INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & MANAGEMENT

STRESS AND WEIGHT ANALYSIS OF LADDER FRAME OF LIGHT DUTY TRUCK

Akshay Jain[1] and Mr G.V.R. Seshagiri Rao[2]
[1](P.G. Student of Mechanical Engineering Dept. BM College of Technology, Indore (M.P.))
[2](Head of Mechanical Engineering Department BM College of Technology, Indore (M.P.))

ABSTRACT
Automobile chassis can be considered as the backbone of any vehicle. Chassis tasked is to hold all the essential components of the vehicle. Chassis should bear less stress and also light in weight to reduce dead weight on the vehicles. This dissertation is aimed to produce result to rectify problem associated with structures of a commercial vehicle such as strength and deflection properties along with stress.This can be achieved by static analysis of chassis of different thickness and height using Finite Element Method (FEM).The work shows the possibility of reducing stress developed in the chassis frame with in desired load carrying capacity and increase load carrying capacity by decreasing maximum stress and deflection in the critical area of chassis frame design in early design stages. This although will not give exact solution but can give a near optimal initial design of chassis frame, thus reducing the effort for optimization during the detailed design phase. This study aimed to static load analysis of the chassis of "TATA SUPER ACE" by using ANSYS 16.0 workbench for different thickness and height of chassis frame.
KEYWORDS: design variables, performance criteria, chassis frame, stress analysis, Finite Element Analysis, Weight Optimization

INTRODUCTION
In the era of globalization, the customers are becoming more conscious about quality, life and performance of the equipment. The market is growing but simultaneously competition is also increasing.The chassis structure is the major component in the any automobile vehicle. The vehicle shape and loading capacity dependent on this chassis. Here is the chassis of "TATA SUPER ACE "ladder frame type is studies which has two longitudinal members of C-cross section and five transverse members as cross members of box cross section. The chassis has been modeled in PRO-E (CREO 3) using the most of the actual dimensions. FEM analysis was done using ANSYS 16 workbench. Finite Element Method (FEM) can be used to the magnitude of the stress can be used to decide loading capacity and also predict the life span of the truck chassis. The accuracy ofprediction life of truck chassis is depending on the result of its stress analysis.
Aim of this work to decrease the magnitude of maximum stress by varying thickness and height of the chassis frame so that we can increase load carrying capacity of the light duty truck and minimization in weight for a fixed permissible stress limit.

NEED AND SCOPE OF THE THESIS
Light duty truck is one of the most common ways to transport day to day product in the city so to increase pay load capacity, stress on the Light duty truck chassis should be minimum. The frame studied in this work is a simple ladder frame with two long members and five cross members. The frame is simplified for the sake of convenience in analysis. It is having its structure close to actual frame. In this project for studied of chassis (TATA SUPER ACE) a light duty truck is selected, Models are prepared in PRO-E (CREO 3) and then optimization is performed on their actual frame dimension by ANSYS 16.0. With varying chassis cross section dimension and thickness.

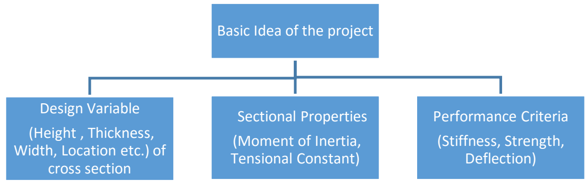


Figure: Basic design criteria of the project

METHODOLOGY

To achieve the objectives of the study the following steps are used.

- Literature review: Survey of books, journal articles, research papers, standard and other relevant literature is carried out.
- Analytical method: Analytical method is used to verify stress and deflection on the chassis result under similar loading condition.
- Modeling: 3D Modeling is done using PRO-E (CREO 3.0).
- Analysis: Modal analysis is done for Static stress analysis using ANSYS 16.0 to find stress and deformation pattern.
- Conclusion and future scope.

STRUCTURAL ANALYSIS OF EXISTING CHASSIS

Here the chassis of TATA super ace is of ladder frame type which has two side members or longitudinal members of C- cross section and five transverse members called cross members of box cross section. The chassis has been modelled in PRO-E (CREO 3.0) using the most of the actual dimensions. FEM analysis was done using ANSYS 16 workbench.

CHASSIS SPECIFICATIONS

Length of vehicle= 4340 mm
Width of vehicle = 1565 mm
Height of vehicle = 1858 mm
Wheelbase = 2380 mm
Track width = 1320 mm
Material of chassis = structural steel
Young's modulus = 2 e+5
Poisson's ratio = 0.3
Length of chassis = 4201 mm
Width of chassis = 808 mm
Gross vehicle weight (G.V.W) = 2180 kg
Dimensions of cross bar = 90 mm x 90 mm
Ker weight = 1180 kg
Dimensions of side bar = 100x36x5mm^3
The above load (G.V.W) is applied in the form of pressure.
From chassis dimensions = 1182600 mm^2. Pressure to be applied = 21091.5/1182600 = 0.017834 MPaHence the total area of application of load as calculated Total load to be applied = 2150 x 9.81 = 21091.5 N
Dimensions of side bar = 100 x 36 x 5 mm^3

FEM ANALYSIS OF CHASSIS

For carrying out the FE analysis of the frame the CAD model is prepared in PROE (CREO 3.0) and then the analysis is done in ANSYS 16 workbench. CAD model is prepared using following dimensions:-

Length of chassis = 4201 mm

Width of chassis = 808 mm

Dimensions of side bar =100 x 36 x5mm^3

Dimensions of cross bar = 90 mm x 90 mm

3D MODEL OF CHESSIS C SECTION & LADDER TYPE CHASSIS FRAME

Here is 3D drawing of C section of ladder frame with actual dimension shown in drawingChassis drawing is prepared in PRO-E and then analysis in ANSYS 16.with above dimension

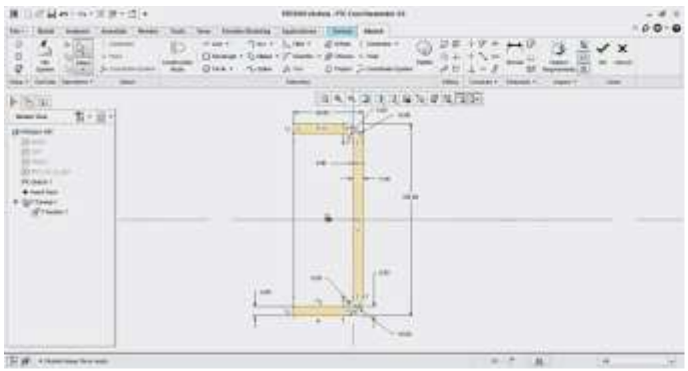


Figure: 3D model of chassis cross section

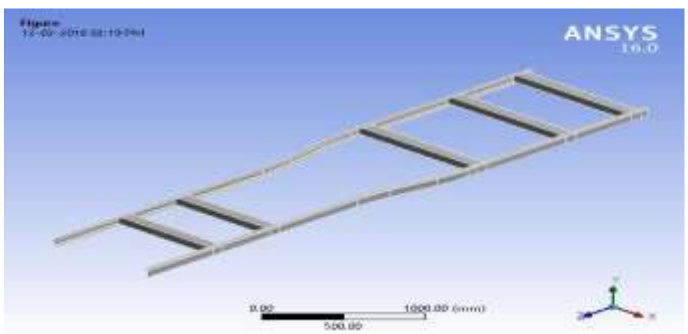


Figure: 3D model of chassis frame

MESHING

Meshing is done using ANSYS 16 using triangle surface which have following characteristics and then analysis is carried out, result can be improved by increasing number of nodes and elements but it will time consuming.

No. of Nodes	20503
No. of Elements	10451
Mesh Metric	None

ISSN: 2277-5528
Impact Factor: 4.015

Figure:Meshed model of chassis

LOAD APPLICATIONS AND BOUNDARY CONDITIONS

The Ladder frame chassis model is loaded with static forces from the truck body and load. For this model, the maximum loaded weight of truck plus body is 2150 kg. The load is assumed as a uniform distributed obtained from the maximum loaded weight divided by the total length of chassis frame. Detail loading of model is shown in Figure. The magnitude of force on the upper side of chassis is 21091 N. chassis frame as a part of loading. There are 4 boundary conditions of model; the first and the second are the forces applied on each beam, the remaining are the fixed supports at the front and the rear overhang. Load is applied in the form of pressure of magnitude 0.017834 MPa. The detailed loading is shown in Figure.

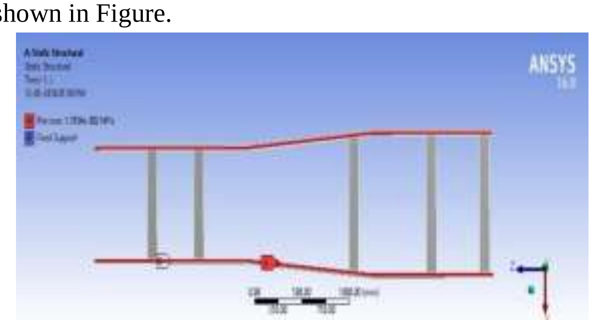


Figure:Fixed support and pressure application

RESULTS WITHOUT OPTIMISATION

Load analysis of original chassis gives maximum stress intensity of magnitude 137.24 MPa in close proximity of rear axle at the joint of side member and cross member. The von mises stress magnitude is 137.24 MPa. Also the magnitude of total deformationis 3.37 mm.

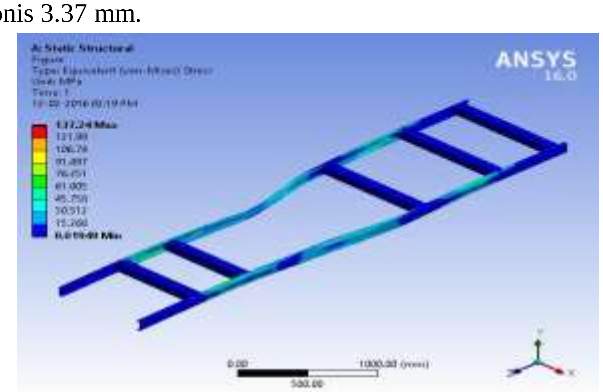


Figure: Equivalent (Von Mises) Stress

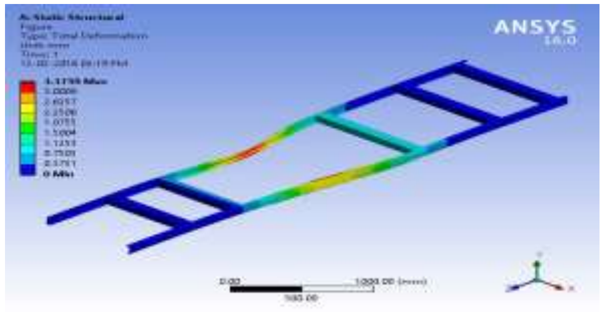
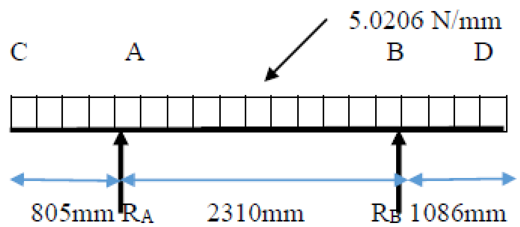


Figure: Equivalent Total Deformations

VERIFICATION OF RESULTS USING SOLID MECHANICS

Verification of software results can be done by considering the chassis as an overhanging beam carrying a uniformly distributed load (U.D.L).Uniformly distributed load = total load/length of chassis =21091.5/4201 =5.0209 N/mm



Total Length of chassis frame 4201 mm
Figure: Chassis as an overhanging beam

Calculating the reactions RA and RB:-
Here
RA + RB = 21091.5 N
Taking the moment about A,
RB x 2310 = 5.0206 x3396 x 1698 – 5.0206 x805 x 402.5
RB = 11827 N
RA = 21091.5-11827=9264.5N
BENDING MOMENTS:-
BMB (at B) = - {5.0206 x (1086)2 }/2 = -2960637.7 N-mm
BMA (at A) = - {5.0206 x (3396)2}/2 + 11827 x 2310 = -1630458 N-mm

Hence the maximum bending moments occurs at B.
MOMENT OF INERTIAS:-
M.O.I. of side members (I1) = 36 x (100)3 /12 - 31 x (90)3 /12 = 1116750 mm 4
M.O.I. of cross members (I2) = 90 x (90)3 /12 -80 x (80)3 /12 = 2054166 mm4
Total M.O.I (I) = 1116750 x 2 + 2054166 x 5 = 12504333.33 mm4

Using the bending equation,

$M/I=\sigma_b/y$, (1)

$\sigma_b = My/I_1 = 2960637 \times 50/ 1116750 = 132.55$ MPa

Deflection of the chassis can be calculated using the empirical formula (ref to the structural analysis of ladder chassis frame ISSN 2232-2587)

$$Y = \frac{wL(b-L)[\ L(b-L)+b2-2(c2+a2) - 2b-1\{c2 \quad L + a2\ (b- L)\}\ ]}{24\ EI}$$

$$= 3.0803 \text{ mm}$$

Hence the stress and the deflection calculated are close to software values i.e. 137 MPa and 3 mm. the slight deviations in the values are may be because software not able to reproduce actual conditions and simplification of the chassis model.

DESIGN MODIFICATIONS FOR WEIGHT REDUCTION

SENSITIVITY ANALYSIS

To analyze the sensitivity of frame with different web height and thickness for the approximately same section modulus.

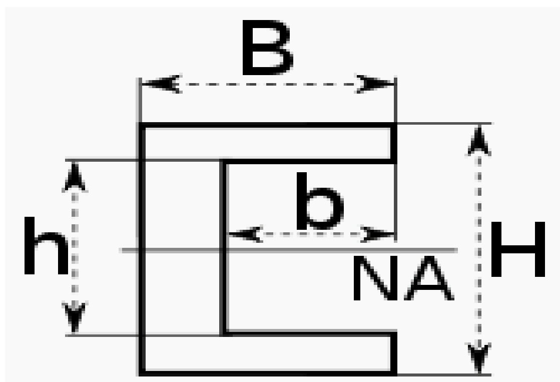


Figure 7.1 Dimensions of Sections for Section Modulus Calculation Section Modulus (Z)

$$Z = I_{XY}/y$$
$$Z = (BH^3/12-bh^3/12)/(H/2)$$
$$Z= (BH^3-bh^3)/6H$$
$$Z= \{BH^3-(B-t)\ (H-2t)^3\}/6H$$

Now, as B>>t and H>>2t

Therefore, B-t = B

H-2t = H

We get,

$$Z = (BH^2/6\ ) - B(H)(H-2t)^2/6H$$
$$6Z/B = H^2 - (H - 2t)^2$$

Section modulus (Z) and flange width (B) being constant K is constant parameter. Taking H as dependent parameter and t as independent parameter. Differentiate the above equation we get,

$$6Z/B = 4tH - 4\ t^2$$
$$-tdH /dt = (H-2t)$$
$$-tdH /dt = H$$

This concludes that with increase in web height, thickness of frame can be reduced. With thisrelation an approximate value can be obtained with increase in web height and decrease in thickness, By using equation, the following cases are derived by reducing the value of thickness (t) between the intervals of 6 mm to 4 mm with a common difference of 0.50 mm

MODIFIED CROSS-SECTIONS OF CHASSIS FRAME

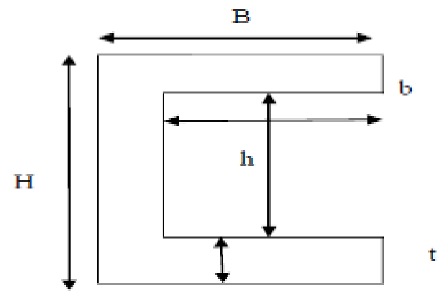


Figure: Modified Cross-sections of Chassis

Modified cross-sections are calculated from above equation by change in thickness of chassis frame height of the chassis also change for constant Section Modules (Z). Modification of cross section of chassis frame member is made in three different cases. The inside fillet radius is also increased by 2 times than the thickness of the cross section which is shown in the table below

Modified cross-sections:

Case	Thickness (t) (mm)	Height (H) (mm)	Width (B)(mm)
Existing	5	100	36
Case1	4.5	109	36
Case 2	5.5	91	36

TABLE: Modified cross-sections

FINITE ELEMENT ANALYSIS OF MODIFIED CROSS-SECTION
MODIFIED CROSS-SECTION CASE I
CASE I

H*B*t are 109 mm x 36 mm x 4.5 mm

In a first case we decrease the thickness of flange width is constant and thickness of chassis is varying by 0.5 mm which is 4.5 mm due to change in thickness height of the chassis also change by the above formula which is 109 mm flange width taking constant

Flange Thickness (t)	4.5 mm
Height of the Chassis (H)	109 mm
Flange Width(B)	36 mm

TABLE: Modified cross-sections CASE I

MODIFIED CROSS-SECTION

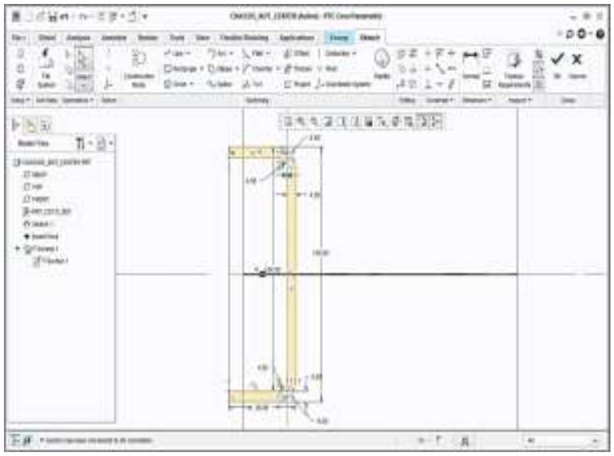


Figure: Cross-Section of Chassis for CASEI

RESULTS OF FINIITE ELEMENT ANALYSIS OF CASE I

Loading and boundary conditionsfor CASE 1 are same as existing Ladder frame chassis model
The location of maximum Von Misses stress and maximum shear stress are at middle of side bar, which is shown in Fig. 8.4. The Von Misses stress magnitude of critical point is 112.29 MPa.

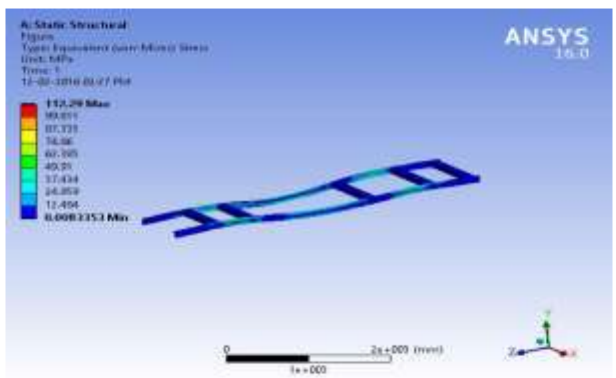


Figure: Equivalent (Von-Mises) Stress in the Chassis for CASE 1

The displacement of chassis and location of maximum displacement is shown in Fig. 8.5 the magnitude of maximum displacement is 1.5843 mm.

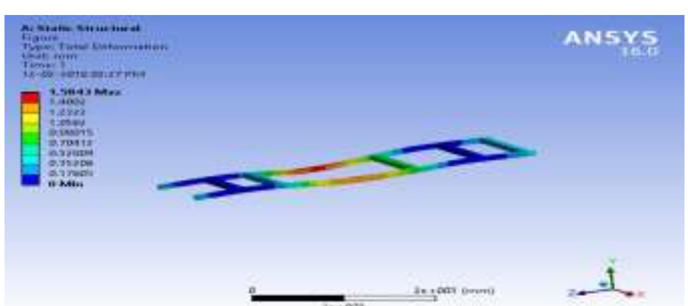


Figure: Maximum Displacement in Chassis of CASE I

MODIFIED CROSS-SECTION CASE II
CASE II

H*B*t are 91 mm x 36 mm x 5.5 mm

In a Second case we increase the thickness of flange is varying by 0.5 mm which is 5.5 mm due to change in thickness height of the chassis also change by the above formula which is 91 mm, flange width taking constant

Flange Thickness (t)	5.5 mm
Height of the Chassis (H)	91 mm
Flange Width (B)	36 mm

TABLE: Modified cross-sections CASE II

MODIFIED CROSS-SECTION

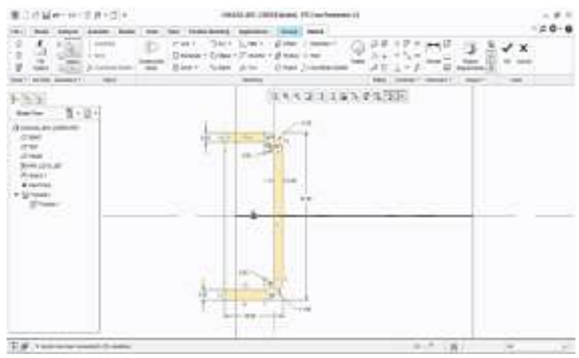


Figure: Cross-sections of Chassis for CASEI

RESULTS OF FINIITE ELEMENT ANALYSIS OF CASE II

Loading and boundary conditions for CASE 1I are same as existing Ladder frame chassis model The location of maximum Von Misses stress and maximum shear stress are at middle of side bar, which is shown in Fig. 8.7 . The Von Misses stress magnitude of critical point is 76.527 MPa.

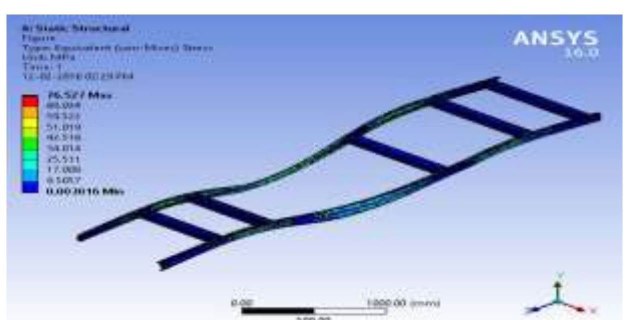


Figure: Equivalent (Von-Mises) Stress in the Chassis for CASE 1I

The displacement of chassis and location of maximum displacement is shown in Fig. 8.8The magnitude of maximum displacement is 1.8523mm.

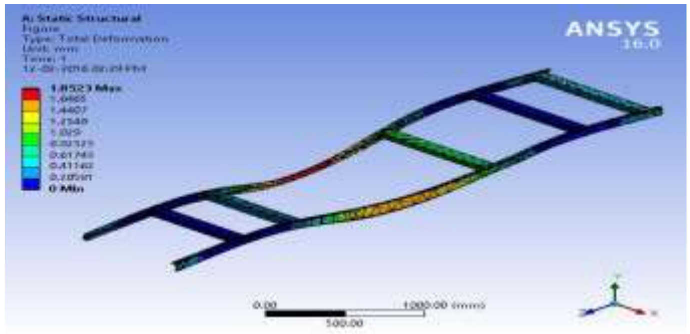


Figure: Maximum Displacement of CASE II

RESULTS OF FE ANALYSIS OF DIFFERENT CASES

Comparison of the results is shown in the table

Sr. No.	Section	Max.Equiv. Stress(MPa)	ChassisWeight(Kg.)	Max. Disp. (mm)
1	Existing Section	137.24	113.23	3.3759
2	Case 1	112.29	111.75	1.5843
3	Case 2	76.327	111.87	1.8523

From the above results, it is seen that CASE I and CASE II is the most appropriate case as the Maximum Displacement and Maximum Equivalent Stress are all less than that induced in existing.
As compared to existing chassis of CASE I and CASE II, CASE II is the most optimum as maximum weight is reduced in this case without failure. Hence, total weight reduced is 1.36 kg (1.2 %) Nearly equal to the existing.

RESULTS

The maximum shear stress induced on the modified chassis is . The Von-Mises Stress and Total deformation are 76.327 MPa and 1.8523 mm respectively. From the above table it can be clearly seen that for the same weight of the existing and the modified chassis The Shear Stress, Von-Mises Stress and Total Deformation for the modified chassis are less than the existing chassis. Also, the main objective, i.e., to reduce the Total Von-Mises Stress of the vehicle is achieved. At a point, either weight is reduced by 1.36 kg (1.2%) Therefore, the following objectives were achieved with the help of the project: The results are shown below.

1. Reduction in Maximum Deformation by1.52 mm (45.2 %)
2. Reduction in Von-Mises Stress induced by 60.913 MPa (44.46%)
3. Reduction in weight of the Chassis by1.36 kg (1.2 %)
4. Increase in loading capacity by 40% (Approximate)

CONCLUSION AND FUTURE WORK

Conclusion

Here an attempt is made to optimize the ladder frame of light duty truck (TATA ACE) using ANSYS 16.0. Thesis includes, literature survey, basic information of ladder type frame, vehicle regulations related to design data, vehicle frame calculation by analytical method, static stress analysis and optimization using ANSYS 16.0. Following are the conclusions drawn from above study

1. Linear static stress analysis is carried out to obtain the location of maximum stress, which is found near the location of middle of the front and rear axle and it is well within limits.
2. Without making the prototype the loading condition can be simulated and make the necessary changes at the design level, if required for the proper functioning of the actual frame.
3. TATA ACE Ladder frame is optimized and feasible design was obtained with 1.2% reduction in mass as shown in Table 8.4. And payload capacity is increased 390 kg approximately.
4. Another prototype can be developed with reduction in weight for a desired stress condition.

Future Word

Here from study we see that by change in chassis frame thickness we can increase loading capacity of light duty truck and decrease in total stress developed in the chassis and also decrease in weight for desired condition. After studied we further analysis for other component of light duty truck for weight reduction and minimization of stress so that we will increase in overall performance of light duty truck.

REFERENCES

1. Monika S.Agrawal "Finite Element Analysis of Truck Chassis Frame" Mechanical Engineering, Department, Trinity College of Engineering Pune, India.
2. M singh bajwa, S pundir, A joshi "static load analysis of TATA super ace chassis and stress optimization using standard techniques"
3. M baker "multi-material size optimization of a ladder frame chassis" in queen's university Kingston, Ontario, Canada (march, 2015)
4. Caffrey, C., Bolon, K., Kolwich, G., Johnston, R. et al., "Cost-Effectiveness of a Lightweight Design for 2020-2025: An Assessment of a Light-duty Pickup Truck," SAE Technical Paper 2015-01-0559, 2015.
5. Lucas V. Fornace "Weight Reduction Techniques Applied to Formula SAE Vehicle Design: An Investigation in Topology Optimization" University of California, San Diego 2006
6. Carlos Cosme, Amir Ghasemi and Jimmy Gandevia, Western Star Trucks, Inc. "Application of Computer Aided Engineering in the Design of Heavy-duty Truck Frames." (SAE- 1999-01-3760)