creating holes	After creating holes	Existing model
Maximum shear stress (Mpa)	47.798	50.383	48.06
Equivalent stress (MPa)	83.229	87.853	92.93
Total deformation (mm)	1.6138	1.7038	3.03

Volume of existing chassis = 0.074 mm^3 Volume of modified chassis model = 0.073 mm^3 Density = 7800 kg/m^3
Weight of the chassis of existing model =577.2 kg Weight of the chassis of our proposed model =569.4 kg Percentage of weight reduction = (577.2 569.4) / 577.2=0.0137 × 100 =1.37 %

IV. CONCLUSION & FUTURE SCOPE

Static structural analysis of chassis with I-section long members and C-section cross members has been done before and after the removal of material. The various parameters such as maximum von-mises stress, maximum shear stress and total deformation are analyzed. From results the modified model with I-section long members and C-section cross members gives better results compared to existing model. The weight of the chassis is reduced by 1.37%, i.e. approximately 7.2 kgs from its total weight, i.e. from 577.2 kgs to 569.4 kgs. This study makes a case for further investigation on the design of truck chassis.By changing the material we can reduce the weight of chassis with better results.

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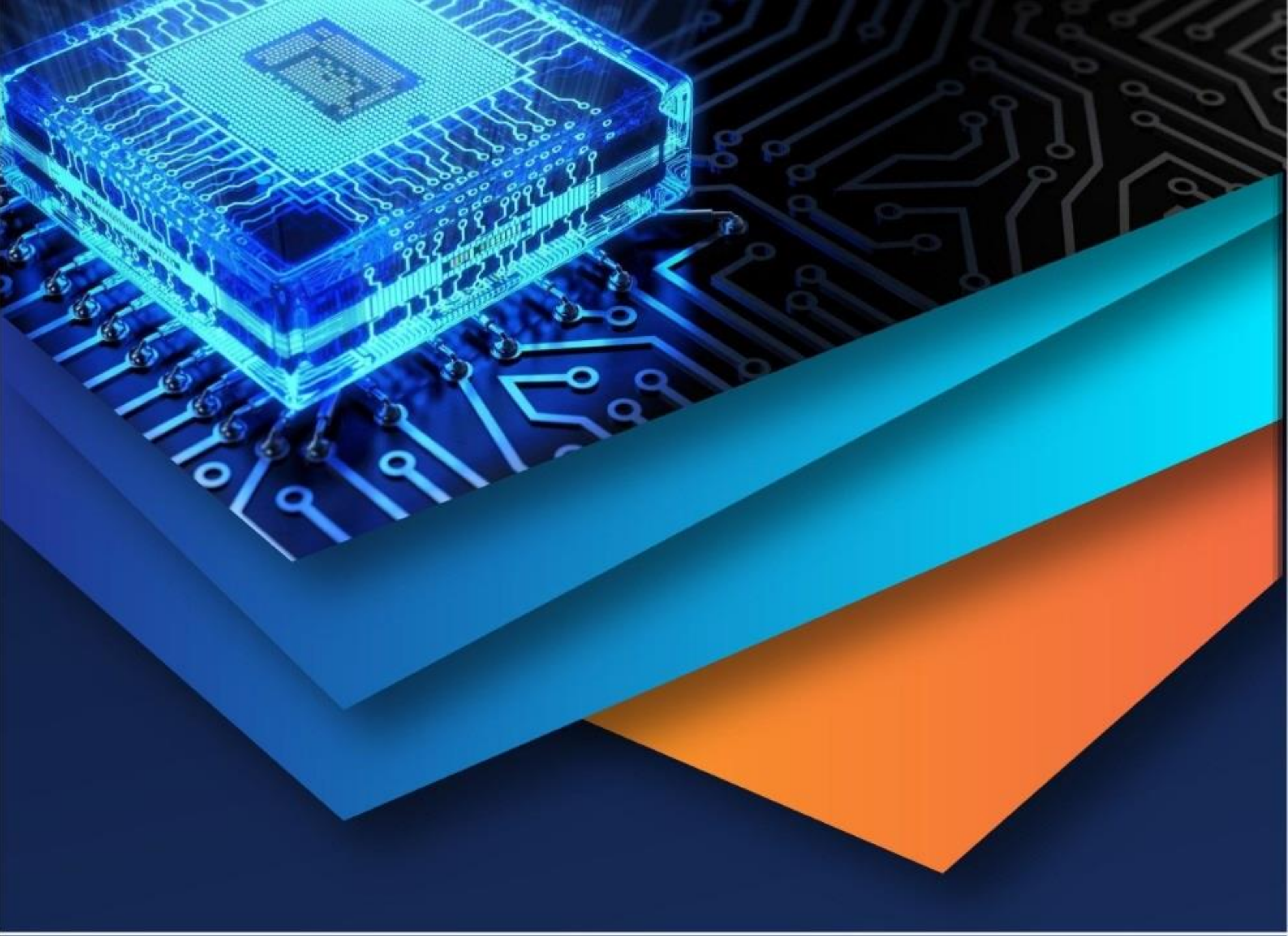

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