International Research Journal of Engineering and Technology (IRJET) **e-ISSN: 2395-0056**
Volume: 07 Issue: 08 | Aug 2020 **www.irjet.net** **p-ISSN: 2395-0072**

Design & Analysis of Ladder Frame Chassis

Yagyansh Mishra

Dept. of Automobile Engineering, SRM Institute of Science and Technology, Chennai, Tamil Nadu, India

***

Abstract - Automotive chassis is the most important part of any automobile onto which other mechanical parts like engine, wheels, axle assemblies, etc. are mounted. It acts as the backbone of any vehicle. The chassis has to withstand the shocks, vibrations, and any stresses induced in the vehicle. Hence the material and the design of the chassis decide the overall strength and stability of the vehicle. On chassis, maximum shear stress and deflection under maximum load are important criteria for design and analysis. It should be able to withstand these forces without much bending or twisting. In this work, TATA LPT 1618 truck is used to create the chassis with different cross-sections namely – C, I, and Rectangular Box (Hollow) type. The modelled chassis is taken for analysis with materials namely ASTM A710 Steel, ASTM A302 Alloy Steel, and Aluminium Alloy 6063-T6 subjected to the same load. The problem to be dealt with for this dissertation work is to Design and Analyse 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 modelling is done using SOLIDWORKS 2019 and the finite element analysis is done using ANSYS 2019 R3.

Key Words: Ladder chassis; modelling; structural analysis; C, I and Rectangular Box (Hollow) type cross sections; SOLIDWORKS 2019; ANSYS 2019 R3

1. INTRODUCTION

A chassis is a load-bearing framework of an artificial object, which structurally supports the object in its construction and function. Automobile chassis is used to mount the parks like wheels, tires, axle assemblies, suspension, etc. 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. Automobile chassis ensures less noise, vibrations, and harshness throughout the automobile. The chassis frame consists of side members attached with a series of cross members. It also decides the safety level of any vehicle. Along with the strength, an important consideration in 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. Stress analysis using Finite Element Analysis (FEA) can be used to locate the critical point which has the highest stress. This critical point is one of the factors that may cause fatigue failure. Accuracy of this analysis helps in deciding the life span of any chassis frame.

Types of chassis frame:

Cruciform frame:

It is a frame to carry torsion loads where no element of the frame is subject to a torsion moment and is made of two straight beams and a center X shaped cross member. It will only have bending loads applied to the beams. This type of frame has good torsional stiffness provided the joint at the center is satisfactorily designed.

Space frame:

In this type, the suspension, engine, and body panels are attached to a three-dimensional skeletal frame of tubes and the body panels have little or no structural function. To maximize rigidity and minimize weight, the design makes maximum use of triangles and all the forces in each strut are either tensile or compressive, never bending, so they can be kept as thin as possible.

Ladder frame:

It is clear from its name that the ladder chassis resembles a shape of a ladder having two longitudinal rails inter linked by lateral and cross braces. This design offers good beam resistance because of its continuous rails from front to rear, but poor resistance to torsion or warping.

2. OBJECTIVE

The objective of this work is to find the best material and cross-section type for the ladder frame of TATA LPT 1618 truck with the constraints of maximum shear stress, equivalent (von mises) stress, and total deformation under maximum loading conditions. At present, the most common types of ladder frame used for buses and trucks are of C and I section type made up of Steel Alloy. The number of passengers traveling in these commercial vehicles is not fixed in countries like India. Hence, frames must be strong enough to avoid any failure due to high loads. In this work, all the three types of frames based on their cross sections are compared to each other to determine the best type of frame.

3. SOLUTION METHODOLOGY

The solution is done in three steps, namely – Theoretical Analysis, Creating 3-D model, and Finite Element Analysis (FEA).

Theoretical Analysis:
The ladder frame is considered as an overhanging beam with roller supports corresponding to the front and rear wheels. The total load acting on the chassis is taken as the sum of the weight of the engine and body, and capacity of the chassis. The load acting is considered to be uniformly distributed over the beam (UDL). With the concepts of Strength of Materials, the reaction forces, shear forces, and bending moment are calculated.

Creating 3-D model:
The three-dimensional model of the chassis of different cross sections are created in SOLIDWORKS 2019, and then imported to ANSYS 2019 R3 for Finite Element Analysis.

Finite Element Analysis:
There are three main steps involved, namely – pre-processing, solution, and post-processing. Pre-processing includes - defining 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.

The next step is the solution. In this step, the governing algebraic equations in matrix form and the unknown values of the primary field variable(s) are assembled. The computed results are then used by back substitution to determine additional, derived variables, such as reaction forces, element stresses, and heat flow.

In post-processing, the analysis and evaluation of the result are conducted. Examples of operations that can be accomplished include sort element stresses in order of magnitude, check equilibrium, calculate factors of safety, plot deformed structural shape, animate dynamic model behaviour, and produce colour-coded temperature plots.

4. SPECIFICATION OF MATERIAL USED

Property	ASTM A710 Steel	ASTM A302 Alloy Steel	Aluminium Alloy 6063-T6
Mass density (gm/cm^3)	7.85	7.79	2.8
Yield Strength (MPa)	450	340	220
Ultimate Tensile Strength (MPa)	515	590	250
Poisson's ratio	0.29	0.33	0.32
Shear Modulus (GPa)	80	78	26
Young's Modulus (GPa)	205	210	69

Table –1: Properties of Materials used

5. DESIGN CALCULATION FOR CHASSIS

Material and Geometry of TATA LPT 1618 truck

Side bar of the chassis are made from "C" Channels with 285mm x 60 mm x 7 mm

Front Overhang (a) = 1185 mm

Rear Overhang (c) = 1970 mm

Wheel Base (b) = 4225 mm

Modulus of Elasticity, E = 2.10 x 10^5 N / mm2

Poisson Ratio = 0.28

Capacity of Truck = 11.8 tons = 11800 kg = 115758 N

Capacity of Truck with 1.25% = 144697.5 N

Weight of the body and engine = 4.4 ton = 4400 kg = 43164 N

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

= 144697.5 + 43164 = 187861.5 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 beam = 187861.5/2 = 93930.75 N/Beam

A) Calculation for Reaction:

The beam is considered to be simply supported beam, with supports at points C and D and uniformly distributed load.

Load acting on the entire span of the beam = 93930.75 N

Length of the beam = 7380 mm

Uniformly Distributed Load = 93930.75 / 7380

= 12.73 N/mm

For getting the loads at reaction C and D, the moment about C is calculated.

Moment about C:

$12.73\times1185\times1185/2 = (12.73\times4225\times4225/2) - (R_d\times4225) + (12.73\times1970\times5210)$

$R_D = 55701.35$ N

Total load acting on the beam = 93930.75 N

$R_C + R_D = 93930.75$ N

$R_C = 38229.4$ N

B) Calculation of Shear Force and Bending Moment:

Shear Force calculation:

$F_A = 0$ N

$F_C = (-12.73\times1185) + 38229.4$

$= 23144.35$ N

$F_D = (-12.73\times5410) + 55701.35 + 38229.4$

$= 25061.45$ N

$F_B = 0$ N

Bending Moment calculation:

$M_A = 0$ Nmm

$M_C = (-12.73\times1185\times1185)/2$

$= -8937892.125$ Nmm

$M_D = [(-12.73\times5410\times5410)/2] + (38229.4\times4225)$

$= -24772241.5$ Nmm

$M_B = 0$ Nmm

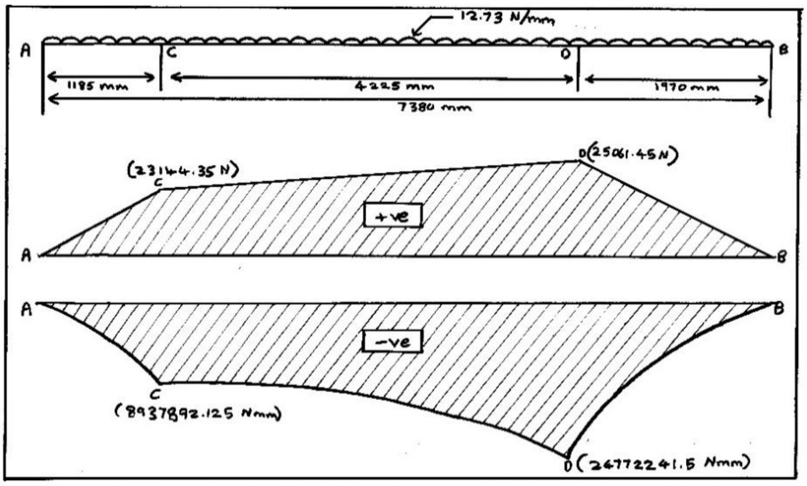
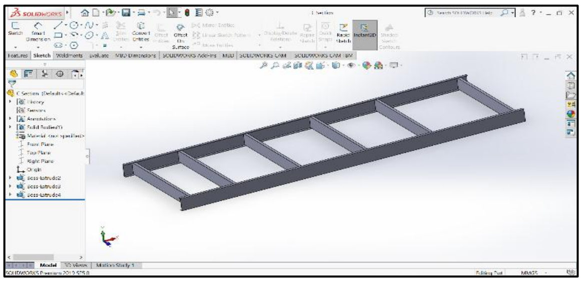


Fig. -1: Loading diagram, SFD & BM

6. MODELLING OF CHASSIS

The models of the existing chassis as per the dimension with different cross-sections are created in SOLIDWORKS 2019. 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. 2(a), 2(b), and 2(c) respectively.



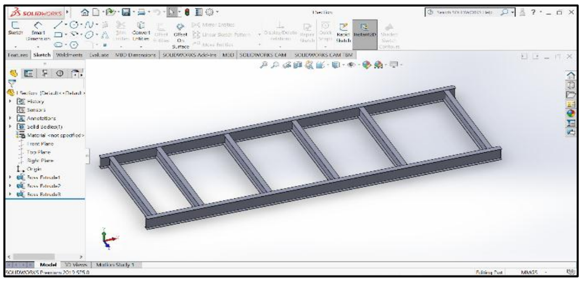


Fig. -2(a): 3-D Model of C Section Ladder Frame
Fig. -2(b): 3-D Model of I Section Ladder Frame

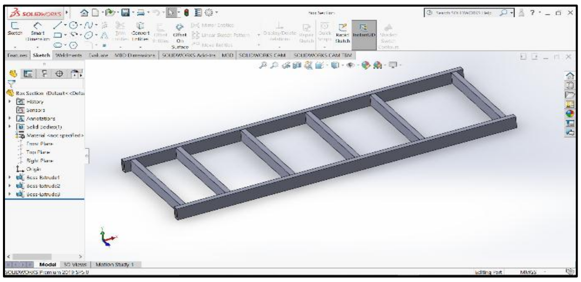


Fig. -2(c): 3-D Model of Box Section Ladder Frame

7. FINITE ELEMENT ANALYSIS OF CHASSIS

This model is saved in IGES format which can be directly imported to ANSYS workbench. An example of C section model been imported to ANSYS workbench is shown in Fig. 3.

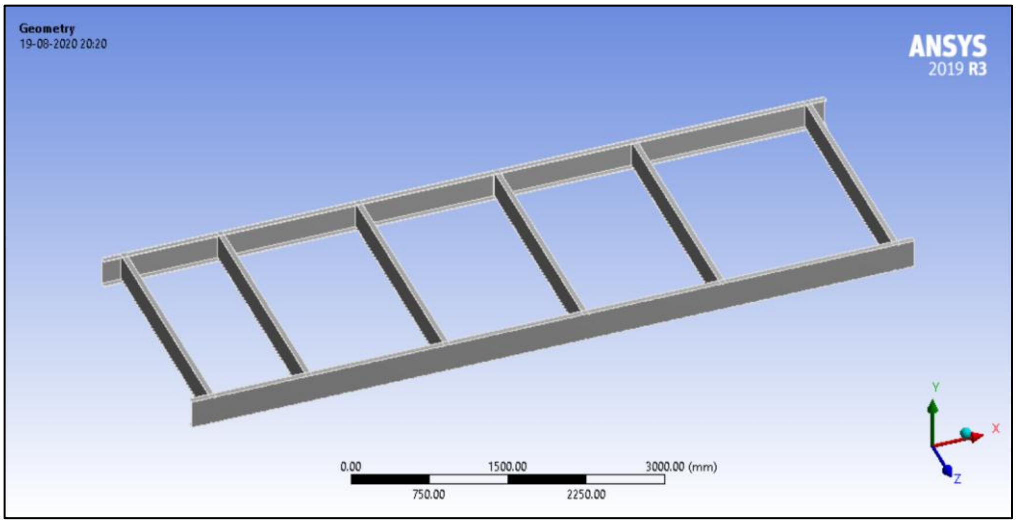


Fig. -3: Model Imported to ANSYS Workbench

A) Meshing:

FEA software typically uses a CAD representation of the physical model and breaks it down into small pieces called finite “elements”. This process is called “meshing”. Higher the quality of the mesh enhanced the mathematical representation of the physical model. The meshing is done on the model using tetrahedral elements. An example of a model been meshed is shown in Fig. 4.

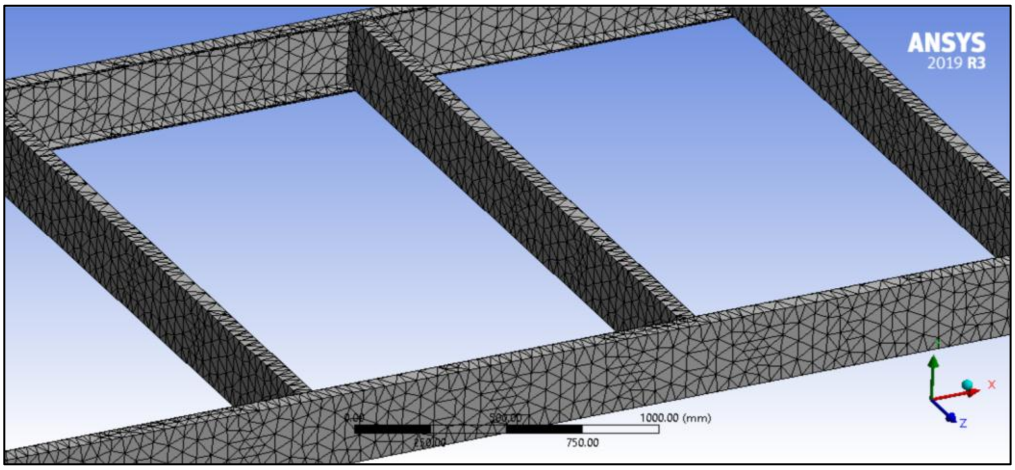


Fig. -4: Meshing of Chassis Frame

B) Loading and Boundary Conditions:

The truck chassis model is loaded by static forces from the truck body and cargo. The magnitude of the force acting on the upper side of the chassis is 187861.5 N. This force is carried by two beams. Hence, the load carried by a single beam is equal to 187861.5/2 = 93930.75 N. An example of load been applied to the chassis is shown in Fig. 5.

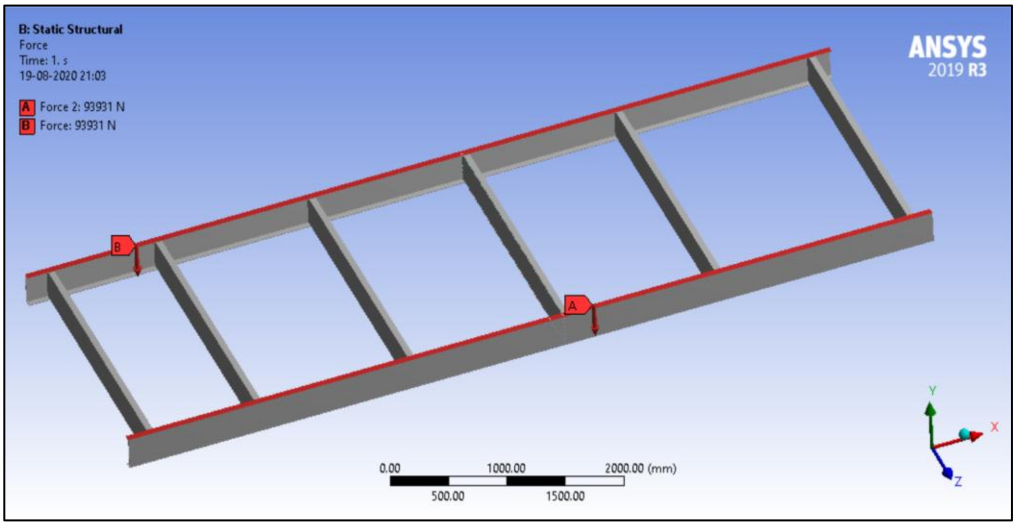


Fig. -5: Load Applied on Ladder Frame

C) Structural Analysis of Ladder Frame:

Structural analysis of the ladder frame with different cross-sections namely, C, I, and Box type was conducted with three different types of materials namely, ASTM A710 Steel, ASTM A302 Alloy Steel, and Aluminum Alloy 6063-T6. The contour plots of Total Deformation, Equivalent (Von-Mises) Stress, and Maximum Shear Stress for different cross-section frame along with three different materials are shown in Fig. 6(a) to Fig. 8(c).

C-1) Structural Analysis of C type cross-section Ladder Frame:

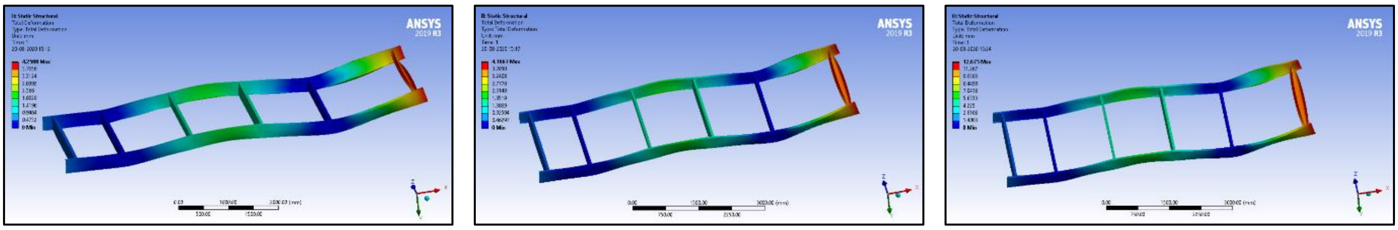


Fig. -6(a): Total Deformation Contour of ASTM A710 Steel, ASTM A302 Alloy Steel, & Aluminium 6063-T6

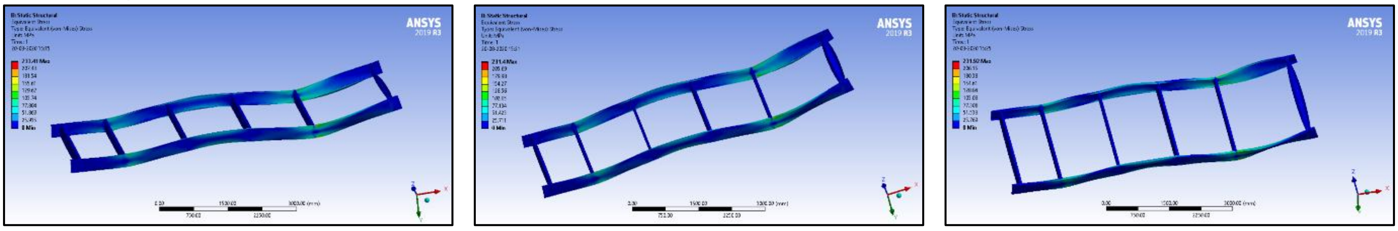


Fig. -6(b): Von-Mises Stress Contour of ASTM A710 Steel, ASTM A302 Alloy Steel, & Aluminium 6063-T6

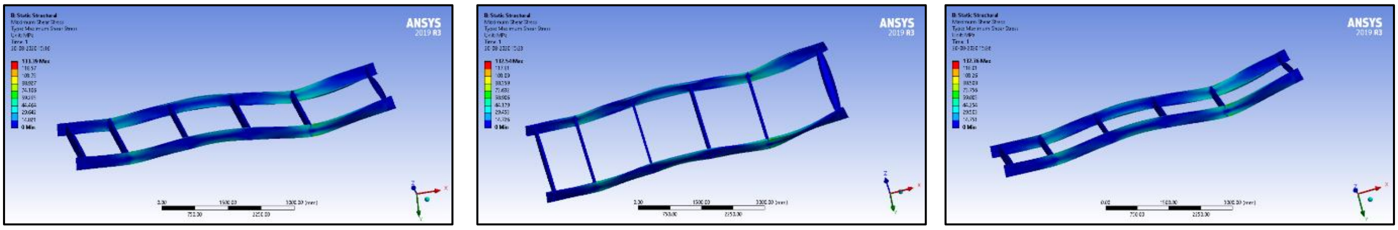


Fig. -6(c): Maximum Shear Stress Contour of ASTM A710 Steel, ASTM A302 Alloy Steel, & Aluminium 6063-T6

C-2) Structural Analysis of I type cross-section Ladder Frame:

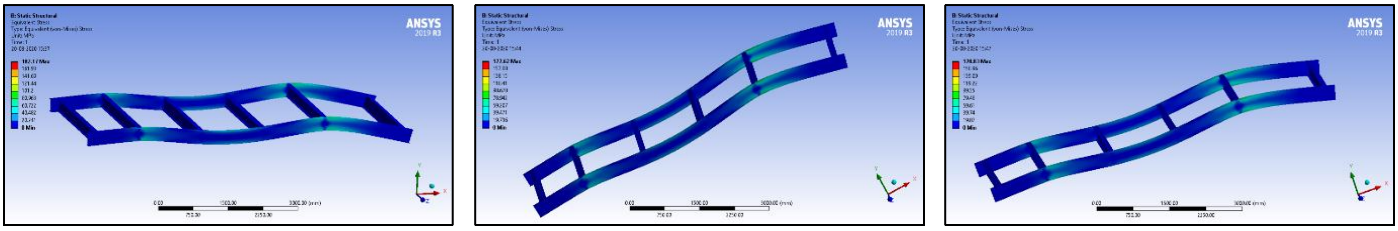


Fig. -7(a): Total Deformation Contour of ASTM A710 Steel, ASTM A302 Alloy Steel, & Aluminium 6063-T6

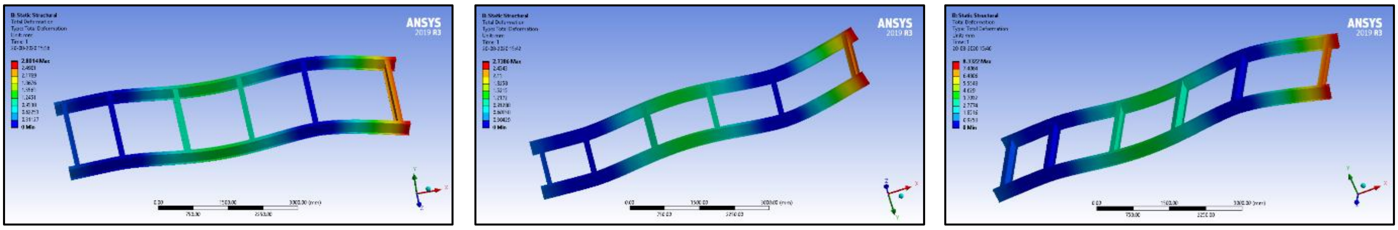


Fig. -7(b): Von-Mises Stress Contour of ASTM A710 Steel, ASTM A302 Alloy Steel, & Aluminium 6063-T6

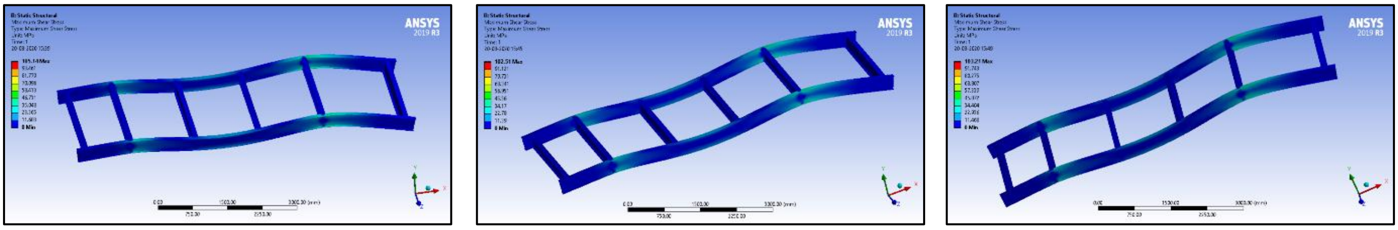


Fig. -7(c): Maximum Shear Stress Contour of ASTM A710 Steel, ASTM A302 Alloy Steel, & Aluminium 6063-T6

C-3) Structural Analysis of Box (Hollow Rectangular) type cross-section Ladder Frame:

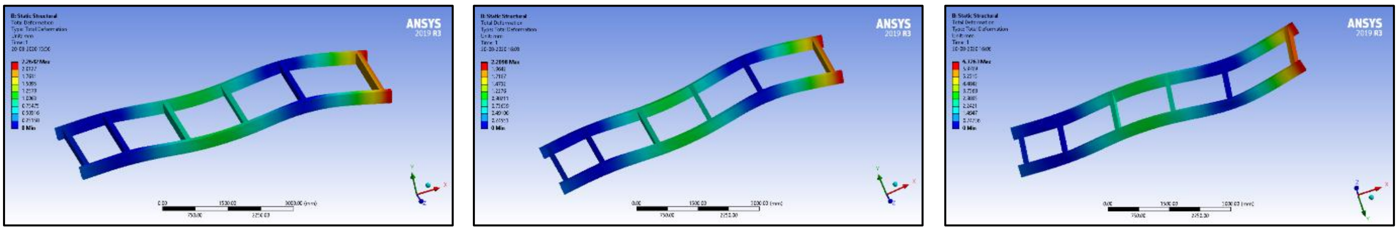


Fig. -8(a): Total Deformation Contour of ASTM A710 Steel, ASTM A302 Alloy Steel, & Aluminium 6063-T6

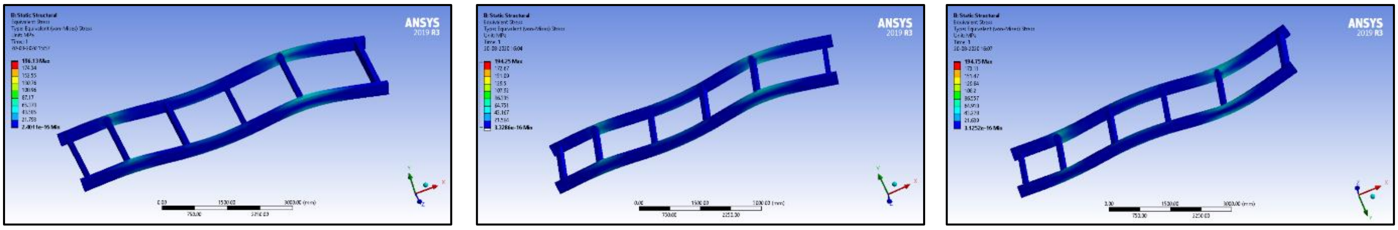


Fig. -8(b): Von-Mises Stress Contour of ASTM A710 Steel, ASTM A302 Alloy Steel, & Aluminium 6063-T6

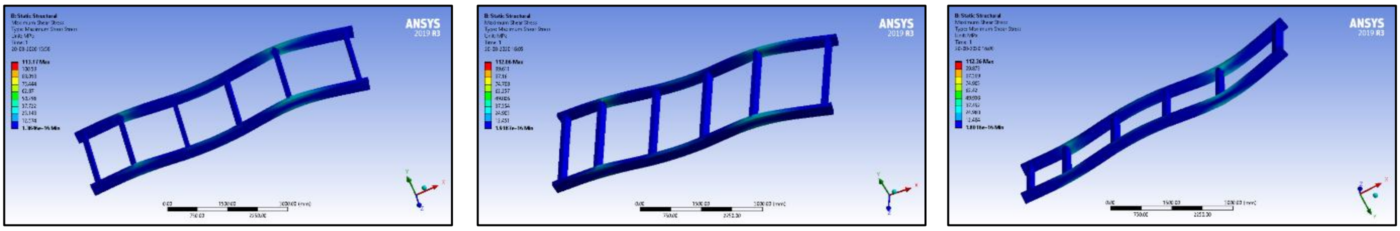


Fig. -8(c): Maximum Shear Stress Contour of ASTM A710 Steel, ASTM A302 Alloy Steel, & Aluminium 6063-T6

8. RESULTS

A) Results for C type cross-section Ladder Frame:

Material	Total Deformation (mm)	Von-Mises Stress (MPa)	Maximum Shear Stress (MPa)
ASTM A710 Steel	4.2588	233.41	133.39
ASTM A302 Alloy Steel	4.1667	231.4	132.54
Aluminium 6063-T6	12.675	231.92	132.76

Table -2: Results for C type cross-section

B) Results for I type cross-section Ladder Frame:

Material	Total Deformation (mm)	Von-Mises Stress (MPa)	Maximum Shear Stress (MPa)
ASTM A710 Steel	2.8014	182.17	105.14
ASTM A302 Alloy Steel	2.7386	177.62	102.51
Aluminium 6063-T6	8.3322	178.83	103.21

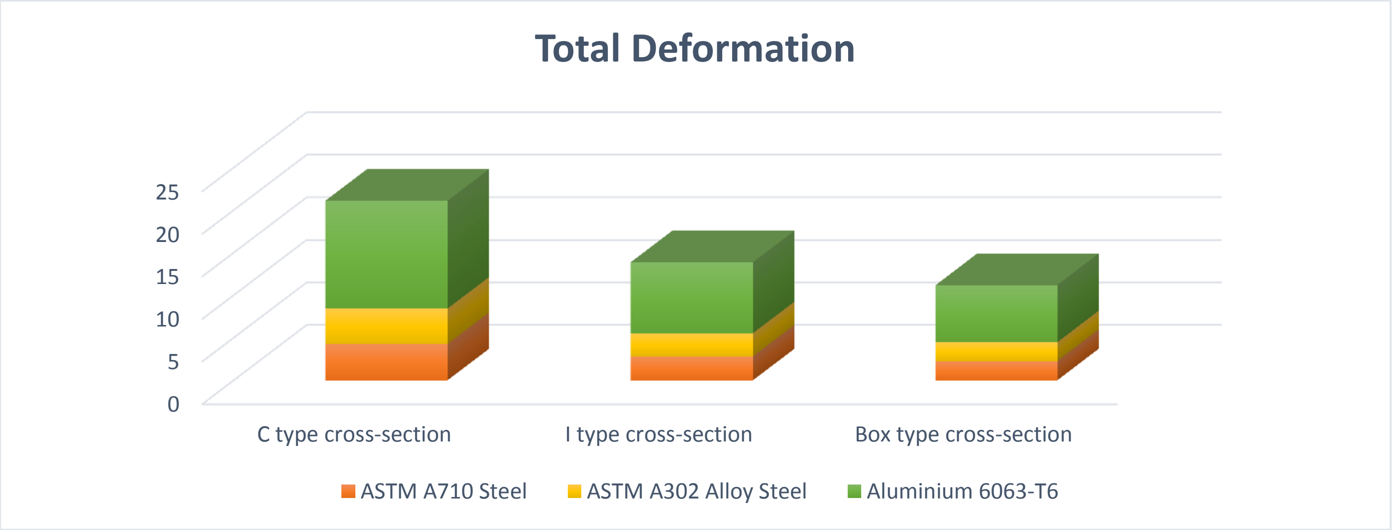
Table -3: Results for I type cross-section

C) Results for Box (Hollow Rectangular) type cross-section Ladder Frame:

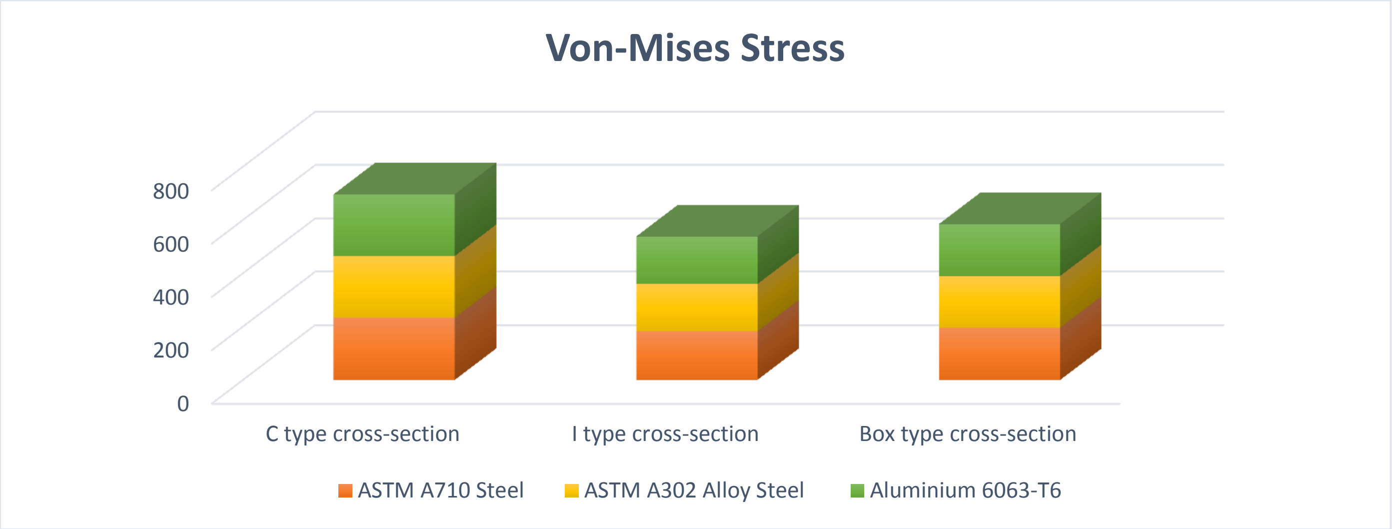
Material	Total Deformation (mm)	Von-Mises Stress (MPa)	Maximum Shear Stress (MPa)
ASTM A710 Steel	2.2642	196.13	113.17
ASTM A302 Alloy Steel	2.2098	194.25	112.06
Aluminium 6063-T6	6.7263	194.75	112.36

Table -4: Results for Box type cross-section

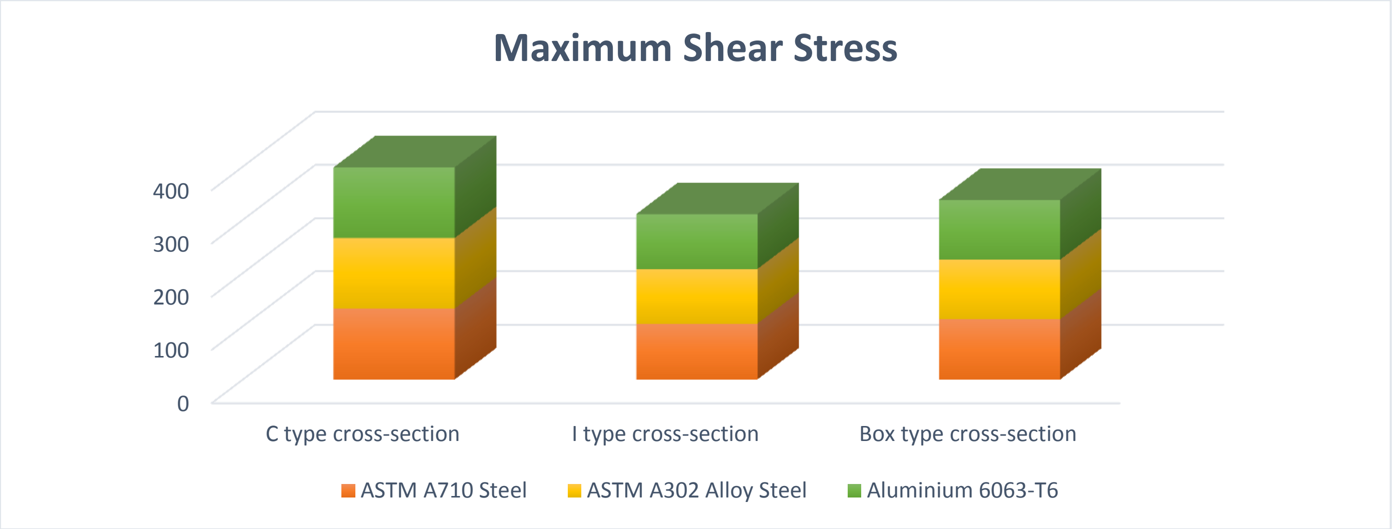
D) Graph for Total Deformation, Von-Mises Stress & Maximum Shear Stress:



Graph -1: Graph representing Total Deformation for different cross-section type & material



Graph -2: Graph representing Von-Mises Stress for different cross-section type & material



Graph -3: Graph representing Maximum Shear Stress for different cross-section & material

9. Conclusions

In the present work, the ladder-type chassis frame for TATA LPT 1618 truck was analysed using ANSYS 19 R3 software. From the results, it is observed that Box type cross-section has more strength than the C and I type cross-section ladder frame. The least Von-Mises Stress and Maximum Shear Stress are for Aluminium 6063-T6 for all the three types of the cross-section. Finite Element Analysis is effectively utilized for addressing the conceptualization and formulation of the design stages. Based on the analysis results of the present work, the following conclusions can be drawn:

1) The generated shear stresses are less than the permissible value so the design is safe for all the three materials.
2) Shear stresses were found maximum in ASTM A710 Steel and minimum in Aluminium 6063-T6 under given boundary conditions.
3) The total deflection was found maximum in Aluminium 6063-T6 and minimum in ASTM A302 Alloy Steel under given boundary conditions.
4) The least deflection is found to be in Box cross-section type of ladder frame.

References

[1] Francis, Vishal, et al. "Structural analysis of ladder chassis frame for jeep using ansys." International Journal of Modern Engineering Research 4 (2014): 41-47.

[2] Kumar, A. Hari, and V. Deepanjali. "Design & analysis of automobile chassis." International Journal of Engineering Science and Innovative Technology (IJESIT) 5.1 (2016): 187-196.

[3] Contractor, Amar R., Gaurav P. Rathod, and Tushar M. Patel. "Design and analysis of ladder frame chassis considering support at contact region of leaf spring and chassis frame." IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) 12.2 (2005): 63-71.

[4] Patil, Kamlesh Y., and Eknath R. Deore. "Stress analysis of ladder chassis with various cross sections." IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) 12.4 (2015): 111-116.

[5] Singh, Abhishek, Vishal Soni, and Aditya Singh. "Structural analysis of ladder chassis for higher strength." International Journal of Emerging Technology and Advanced Engineering 4.2 (2014): 253-259.