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MODELING AND STATIC STRUCTURAL ANALYSIS OF CRANE TRUCK CHASSIS FRAME BY USING FINITE ELEMENT METHOD

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ABSTRACT

Chassis is the French word was used to denote the frame parts or main structure of vehicle, which is now, denotes the whole vehicle except body in case of heavy vehicles (that is vehicle without body is called chassis). In case of light vehicles of mono construction, it denotes the whole vehicle except additional fittings in the body. Automobile chassis usually refers to the lower body of the vehicle including the tires, engine, frame, driveline and suspension. Out of these, the frame provides necessary support to the vehicle components placed on it. Role of the chassis frame is to provide a structural platform that can connect the front and rear suspension without excessive deflection. Also, it should be rigid enough to withstand the shock, twist, vibration and other stresses caused due to sudden braking, acceleration, shocking road condition, centrifugal force while cornering and forces induced by its components. So, strength and stiffness are two main criteria for the design of the chassis. The present study has analyzed the various literatures. After a careful analysis of various research studies conducted so for it has been found that there is the scope of optimizing different factors like weight, stress-strain values and deformation etc. by varying cross sections for modeling and analysis. This paper describes the design and Structural analysis of the heavy vehicle chassis with constraints of maximum stress, strain and deflection of chassis under maximum load. In the present work, the dimension of he TATA 2518TC chassis is used for the structural analysis of the heavy vehicle chassis by considering three different cross-sections, Namely C, I, and Hollow Rectangular (Box) type cross sections subjected to the same conditions. A three dimensional solid Modeled in the CAE software SOLIDWORKS and analyzed in ANSYS. The numerical results are validated with analytical calculation considering the stress distribution and deformation.

KEYWORDS: *Heavy truck chassis frame, SOLIDWORKS, ANSYS, FEM, Assembly weight, stress, deformation*

INTRODUCTION TO CRANE TRUCK CHASSIS

The major challenge in today's ground vehicle industry is to overcome the increasing demands for higher performance, lower weight, and longer life of components, all this at a reasonable cost and in a short period of time.

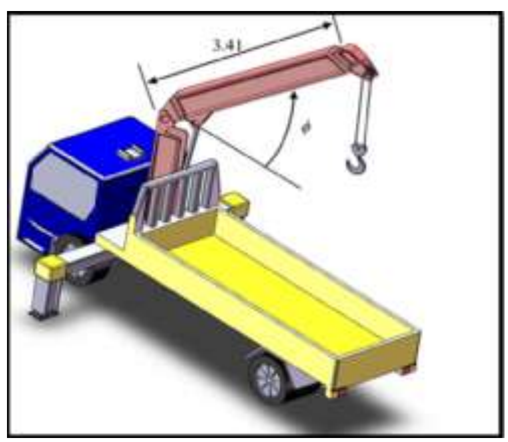

Figure 1 truck mounted crane

Industrial Engineering Journal
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The chassis of trucks is the backbone of vehicles and integrates the main truck component systems such as the axles, suspension, power train, cab and trailer. Since the truck chassis is a major component in the vehicle system, it is often identified for refinement. There are many industrial sectors using this truck for their transportations such as the logistics, agricultures, factories and other industries.

TYPES OF CHASSIS

- **LADDER FRAME CHASSIS LADDER CHASSIS**
  This is considered to be one of the oldest forms of automotive chassis or automobile chassis that is still been used by most of the SUVs till today. It is also resembles a shape of a ladder which having two longitudinal rails inter linked by several lateral and cross braces.

Figure 2 ladder frame chassis ladder chassis

- **BACKBONE CHASSIS**
  The other type of chassis is backbone chassis which has a rectangular tube-like backbone and simple in structure. It usually made up of glass fiber that is used for joining front and rear axle together and responsible for most of the mechanical strength of the framework. The space within the structure is used for positioning the drive shaft in case a rear-wheel drive. This type of chassis is strong enough to provide support smaller sports car besides it is easy to make and cost effective.
- **MONOCOQUE CHASSIS**
  As for monocoque chassis, most modern cars now a days use this type of chassis. A monocoque chassis is a single piece of framework that gives shape to the car. A one-piece chassis is built by welding several pieces together. It is different from the ladder and backbone chassis as unlike them incorporated with the body in a single piece, whereas the former only support the stress members. The demanding of a monocoque chassis highly increased since it is cost effective and suitable for robotized production.

Figure 3 monocoque chassis

Figure 4 tubular space frame chassis

LITERATURE REVIEW

Literature Survey Many researchers carried out study on truck chassis as follows:

PATEL ET AL [1]have investigated and optimized a chassis design for Weight reduction of TATA 2516TC chassis frame using Pro-Mechanical. Thy first find out the assembly weight, maximum stress, strain and displacement for the existing section of chassis by using ANSYS Software after then they modified the dimensions of existing C-sections and again find all and concluded that the existing "C" sections is better than all the sections with respect to the Stress, Displacement, Strain and Shear stress except the weight. For the weight consideration modified "C" section has less weight than the all sections which are studying in this paper. Finally, By the use of modified "C" section, 105.50 Kg (11 %) weight is saved per chassis assembly and in same manner cost may also be reduced approximately 11%. From the results, modified "C" sections are used as an optimized section.

MURALI ET AL [2]have investigated the critical point which has the highest stress using Finite Element Method (FEM). This critical point is one of the factors that may cause the fatigue failure. For the modifications and analysis, the existing truck chassis were added with stiffeners. Initially the thickness of the model, where the maximum deflection occurs in bending analysis was increased to certain value with acceptable limit. And one more cross beam was added at the center of the wheel base to add stiffness to the model. Series of modifications and tests were conducted by adding the stiffener in order to strengthen and improved the chassis stiffness as well as the overall chassis performances.

S. PRABAKARAN AND K. GUNASEKAR [3] have studies the Structural Analysis of EICHER E2 (or 11.10) Chassis Frame for the existing C-section. They first find out the assembly weight, maximum shear stress, maximum equivalent stress and displacement for the existing C-section of chassis by using SOLID WORKS and ANSYS Software and then they modified the existing C-section taking three different cases and find out the parameters for all cases. They have investigated that the weight, maximum shear stress, maximum equivalent stress and displacement for the third case are reduced respectively 6.68%, 12.14 %, 8.55 % and 11.20 %. So, they concluded that by using FEM software we can optimize the weight of the chassis frame and it is possible to analyze modified chassis frame before manufacturing.

B. RAMANA NAIK AND C. SHASHIKANTH [4]have objective to analyze an automobile chassis for a 10-ton vehicle. The modeling is done using Pro-E, and analysis is done using ANSYS. The overhangs of the chassis are calculated for the stresses and deflections analytically and are compared with the results obtained with the analysis software. Modal Analysis is also done to find the natural frequency of the chassis and seen that it is above than its excitation frequency. The Theoretical calculations and FE analysis results are compared and it is observed that they are within the material properties. This frequency is more than 4 times the highest frequency of the excitation (i.e., 33 Hz) hence the chassis can faithfully transmit the input excitation to the vehicle body without any amplification.

KAMLESH Y. PATIL AND EKNATH R. DEORE [5]have studies the Ladder Chassis frame of TATA 912 Diesel Bus and the model of the chassis was created in Pro-E and analyzed with ANSYS for Various Cross Sections for same load conditions. They observed that the Rectangular Box (Hollow) section is more strength full than the conventional steel alloy chassis with C and I design specifications. The Rectangular Box (Hollow) section is having least deflection i.e., 2.683 mm and stress is 127 N/mm2 in all the three types of chassis of different cross section.

PROBLEM FORMULATION

The present study has analyzed the various literatures. After a careful analysis of various research studies conducted so for it has been found that there is the scope of optimizing different factors like weight, stress-strain values and deformation etc. by varying cross sections for modeling and analysis. This paper describes the design, Structural analysis & optimization of the heavy vehicle chassis with constraints of maximum stress, strain and deflection of chassis under maximum load. Our work is to design and analyze the heavy vehicle chassis to reduce weight, stress strain values and deformation etc...

OBJECTIVES OF PROPOSED WORK

In the present work, the dimension of the TATA 2518TC chassis is used for the structural analysis of the heavy vehicle chassis modeled by considering three different cross-sections, namely C, I, and Rectangular Box (Hollow) type cross sections subjected to the same condition. A three dimensional solid Modeled in the CAE software SOLIDWORKS and analyzed in ANSYS 18.0. The numerical results will be validated with analytical calculation considering the stress distribution, deformation.

METHODOLOGY FOR MODELING AND ANALYSIS

A three-dimensional solid Model of the TATA 2518TC chassis modeled in the CAE software SOLIDWORKS and the analysis done in ANSYS.

The procedure of modeling and analysis consists of:

1. Collection of the dimensions of TATA LPT 2518 TC chassis frame.
2. Design of three different Computer Models of chassis frame using SOLIDWORKS for different cross sections C, I and Box.
3. Each model implemented in ANSYS for FE Analysis for different parameters like: ‘stress’ and ‘deformation’ etc.
4. Checking all parameters whether they are within permissible limit or not for selected materials.
5. Optimization and Validation of result.
6. Final results and Conclusions.

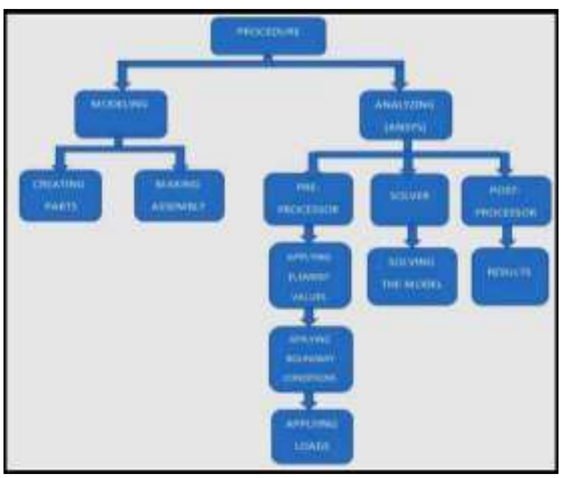

Figure 5 methodology flow chart

SPECIFICATION

Specification of Existing Heavy Vehicle TATA LPT 2518 TC Truck Chassis frame

S. No.	Parameters	Value
1	Total length of the chassis	9010 mm
2	Width of the chassis	2440 mm
3	Wheel Base	4880 mm
4	Front Overhang	1260 mm
5	Rear Overhang	2155 mm
6	Ground Clearance	250 mm
7	Capacity (GVW)	25 ton
8	Kerb Weight	5750 Kgs
9	Payload	19250 Kgs

Table 1 sepcifications of TATA LPT 2518 TC truck chassis frame

ANALYTICAL CALCULATIONS

- Side bar of the existing chassis frame are made from “C” Channels with Height (H) = 285 mm, Width (B) = 65mm, Thickness (t) = 7 mm
- Basic Calculation for Chassis
- Frame Model No. = LPT 2518 TC (TATA)
- Capacity of Truck = 25 ton (Kerb Weight+ Payload) = 25000 kg = 245250 N
- Capacity of Truck with 1.25% = 245250 * 1.25 N = 306562 N
- Total Load acting on the Chassis = 306562 N
- All parts of the chassis are made from “C” Channels with 285mm x 65mm x 7mm.
- Each Truck 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 = Total load acting on the chassis / 2 = 306562 /2 =153281 N / Beam
- Loading Conditions 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 153281 N. Length of the Beam is 9010 mm.
- Uniformly Distributed Load is 153281 / 9010 = 17.0 N/mm

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MATERIAL AND PROPERTIES

Currently the material used for the chassis (TATA 2518TC) is as per IS: - 9345 standard is **structural steel with St 37**. Structural steel in simple words with the varying chemical composition leading to changes in names.

The typical **chemical composition** of the material is:

0.565%C	*1.8% Si*	*0.7%Mn*	*0.045%P*	*0.045%S*

The rapid development of the industry at the present time especially the machinery industry also spurs the development of basic material manufacturing technology such as steel. Given these conditions, sufficient mechanical properties, so that the lifespan can be increased. To overcome this, engine components are usually treated by heat treatment. St 37 steel equivalent to AISI 1045 with chemical composition 0.5% C, 0.8% Mn, and 0.3% Si, is one of the steels produced for the manufacture of various machining components. the mechanical properties of St 37 steel are subjected to heat treatment process by Carburizing. One of the surface hardening processes is solid carburization, which aims to increase the carbon content (C) coated steel surface to obtain greater hardness of surface hardness from the inside. The solid carburizing process can result in improved mechanical properties of machining components such as:

1. Increased surface hardness.

2. Increased wear resistance to contact surfaces.

The alloy steel is a steel formed in accordance with the intended purpose for improving the mechanical properties or the nature of the steel in accordance with the base element of the steel. In alloy steel is divided into 2 types, namely: Low alloy steel (special alloy element 8.0%)) St Steel Characteristics (AISI 1045) St 37 steel is mild steel which is equivalent to AISI 1045, with the chemical composition of Carbon: 0.5%, Manganese: 0.8%, Silicon: 0.3% plus other elements. By hardness ±170 HB and tensile strength 650 -800 N / mm2. Generally, St 37 steel can be used directly without heat treatment, unless special use is required.

PHYSICAL PROPERTY OF THE ST37: -

- Modulus of Elasticity = 210 GPa = 2.10 x 105 N / mm2
- Density = 7850 kg/m3
- Ultimate Tensile Strength = 460 MPa = 460 N / mm2
- Yield Strength = 260 MPa = 260 N / mm2
- Poisson Ratio = 0.29

DESIGN METHOD:

Before you actually design the model, it is helpful to plan out a method of how to create the model. After you identify needs and isolate the appropriate concepts, you can develop the model.

- **Sketch:** Create the sketches and decide how to dimension and where to apply relations.
- **Features:** Select the appropriate features, such as extrudes and fillets, determine the best features to apply, and decide in what order to apply those features.
- **Assemblies:** Select the components to mate and the types of mates to apply.

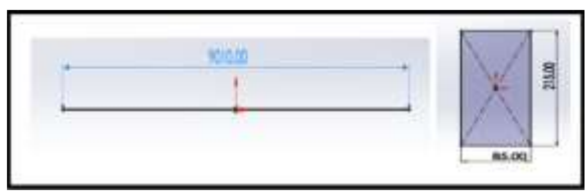

Figure 6 dimensions of guide cureve and profile for beam

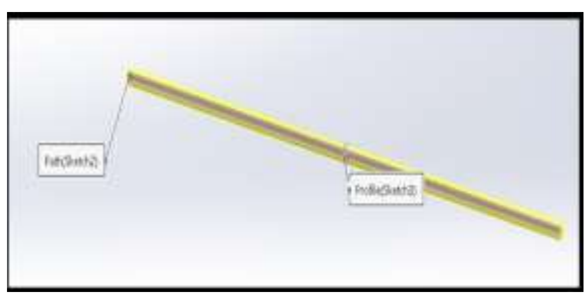

Figure 7 swept boss feature main beam

Industrial Engineering Journal
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CHASSIS FRAME CROSS SECTIONS

To appreciate the design and construction of a vehicle's chassis an understanding of the operational environment is necessary. Once the operating conditions are known, a comparison of the different available chassis-member cross section shapes can be made. The flowing sections examine and illustrate the basic requirements of the chassis.

1. **"C"-Channel sections:**
   It has good resistance to bending, used in long section of the frame

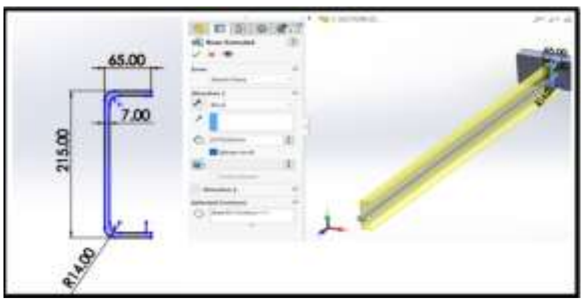

Figure8 dimensions of c-section cross member

Figure 9 isometric view of c-section cross member

2. **"I"- Sections:**
   It has good resistance to both bending and torsion. Due to clamping reason generally "I" section is not used for the practical use.

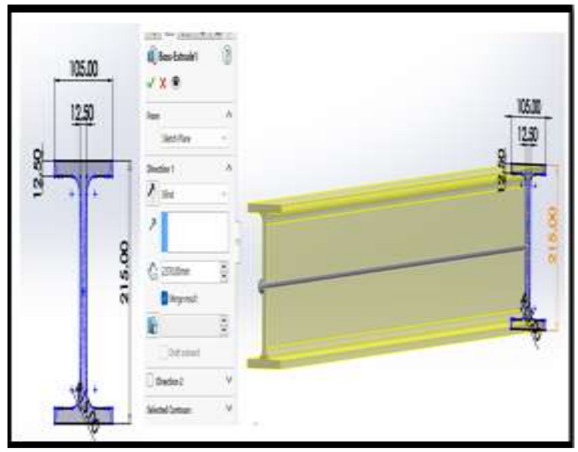

Figure 10 dimensions of i section

Figure 11 dimensions of i-section cross member

3. **Box/Hallow sections**
   It has good resistance to both bending and torsion, used in short members of frames

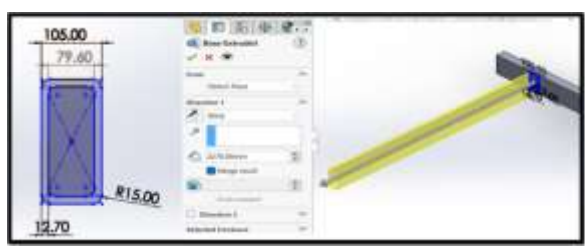

Figure 12 dimensions of hallow section cross member

Figure 13 isometric view of hallow-section cross member

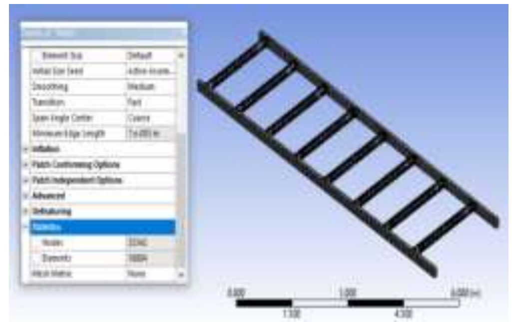

Figure 14 meshing nodes:33342 elements:16804

STATIC STRUCTURAL ANALYSIS

The static structural analysis calculates the stresses, displacements, strains, and forces in structures caused by a load that does not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that the loads and the structure's response are assumed to change slowly with respect to time. A static structural load can be performed using the ANSYS WORKBENCH solver. The types of loading that can be applied in a static analysis.

MESHING

At this point ANSYS understands the makeup of the part. Now define how the modeled system should be broken down into finite pieces. A meshing plan was determined to outline a continuous mesh. Using planar shell elements, the finite elements were meshed from all the geometric 2D surfaces of each component into their correspondingfinite element component. The elements used for the meshing were 2D higher order triangle or quadrilateral elements. The uses for these elements were in the calculations of plane strain and plane stress. This choice of element provides information on local stress and strain for thin walled structures, such as the ladder frame. The meshed model of chassis frame.

BOUNDARY CONDITIONS

Loads and boundary conditions are used to create loading and testing parameters needed to simulate realistic driving conditions of the vehicle. These will be used to simulate driving cases such as driving over potholes, bumpy roads, aggressive cornering and large accelerations (including braking). The constraints of the model depend on both the connectivity of the vehicle components and the particular loading case. For this model the total load acting on chassis frame is 306562 N.

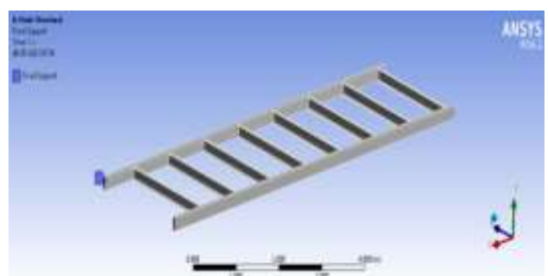

Figure 15 fixed support blue tag

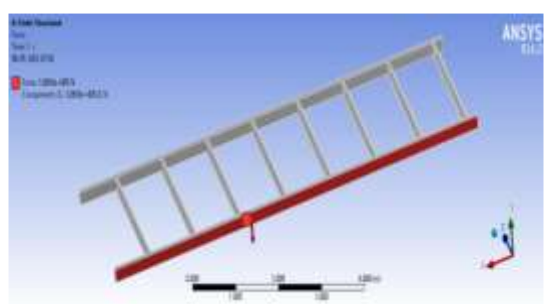

Figure 16 load acting on beams red tag

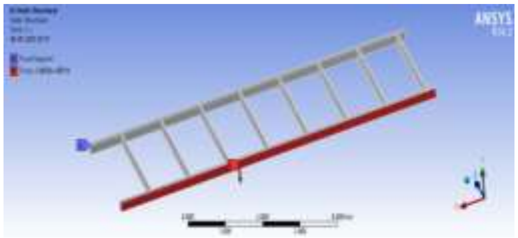

Figure 17 boundary conditions

RESULTS AND DISCUSSION

The followin are the ANSYS simulation results of C Section, I Section and Rectangular box/hallow sections in Static structural analysis. In Static structural analysis we are observing the toatal displacements of beams, Stress distributions as well as factor of safety of individual members.

STRUCTURAL ANALYSIS OF "C"- SECTION

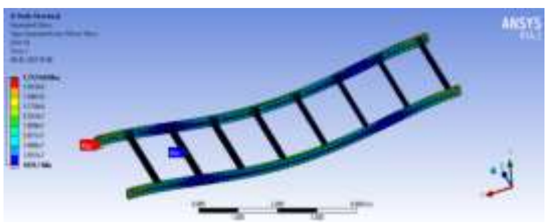

Figure 18 stress distributions in "c"- section

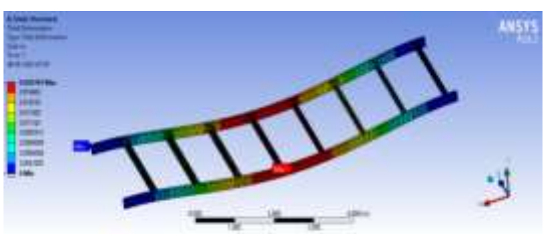

Figure 19 displacement pattern in "c"- section

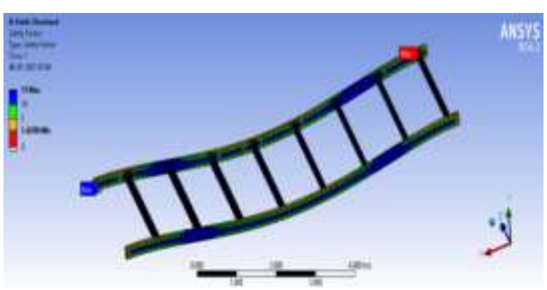

Figure 20 safety factor of "c"- section

STRUCTURAL ANALYSIS OF "I"- SECTION

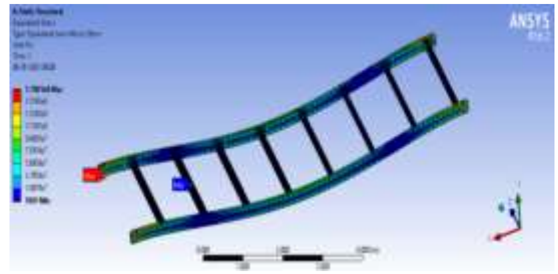

Figure 21 stress distributions in "i"- section

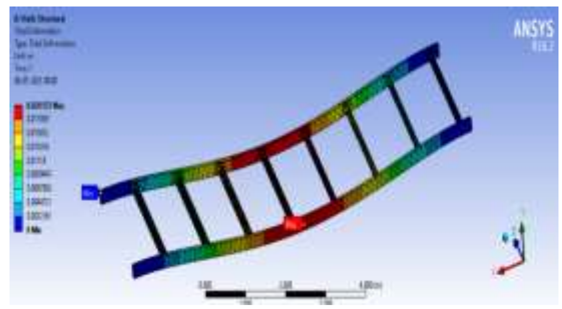

Figure 22 displacement pattern in "i"- section

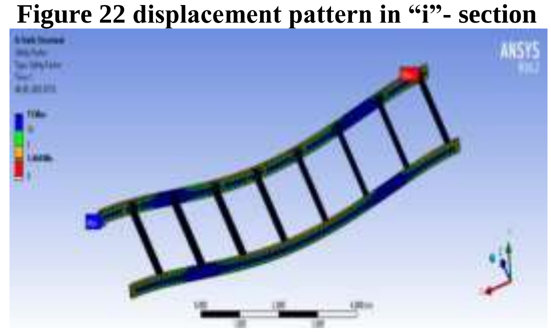

Figure 23 safety factor of "i"- section

STRUCTURAL ANALYSIS OF "HALLOW"- SECTION

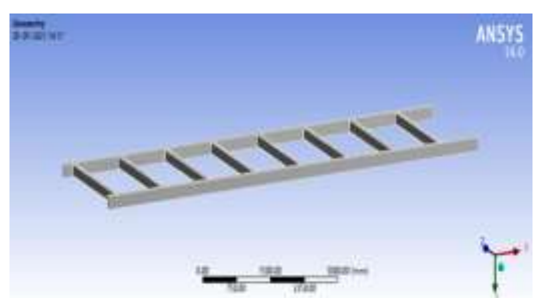

Figure 24 geometric model of hallow-channel section

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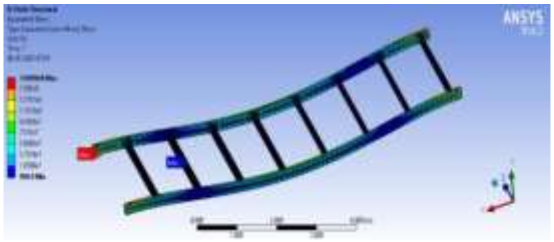

Figure 25 stress distributions in "hallow"- section

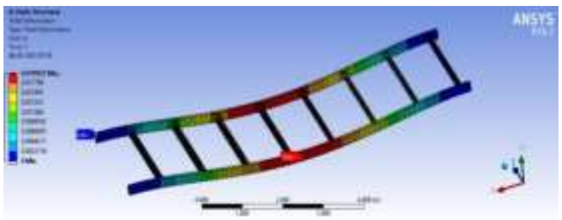

Figure 26 displacement pattern in "hallow"- section

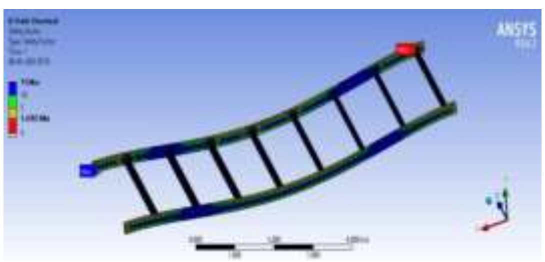

Figure 27 safety factor in "hallow"- section

RESULTS AND DISCUSSION

The stress distribution and deformation pattern for the C-channel cross section .The safety factor, stress distribution and deformation pattern for the I-Cross section is depicted. The stress distribution and deformation pattern for the Box-Cross section is depicted are tabulated as below.

Section/Parameter	Stress (N/mm2)	Deformation(m)	Safety factor
C	1.75e8	0.0207	1.429
I	1.70e8	0.0201	1.444
HALLOW	1.69e8	0.0199	1.478

Table 2 static structural results

From the results, it is observed that the Rectangular Box (Hollow) section is more strength full than the conventional steel alloy chassis with C and I design specifications. The Rectangular Box (Hollow) section is having least deflection i.e., 0.0199 m, factor of safety to be 1.478 and stress is 1.69e8 N/mm2 in all the three types of chassis of different cross section.

CONCLUSION

The existing heavy vehicle chassis of TATA 2518 TC is taken for design and analysis with different cross sections. The model of the chassis was created in SOLIDWORKS and analyzed with ANSYS 18.0 for same load conditions. After analysis a comparison is made between chassis section and other sections in terms of deformation and stresses, to select the best one. From the results, it is observed that the Rectangular Box (Hollow) section is more strength full than the conventional steel alloy chassis with C and I design specifications. The Rectangular Box (Hollow) section is having least deflection i.e., 0.0199 m and stress is 1.69e8 N/mm2 in all the three types of chassis of different cross section. The factor of safety of Hallow section having a better value of 1.478. So, in different cross sections of the chassis box-section chassis is suitable for the heavy trucks. Finally, the analysis using different cross sections has been successfully accomplished. The work not only provides an analysis of the chassis but also presents the scope for its modification in actual. Also, the optimized chassis is capable to carry the loads beyond the previous payload.

FUTURE SCOPE

Research In future, for this heavy vehicle future research might attempt to consider different materials of chassis frame and considering different parameters such as:

- Normal strain, shear strain, shear stress, thermal stress, strain energy, stiffness (both bending and torsion) and fatigue life etc.
- Some other analysis would be done like: Modal analysis and fatigue failure analysis etc.

- Also, the chassis frame would be optimized by modifying the dimensions of chassis frame cross sections.

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