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DESIGN & ANALYSIS OF AUTOMOBILE CHASSIS

A.HARI KUMAR, V.DEEPANJALI

Abstract— The objective of paper is to find out 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). In India number of passengers travel in the bus is not uniform, excess passengers are travelling in the buses daily due to which there are always possibilities of being failure/fracture in the chassis/frame. Therefore Chassis with high strength cross section is needed to minimize the failures including factor of safety in design. In the present work, we have taken higher strength as the main issue, so 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 problem to be dealt for this dissertation work is to Design and Analyze using suitable CAE software for ladder chassis. 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.

***Keywords*: Automobile chassis, chassis loads, modeling, structural analysis.**

I. INTRODUCTION

The chassis is considered to be one of the significant structures of an automobile. It is the frame which holds both the car body and the power train. Various mechanical parts like the engine and the drive train, the axle assemblies including the wheels, the suspension parts, the brakes, the steering components, etc., are bolted onto the chassis. The chassis provides the strength needed for supporting the different vehicular components as well as the payload and helps to keep the automobile rigid and stiff. Consequently, the chassis is also an important component of the overall safety system. Furthermore, it ensures low levels of noise, vibrations and harshness throughout the automobile. Chassis should be rigid enough to withstand the shock, twist, vibration and other stresses. Along the strength, an important consideration is chassis design is to have adequate bending and torsional stiffness for better handling characteristics. So, strength and stiffness are two important criteria for the design of chassis. The load carrying structure is the chassis, so the chassis has to be so designed that it has to withstand the loads that are coming over it.

II. PROBLEM STATEMENT

The objective of thesis work is to find out 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. The problem to be dealt with for this dissertation work is to Design and Analyze using suitable CAE software for ladder chassis. 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). In India no of passengers travel in the bus is not uniform, excess passengers are travelling in the buses daily due to which there are always possibilities of being failure/fracture in the chassis/frame. Therefore Chassis with high strength cross section is needed to minimize the failures including factor of safety in design. Basically C cross section type of chassis is used in buses and I cross section type in heavy trucks where high strength is required. So we have taken Rectangular Box type cross section for making ladder chassis by fabricating it which is used in small trucks. It will give best strength among all above three.

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FIG 1 Eicher E2 (Model No.11.10) Truck

III. SOLUTION METHODOLOGY

The solution for the problem is performed in three stages - Theoretical Analysis, Creating a Solid Model, Finite Element Analysis.

A. Theoretical Analysis

Theoretical Analysis is performed by using the basic concepts of Strength of Materials. The Chassis Ladder of this problem is considered as an overhanging beam with roller supports corresponding to front and rear wheels. Total load acting on the Chassis is taken as a sum of capacity of the chassis and weight of the body and engine. This total load is considered as uniformly distributed load acting throughout the span of the beam [1]. Reaction forces, Shear forces and Bending moment are calculated based on the total load.

B. Creating a Solid Model

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

C. Finite Element Analysis

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.

IV. SPECIFICATION OF MATERIAL

Property	ASTM A710 Steel	ASTM A302 Alloy Steel	Aluminium Alloy 6063-T6
Mass density(g/cm3)	7.85	7.79	2.8
Yield strength(MPa)	450	340	220
Ultimate Tensile strength(MPa)	515	590	250
Poisons ratio	205	210	69
Shear Modulus(GPa)	0.29	0.33	0.32
Young’s Modulus(GPa)	80	78	26

V. DESIGN CALCULATIONS FOR CHASSIS FRAME

Material and Geometry of Eicher E2 (Model No.11.10) Truck
Side bar of the chassis are made from “C” Channels with 210mm x 76 mm x 6 mm
Material of the chassis is ASTM A710 Steel
Front Overhang (a) = 935 mm
Rear Overhang (c) = 1620 mm

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Wheel Base (b)	= 3800 mm
Modulus of Elasticity, E	= 2.10 x 10^5 N / mm^2
Poisson Ratio	= 0.28
Capacity of Truck	= 8 tons = 8000kg = 78480 N
Capacity of Truck with 1.25%	= 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
	= 98100 + 19620
	= 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 single frame	= 117720/2
	= 58860 N / Beam

A. 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.

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.

Moment about *C*:

9.26×935×935/2	= (9.26×3800×3800/2) - (R_d×3800) + (9.26×1620×4610)
R_d	= 34727.65 N
Total load acting on the beam	= 9.26 × 6355
	= 58847.3 N
$R_c + R_d$	= 58847.3
R_c	= 24119.65 N

B. Calculation of shear force and bending moment:

Shear force calculations:

F_a	= 0 N
F_c	= (-9.26×935) + 24119.65
	= 15461.55 N
F_d	= (-9.26×4735) + 34727.65 + 24119.65
	= 15001.2 N
F_b	= 0 N

Bending moment calculations:

M_a	= 0 Nmm
M_c	= (-9.26×935×935)/2
	= -4047661.75 Nmm
M_d	= [(-9.26×4735×4735)/2] + (24119.65×3800)
	= -12150971.75 Nmm
M_b	= 0 Nmm

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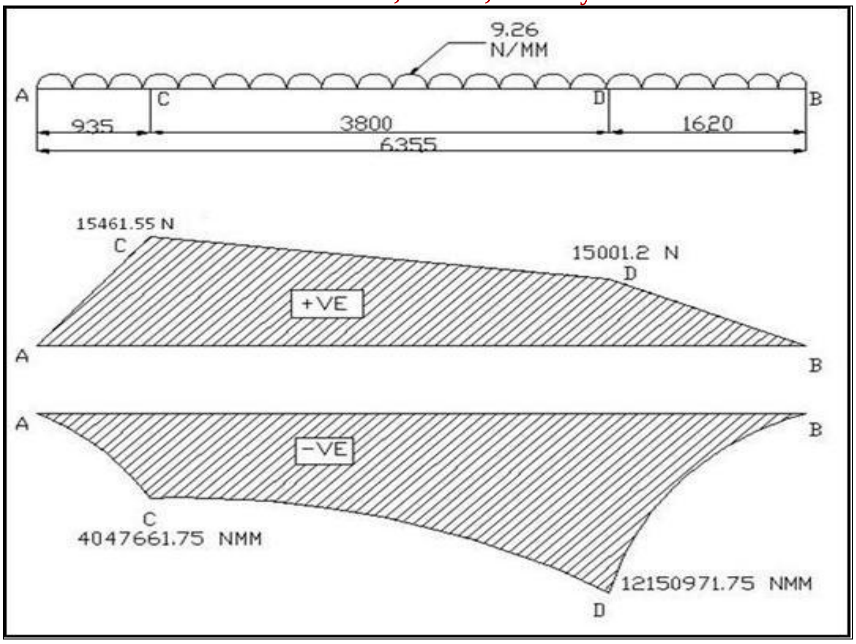

FIG 2 Loading diagram, SFD & BMD

C. Bending Stress Calculations

Moment of inertia about x-x axis, $I = \frac{bh^3}{12} - \frac{b_1h_1^3}{12}$ I = 13372380 mm^4

Basic bending equation is given by, $\frac{M}{I} = \frac{\sigma}{Y} = \frac{E}{R}$

Maximum bending moment acting on the beam, M_{max} = 12150971.75 Nmm

Bending stress acting on the beam = 95 N/mm^2

D. Shear Stress Calculations

Assume angle of twist = 1°

θ = $1° \times \frac{\pi}{180}$

= 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 = 2250mm

Length of chassis = 6355mm

Distance between two reaction = 3800mm

Modulus of rigidity for mild steel = 78.125 N/mm^2

Now basic rule for Twisting Moment is: $\frac{T}{J} = \frac{\tau}{r} = \frac{G\theta}{L}$

Shear stress, τ = (5737971.47×2250)/26744760

= 482.72 N/mm^2

According to Von Mises Stress Theory,

Von Mises Stress = $\sqrt{\sigma^2 + 3\tau^2}$

= 448.5 MPa

Principal Stresses, $\sigma_{1,2} = \frac{1}{2}\left[(\sigma x + \sigma y) \pm \left(\sqrt{(\sigma x - \sigma y)^2 + 4\tau xy^2}\right)\right]$

Where σ_1 and σ_2 are the major & minor Principle Stresses respectively

Maximum Shear Stress = $\frac{\sigma_1 - \sigma_2}{2}$

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= 257.5 MPa

Deflection of Chassis $= \frac{W \times (b-x)}{24EI}\left[x(b-x) + b^2 - 2(c^2 + a^2) - \frac{2}{b}\left[xc^2 + a^2(b-x)\right]\right]$

Where W = Weight of Chassis

= 58860 N

a, b and c are the front overhang, wheel base and rear overhang respectively.

x = Total length/2

Deflection of Chassis = 2.66 mm

VI. DESIGN OF CHASSIS FRAME USING CATIA

The geometric modeling of Ladder chassis with *C*, *I* and *Rectangular Box* type cross-sections is done using CATIA. The three-dimensional model of the ladder chassis of *C* type cross-section, *I* type cross-section and *Rectangular Box* type cross-section is shown in Fig. 3, 4 and 5 respectively.

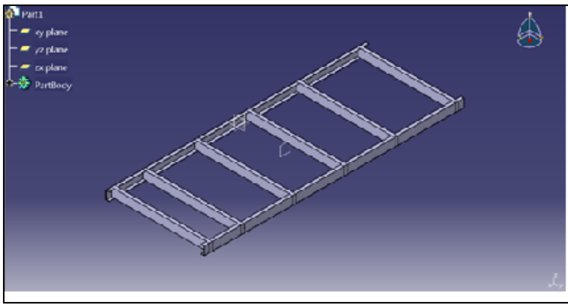

FIG 3 CATIA Model of *C* Cross-Section typeof Ladder Chassis

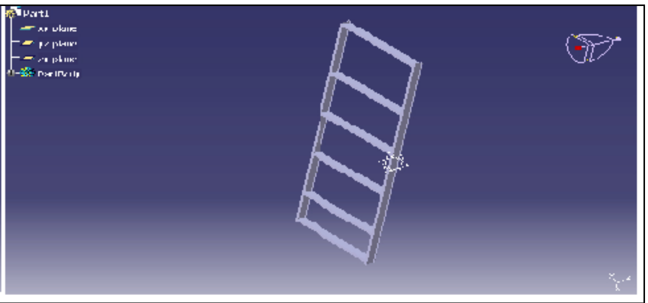

FIG 4 CATIA Model of *I* Cross-Section type of Ladder Chassis

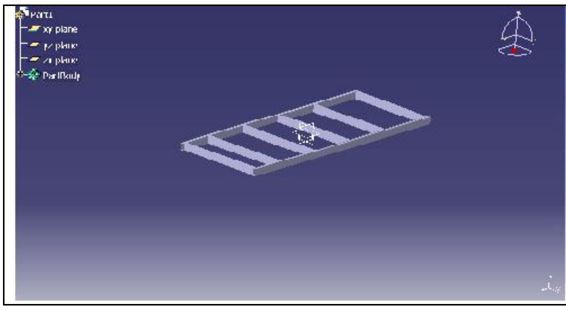

FIG 5 CATIA Model of *Rectangular Box* Cross-Section type of Ladder Chassis

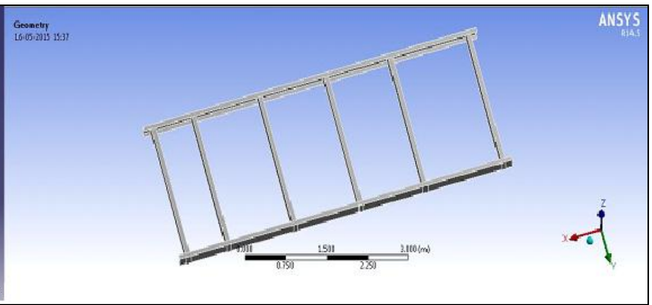

FIG 6 Imported Model in Ansys Workbench

VII. FINITE ELEMENT ANALYSIS OF CHASIS USING ANSYS WORKBENCH

The model of chassis is saved in IGES format which can be directly imported into ANSYS workbench. The model imported to Ansys workbench is shown in Fig.6.

A. *Meshing and Boundary Conditions*

The meshing is done on the model with 3504 number of nodes and 10282 numbers of tetrahedral elements. The truck chassis model is loaded by static forces from the truck body and load. For this model, the maximum loaded weight of truck plus body is 10,000 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 Fig. 7.

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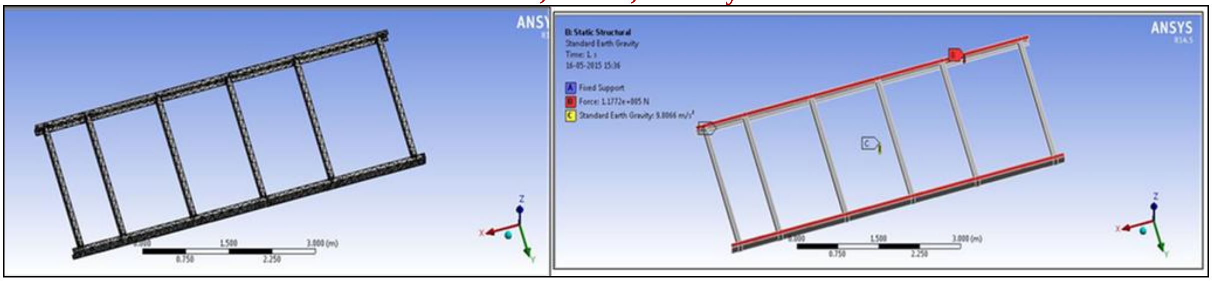

FIG 7 Mesh and Boundary Conditions for Ladder Chassis

B. *Structural Analysis of Ladder Chassis*

A linear finite element structural analysis of the ladder chassis finite element models under the Y-directional load was conducted with three different cross-sections – ‘C’, Rectangular Box and ‘I’ type cross-sections. Also, three different types of materials - ASTM A710 Steel, ASTM A302 Alloy Steel and Aluminum Alloy 6063-T6 were used for analysis of three cross-sections of chassis separately. The contour plots of Von Mises stress distribution, Maximum Stress and Deformation for the three cross-sections with three different materials are shown from Fig. 8 to Fig. 16.

C. *Structural analysis of C Cross-section type of Ladder Chassis*

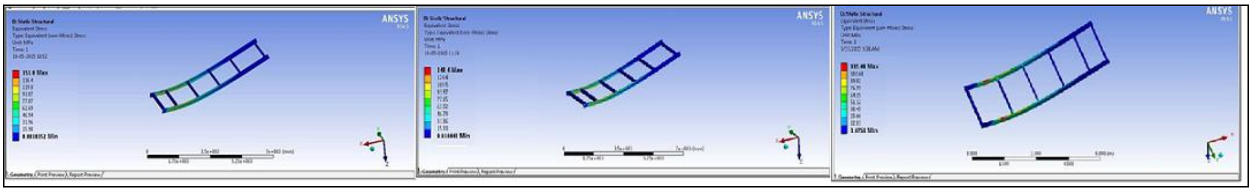

FIG 8 Von Mises Stress Distribution of ASTM A710 Steel, ASTM A302 Alloy Steel & Aluminum Alloy 6063-T6

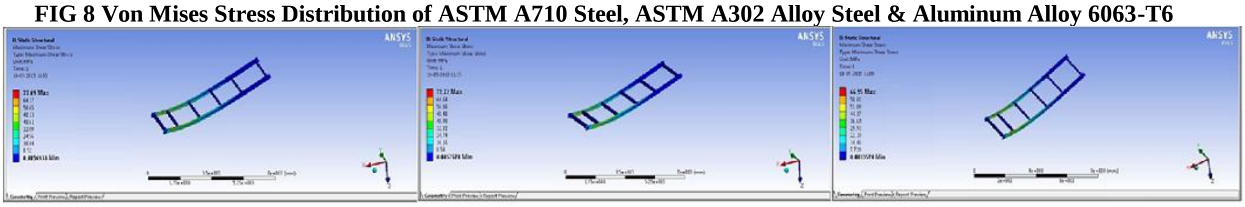

FIG 9 Maximum Stress contour of ASTM A710 Steel, ASTM A302 Alloy Steel & Aluminum Alloy 6063-T6

FIG 10 Deformation contour of ASTM A710 Steel, ASTM A302 Alloy Steel & Aluminum Alloy 6063-T6

D. *Structural analysis of Rectangular Box Cross-section type of Ladder Chassis*

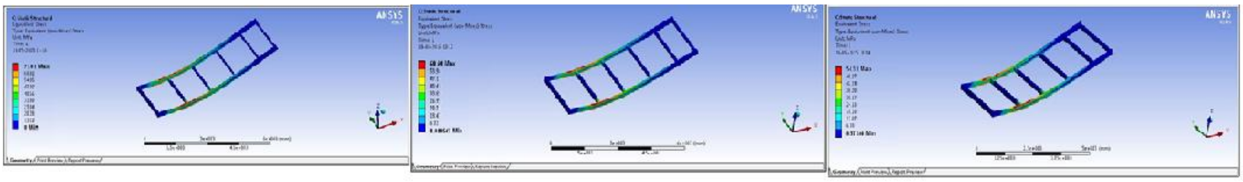

FIG 11 Von Mises Stress Distribution of ASTM A710 Steel, ASTM A302 Alloy Steel & Aluminum Alloy 6063-T6

FIG 12 Maximum Stress contour of ASTM A710 Steel, ASTM A302 Alloy Steel & Aluminum Alloy 6063-T6

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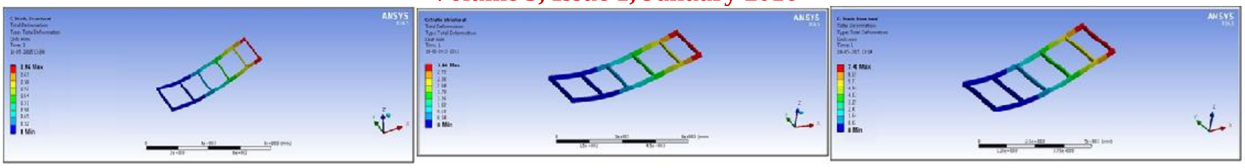

FIG 13 Deformation contour of ASTM A710 Steel, ASTM A302 Alloy Steel & Aluminum Alloy 6063-T6

E. *Structural analysis of I Cross-section type of Ladder Chassis*

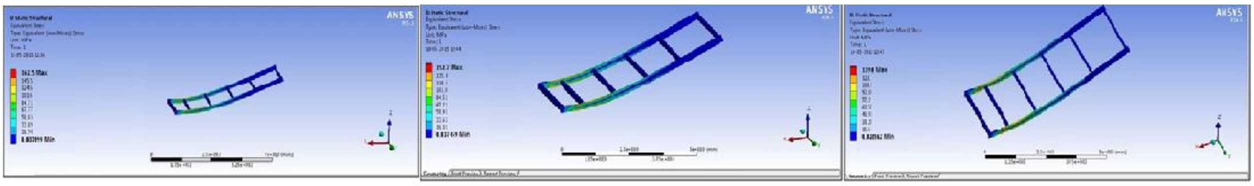

FIG 14 Von Mises Stress Distribution of ASTM A710 Steel, ASTM A302 Alloy Steel & Aluminum Alloy 6063-T6

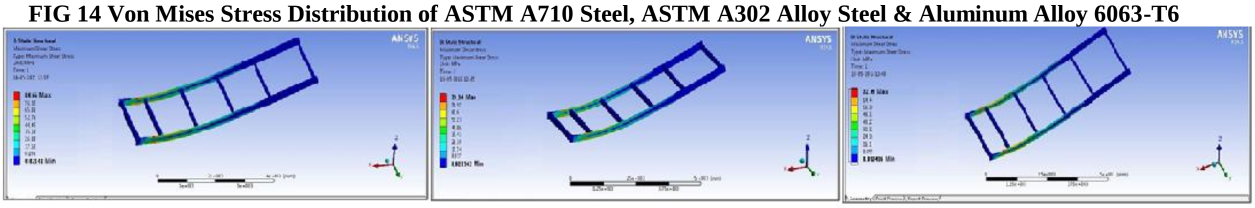

FIG 15 Maximum Stress contour of ASTM A710 Steel, ASTM A302 Alloy Steel & Aluminum Alloy 6063-T6

FIG 16 Deformation contour of ASTM A710 Steel, ASTM A302 Alloy Steel & Aluminum Alloy 6063-T6

VIII. RESULTS

A. *Theoretical Results for C & I Cross-Section type of Ladder Chassis*

Material	Von Mises Stress (MPa)	Max. Shear Stress (MPa)	Deformation (mm)
ASTM A710 Steel	438	251.5	2.66
ASTM A302 Alloy Steel	335	190.75	2.57
Aluminum alloy 6063-T6	168	92.75	7.9

B. *Theoretical Results for Rectangular Box Cross-Section type of Ladder Chassis*

Material	Von Mises Stress (MPa)	Max. Shear Stress (MPa)	Deformation (mm)
ASTM A710 Steel	434	249.75	2.064
ASTM A302 Alloy Steel	328	188.55	2.015
Aluminum alloy 6063-T6	157	88	6.132

C. *FEA (Ansys) Results for C Cross-Section type of Ladder Chassis*

Material	Von Mises Stress (MPa)	Max. Shear Stress (MPa)	Deformation (mm)
ASTM A710 Steel	151.8	77.69	5.92
ASTM A302 Alloy Steel	140.4	72.22	9.5
Aluminum alloy 6063-T6	115.48	66.55	15.18

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D. ***FEA (Ansys) Results for I Cross-Section type of Ladder Chassis***

Material	Von Mises Stress (MPa)	Max. Shear Stress (MPa)	Deformation (mm)
ASTM A710 Steel	162.5	84.65	7.592
ASTM A302 Alloy Steel	152.7	79.34	11.20
Aluminum alloy 6063-T6	139.8	72.49	15.48

E. ***FEA (Ansys) Results for Rectangular Box Cross-Section type of Ladder Chassis***

Material	Von Mises Stress (MPa)	Max. Shear Stress (MPa)	Deformation (mm)
ASTM A710 Steel	71.81	16.05	2.12
ASTM A302 Alloy Steel	60.64	11.168	3.06
Aluminum alloy 6063-T6	54.31	5.98	7.42

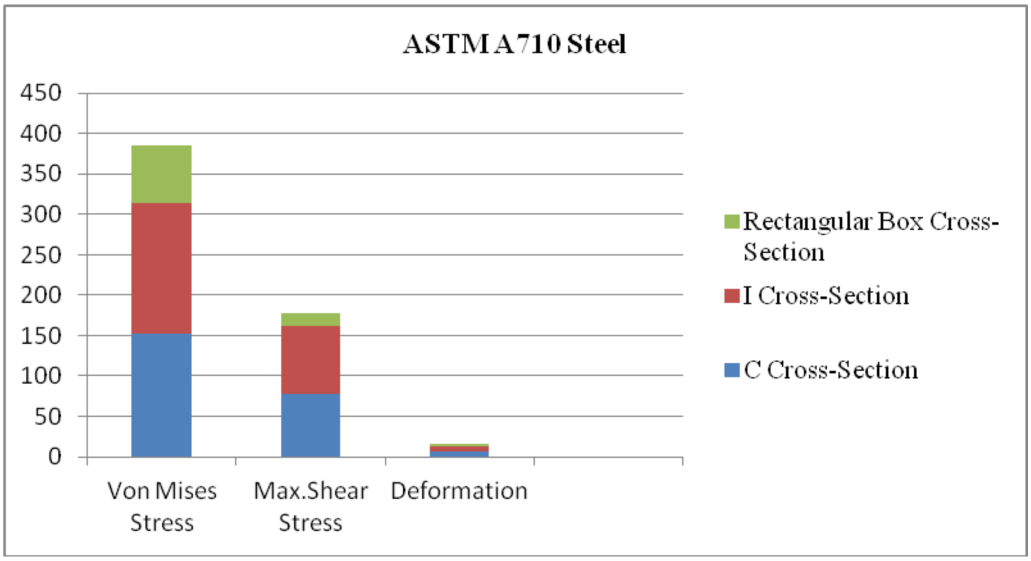

FIG 17 Graph showing Cross-Section v/s Stresses for ASTM A710Steel

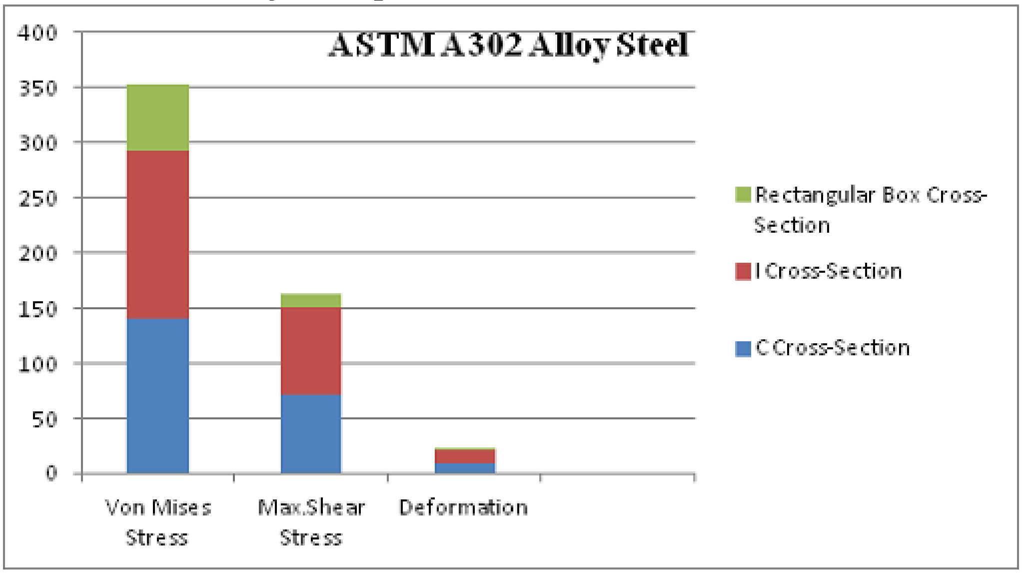

FIG 18 Graph showing Cross-Section vs Stresses for ASTM A302 Alloy Steel

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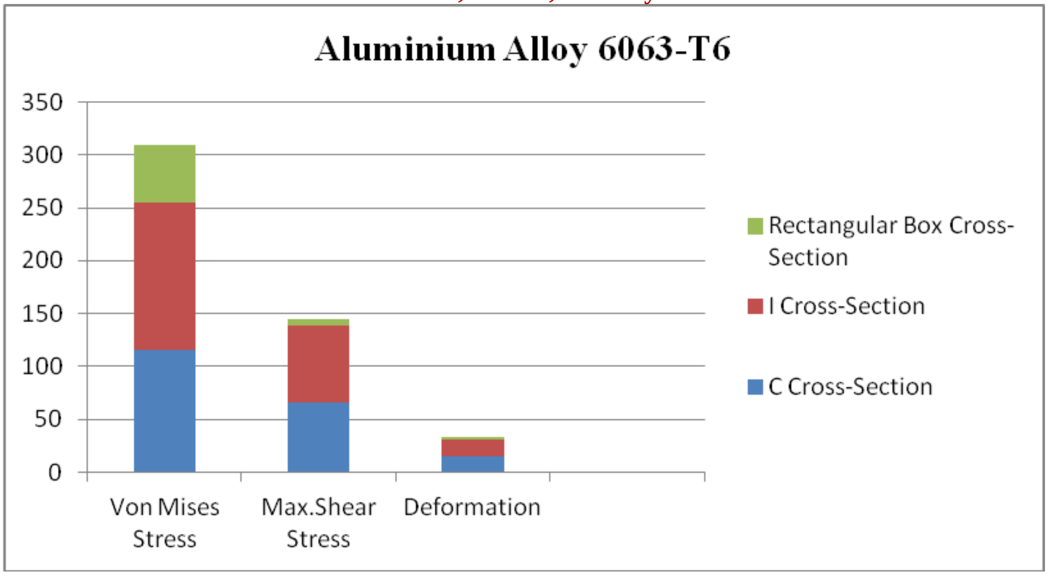

FIG 19 Graph showing Cross-Section vs Stresses for Aluminum Alloy 6063-T6

IX. CONCLUSIONS

In the present work, ladder type chassis frame for TATA Turbo Truck was analyzed using ANSYS 14.5 software. From the results, it is observed that the Rectangular Box section is having more strength than *C* and *I* Cross-section type of Ladder Chassis. The Rectangular Box Cross-section Ladder Chassis is having least deflection i.e., 2.96 mm and least Von Mises stress and Maximum Shear stress i.e., 54.31MPa & 5.98MPa respectively for Aluminum Alloy 6063-T6 in all the three types of chassis of different cross section. Finite element analysis is effectively utilized for addressing the conceptualization and formulation for the design stages. Based on the analysis results of the present work, the following conclusions can be drawn.

1) Part is safe under the given loading condition.
2) To improve performance, geometry has been modified which enables to reduce stress levels marginally well below yield limit.
3) The generated Von Mises Stress & Maximum Shear Stress is less than the permissible value so the design is safe for all three materials.
4) Shear stresses were found minimum in Aluminum alloy 6063-T6 and maximum in ASTM A710 steel under given boundary conditions.
5) Von Mises stresses were found minimum in Aluminum alloy 6063-T6 and maximum in ASTM A710 Steel under given boundary conditions.
6) The Rectangular Box Cross-section Type of Ladder Chassis is having least deflection, Von Mises stress and Maximum Shear stress for Aluminum Alloy 6063-T6 in all the three types of materials of three different cross section type of Ladder Chassis.

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