Structural Analysis of Automotive Chassis Frame and Design Modification for Weight Reduction

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Abstract

Automotive chassis is an important part of an automobile. The chassis serves as a frame work for supporting the body and different parts of the automobile. Also, it should be rigid enough to withstand the shock, twist, vibration and other stresses. Along with strength, an important consideration in chassis design is to have adequate bending stiffness for better handling characteristics. So, maximum stress, maximum equilateral stress and deflection are important criteria for the design of the chassis. This report is the work performed towards the optimization of the automotive chassis with constraints of maximum shear stress, equivalent stress and deflection of chassis under maximum load.

Structural systems like the chassis can be easily analyzed using the finite element techniques. A sensitivity analysis is carried out for weight reduction. So a proper finite element model of the chassis is to be developed. The chassis is modeled in PRO-E. FEA is done on the modeled chassis using the ANSYS Workbench

1. Introduction

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. Also the frame should be strong enough to withstand shock, twist, vibrations and other stresses. The chassis frame consists of side members attached with a series of cross members Stress analysis using Finite Element Method (FEM) can be used to locate the critical point which has the highest stress. This critical point is one of the factors that may cause the fatigue failure. The magnitude of the stress can be used to predict the life span of the truck chassis. The accuracy of prediction life of truck chassis is depending on the result of its stress analysis.

.2. Basic Calculation For Chassis Frame

Model No. = 11.10 (Eicher E2)

Side bar of the chassis are made from "C" Channels with 210mm x 76 mm x 6 mm

Front Overhang (a) = 935 mm

Rear Overhang (c) = 1620 mm

Wheel Base (b) = 3800 mm

Material of the chassis is St 52

E = 2.10 x 105 N / mm2

Poisson Ratio = 0.31

Radius of Gyration R = $\dfrac{210}{2}$ =105 mm

Capacity of Truck   = 8 ton

= 8000 kg

= 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 = $\dfrac{117720}{2}$

= 58860 N / Beam

Now we can calculate the maximum shear stress and maximum deflection using the equation given below.

$$\frac{M_e}{I} = \frac{\sigma}{y} = \frac{E}{R} \qquad (1)$$

a. Deflection of chassis

$$Y = \frac{wx\ b-x}{24EI}\left[x\ b-x\ +b^2-2(c^2+a^2)-\frac{2}{b}\ c^2x+a^2(b-x) \right]$$

(2)

= 2.85 mm

That is within safe limit according deflection span

ratio

2. FE analysis of Existing Chassis Frame

For carrying out the FE Analysis of chassis as per standard procedure first it requires to create merge part for assembly to achieve the connectivity and loading and constraining is required to be applied also idealization of parts is done on structure this will lead to faster analysis since the connected structure will not be physical but it will be a sketch with mechanical properties of mechanical structure. Procedure is followed in this section.

A. Cross Section of Main Frame
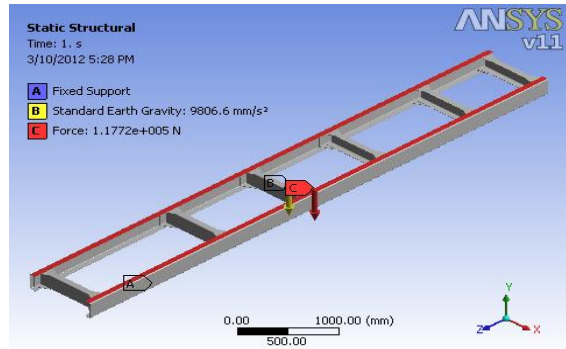
h = 210 mm, b = 76 mm, t = 6 mm
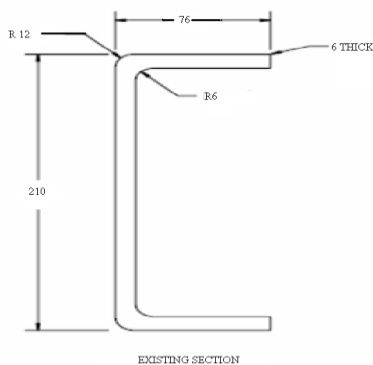
Existing main frame cross section

B. Loading and Boundary condition

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. Detail loading of model is shown in Figure. The magnitude of force on the upper side of chassis is 117720 N. Earth gravity is also considered for the chassis frame as a part of loading.

There are 4 boundary conditions of model; the first two boundary conditions are applied in front of the chassis, the second and the third boundary conditions are applied in rear of chassis, there are shown in Figure.
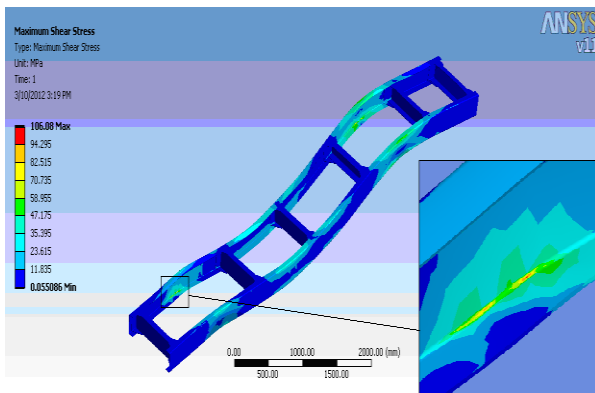

Structural load and boundary condition for chassis frame

C. Results

The location of maximum Von Misses stress and maximum shear stress are at corner of side bar which in Figure. The Von Misses stress magnitude of critical point is 190.38 MPa and the maximum shear stress magnitude is 106.08 MPa.
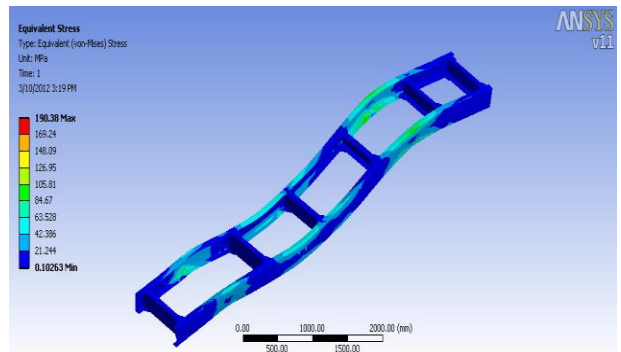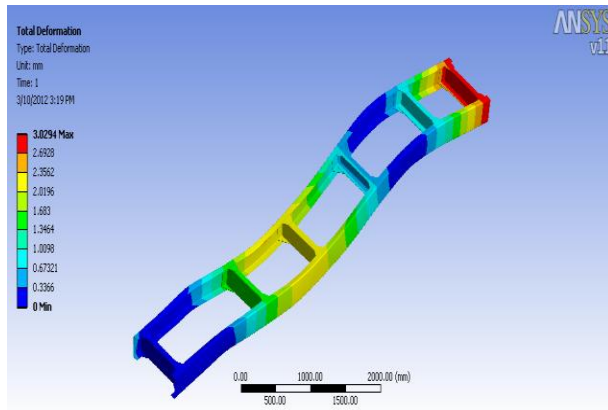

Equivalent stress in chassis frame

Maximum shear stress in chassis frame

D. Displacement

The displacement of chassis and location of maximum displacement is shown in Figure. The magnitude of maximum displacement is 3.0294 mm.

Displacement in chassis frame

3. Design Modification for Weight Reduction

A. Sensitivity analysis

To analyze the sensitivity of frame web height to the change in thickness and vice-versa for the approximately same section modulus and flange width.

Section modulus $Z = \dfrac{bh^3 - b_1 h_1^3}{6h}$ (3)

$$= \frac{bh^2}{6} - \frac{(b-t)(h-2t)^3}{6h} \text{ (But, t}$$

$\ll$ b and t $\ll$ h so taking b - t =b and h - 2t = h)

$$= \frac{bh^2}{6} - \frac{(b-t)(h-2t)^2}{6}$$

$$\frac{6Z}{b} = h^2 - (h-2t)^2$$

$$K = h^2 - (h-2t)^2$$

Section modulus and flange width being constant K is constant parameter. Taking h as dependent parameter and t as independent parameter.

Differentiate equation the above equation we get,

$$h = -t\frac{dh}{dt} \qquad\qquad (4)$$

This concludes that with increase in web height, thickness of frame can be reduced with this relation an approximate value can be obtained. With increase in web height and decrease in thickness.

By using equation $h = -t\dfrac{dh}{dt}$ three cases of different cross section are produced.

Case 1	Case 2	Case 3
h=227.5 mm	h= 236.25mm	h = 245mm
t = 5.5 mm	t = 5.25 mm	t = 5 mm
b = 76 mm	b = 76 mm	b = 76 mm

B. Modified cross section for the weight reduction
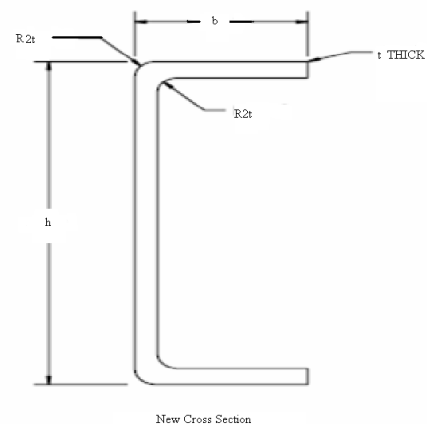
Modified cross section of chassis frame

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.
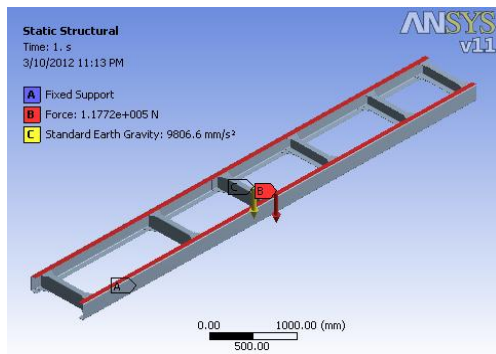
4. FE analysis of modified cross section

Case 1 (227.5 mm x 76 mm x 5.5 mm)
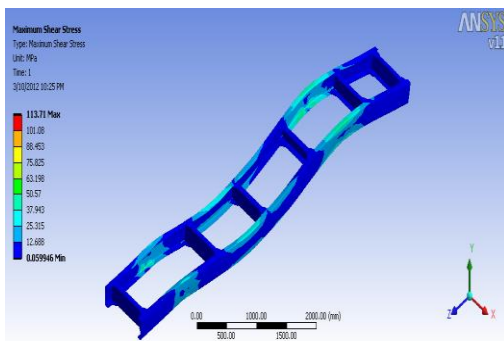
A.   Loading and Boundary condition

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. Detail loading of model is shown in Figure. The magnitude of force on the upper side of chassis is 117720 N. Earth gravity is also considered for the chassis frame as a part of loading.

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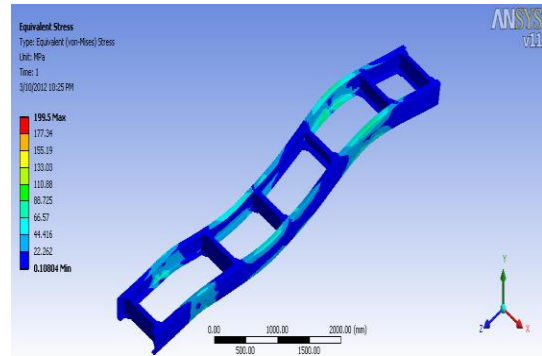

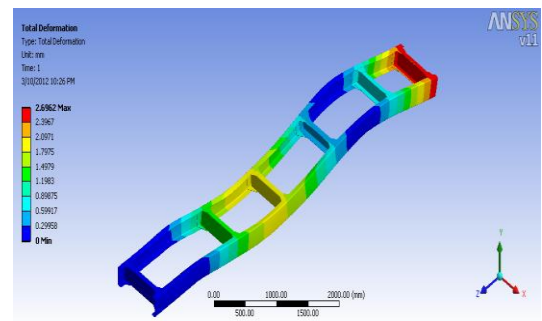loading and boundary condition of modified chassis frame case1

B.   Results

Maximum shear stress in chassis frame
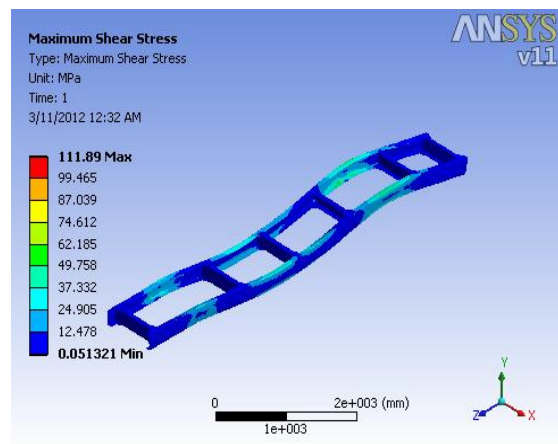

Equivalent stress in chassis frame

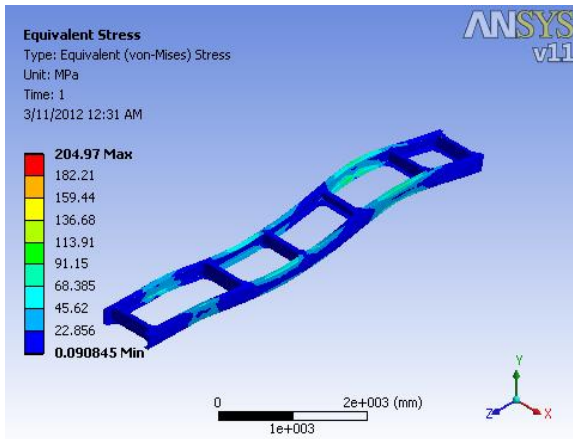Deformation of modified chassis

Case 2. Geometry (236.25 mm x 76 mm x 5.25 mm)

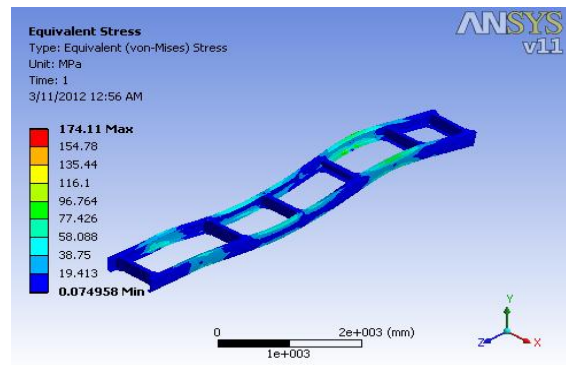Loading and Boundary condition are same as the first case.
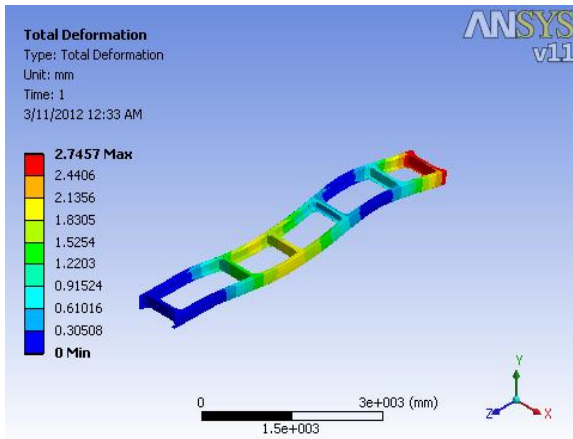
A.   Results

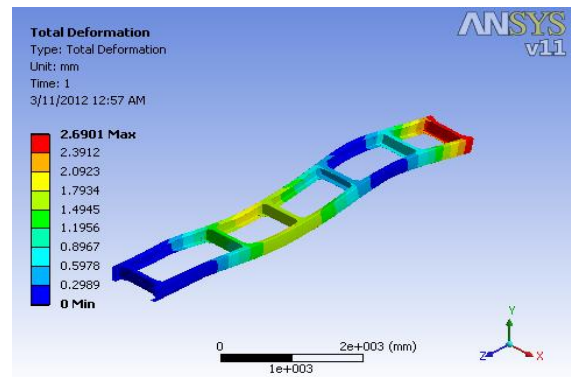Maximum shear stress in chassis frame

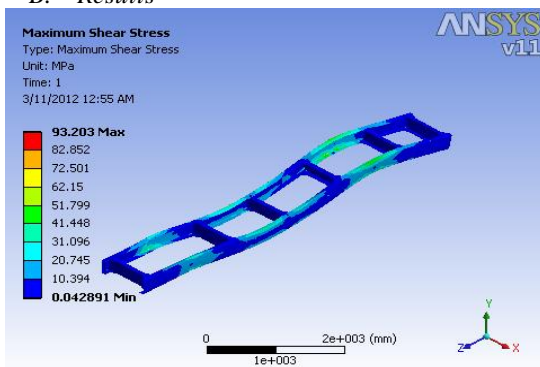Equivalent stress in chassis frame

Equivalent stress in chassis frame

Deformation of modified chassis

Deformation of modified chassis

5. Conclusion

Comparison of the result is shown in the table.

Case 3. Geometry (245 mm x 76 mm x 5 mm)

Loading and Boundary condition are same as the first case.

B. Results

Maximum shear stress in chassis frame

Sr. No	Section	Chassis Weight (Kg.)	Shear Stress (MPa)	Max. Displacement (mm)	Max Equivalent Stress (MPa)
1	Existing Section	326.36	106.08	3.0294	190.38
2	Case 1	318	113.71	2.6962	195.5
3	Case 2	311.45	111.89	2.7457	204.97
4	Case 3	**304.57**	**93.203**	**2.6901**	**174.11**

TABLE 1 COMPARISON OF CHASSIS FRAME

From the above result it is clear that the weight is reduced by 6.68 % of the chassis frame. The maximum shear stress, maximum equivalent stress and displacement are also reduced respectively 12.14 %, 8.55 % and 11.20 %. It is clear that design is safe.

So it is 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.

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