Structural Analysis of Truck Chassis Frame and Design Optimization 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. 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.

Index Terms—optimization, sensitivity, deformation, stress

I. INTRODUCTION

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. 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.

II. CALCULATION FOR CHASSIS FRAME

Widths of the members are assumed to be 200 mm.
Total loading area,

$A = 8.76 \times 10^6$ mm^2

As per standard, permissible axle weight is 18 Ton per axle.
So, Gross laden weight for trailer having six axles is

F = 108 tone = 1059480 N

Load intensity,

$$p = \frac{Gross\ laden\ Weight}{Surface\ Area} = \frac{F}{A}$$

= 0.12094 N/mm.

UDL acting on beam,

$$w = \frac{p \times A}{L} = \frac{p \times (B \times L)}{L}$$

=24.19N/mm

Design for Main/Side Cross Member

P_1 = Equivalent point load due to UDL on main long member
= 9071.25 N

l_1 = 900mm

Maximum bending moment which occurs at end of the span,

$$M_c = (P_1 \times l_1) + \left(\frac{w \times l_1^2}{2}\right)$$

= 17962000 Nmm.

Allowable bending stress,

$$\sigma_{bt} = \frac{\sigma_y}{Factor\ of\ safety} = \frac{250}{2.5}$$

= 100 N/mm^2.

Modulus of section required is,

$$Z_{required} = \frac{M_C}{\sigma_{bt}}$$

= 179620 mm^3

$$A_w = d \times t_w = (D - 2 \times t_w) \times t_w = 900\ mm^2$$

Average shear stress,

$$\tau_\theta = \frac{V}{2 \times A_w}$$

=17.13 N/mm^2

Allowable shear stress,

$$\tau_{av} = 0.577\tau \times \sigma_{bt} = 57.7\ N/mm^2$$

As $\tau_\theta < \tau_{av}$, Design is safe in shear.

Check for deflection,
Allowable deflection is,

$$\delta_{allowable} = \frac{l_1}{325}$$

=2.769 mm

Maximum deflection occurs at free end

$$\delta = \left(\frac{w \times l^3}{8 \times E \times l}\right) + \left(\frac{P_1 \times l^3}{3 \times E \times l}\right) = 122.22\ mm$$

- Design for Side Long Member

P_1= 36285 N

l_1= 750 mm

Design for bending stress,

Maximum bending moment which occurs at end of the span,

M_c=34017187.5 Nmm

Modulus of section required is,

Manuscript received on April, 2013.

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$Z_{required}$=340172 mm^3

Check for shear stress
Effective area of web,

A_w = 1600 mm^2.

Average shear stress,

τ_θ = 17 N/mm^2.

Allowable shear stress,

τ_{av}=57.7 N/mm^2

As $\tau_\theta < \tau_{av}$, Design is safe in shear.

Check for deflection
Allowable deflection is,

$\delta_{allowable}$ = 2.3076 mm

Maximum deflection occurs at free end,

δ = 21.79 mm

- Design for End Cross Member

P_4= 43542 *N*
P_5= 72570 *N*
l_1 = 1500 mm
l_2 = 600 mm
Design for bending stress,

Maximum bending moments are found near to extreme supports a and e,

Ma = Me = 136068750 Nmm

Modulus of section required is,

$Z_{required}$= 5124865 mm^3

Check for shear stress
Effective area of web,

A_w = 12600 mm^2

Average shear stress,

τ_θ = 4.6 N/mm^2

Allowable shear stress,

τ_{av}=57.7 N/mm^2

As $\tau_\theta < \tau_{av}$, Design is safe in shear

Check for deflection,
Allowable deflection is,

$\delta_{allowable}$ = 27.69 mm

Maximum deflection occurs at free end,

δ = 27.66 mm

- Design for Main Long Member

P_1= 18145 N
l_1 = 1800 mm
l_2 = 600 mm
Design for bending stress,

Maximum bending moment which occurs at end of the span,

M_c=68037750 Nmm

Modulus of section required is,

$Z_{required}$== 680377.5 mm^3

Check for shear stress
Effective area of web,

A_w = 2800 mm^2

Average shear stress,

τ_θ = 5.5 N/mm^2

Allowable shear stress,

τ_{av}=57.7 N/mm^2

As $\tau_\theta < \tau_{av}$, Design is safe in shear.

Check for deflection
Allowable deflection is,

$\delta_{allowable}$ = 5.54 mm

Maximum deflection occurs at free end,

δ = 5.2414 mm

III. OPTIMIZATION OF CHASSIS FRAME

Optimization is define as a maximization of wanted properties and minimization of unwanted properties.
In case of structural optimization the chassis:

Desired Properties are:

- Strength
- Stiffness
- Deflection etc…

Undesired Properties:

- Material
- Cost
- Weight etc…

In the case of chassis we can reduce the weight of chassis frame by reducing its thickness, but it will increase the deflection as well as the shear stress. To omit this problem the sensitivity analysis will be helpful to reduce thickness of cross section of chassis frame.

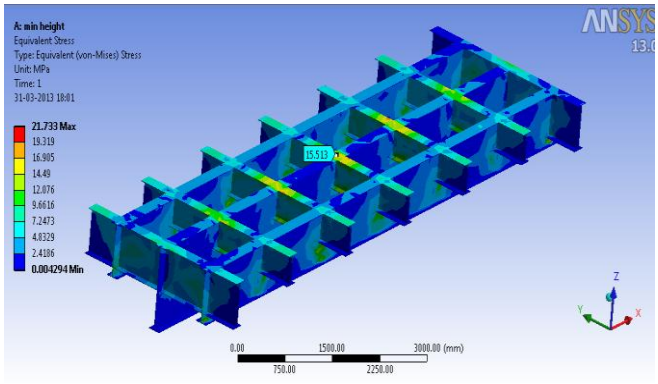
- Sensitivity analysis

To analyze the sensitivity of frame web height to the change in thickness and viceversa. For the approximately same section modulus and flange width.

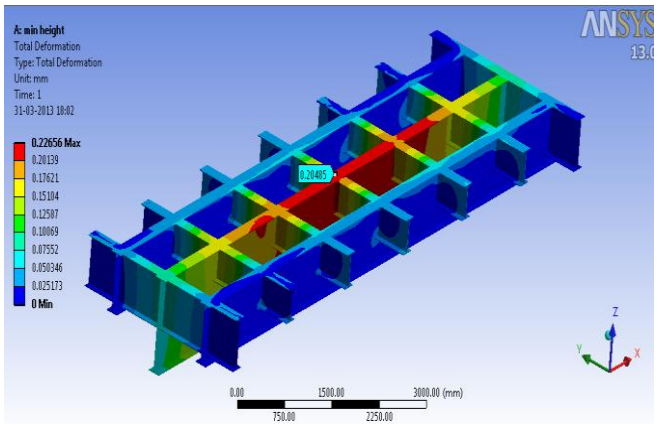
Case 1: Changing height and width.
Cross section of the frame in case 1

MEMBER	1A		1B		1C	
	W	H	W	H	W	H
Main cross	100	500	200	900	180	610
Side long	100	600	200	1000	180	720
End cross	100	300	200	700	180	450
Main long	100	800	200	1400	180	1050

Case 1A: Results
Stress

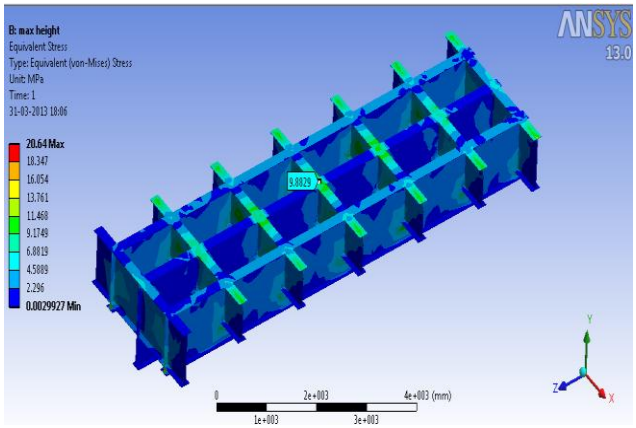


Deformation



Case 1B: Results

Stress



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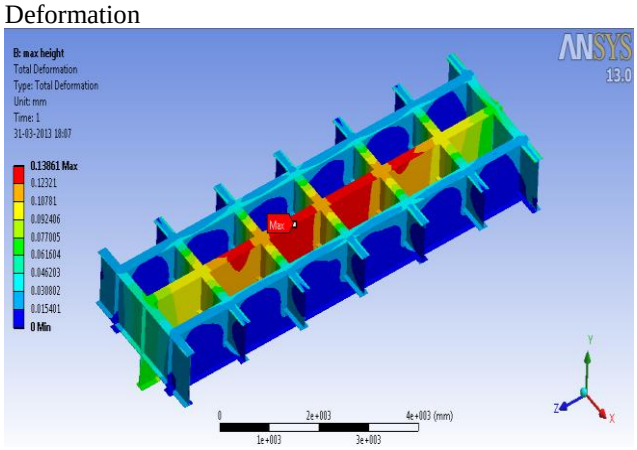
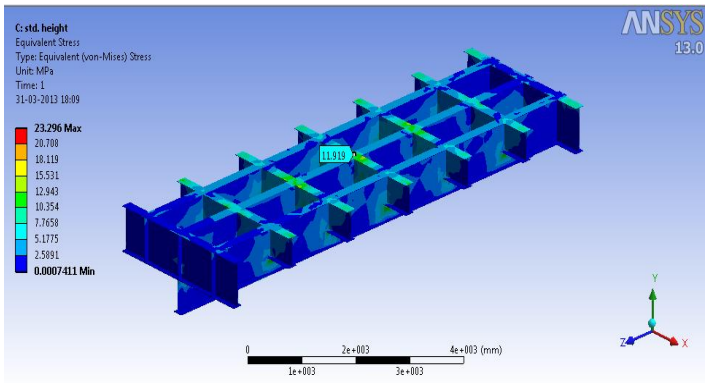


Case 1C: Results

Stress



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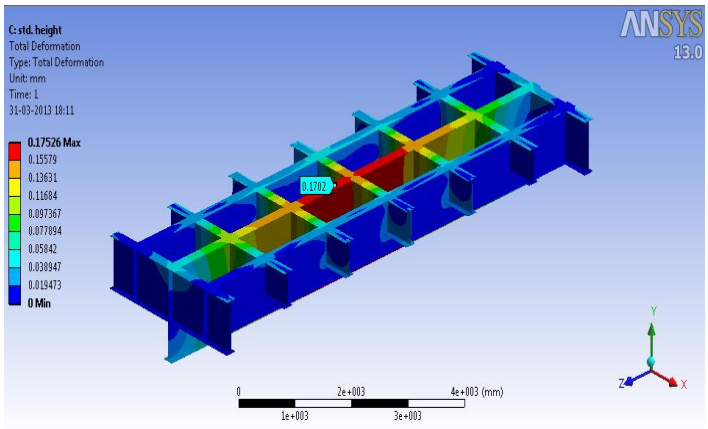


Result Table for Case 1

Cases	Stress	Deformation	Weight
Case 1A	21.733	0.22656	2.64
Case 1B	20.64	0.13861	4.98
Case 1C	23.296	0.17526	3.732

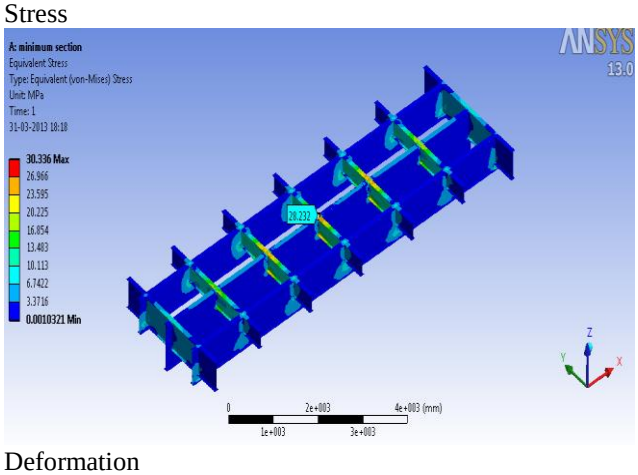
Case 2 : Changing in height.

Cross section of the frame in case 2.

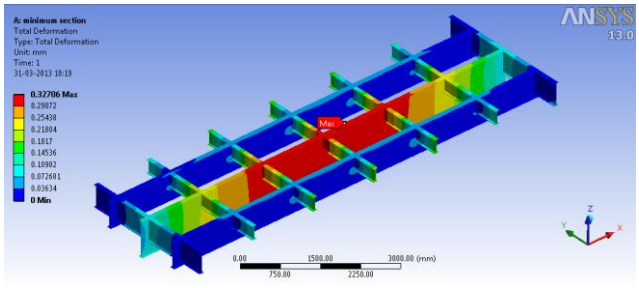
Member	2A	2B	2C
Main cross	600	800	750
Side long	700	900	750
End cross	400	600	500
Main long	1100	1300	1300

Case 2A: Results

Stress

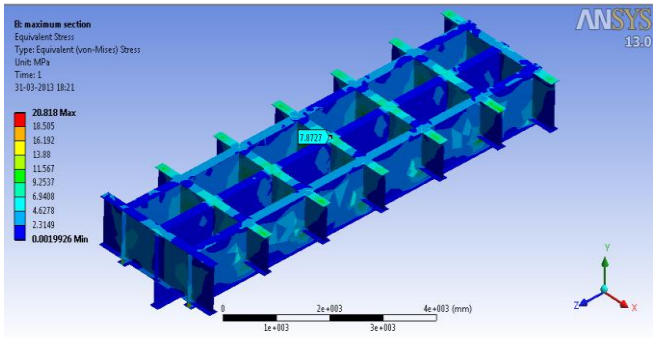


Deformation

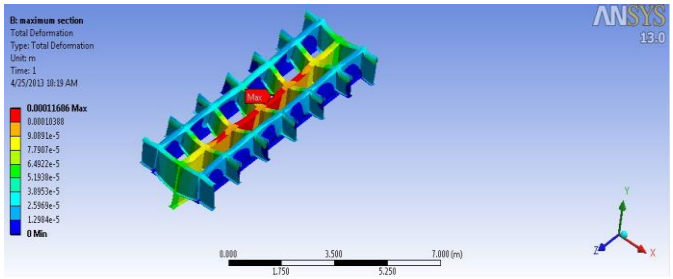


Case 2B: Results

Stress

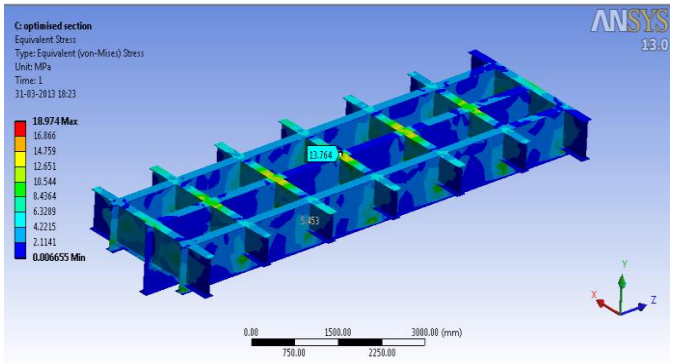


Deformation

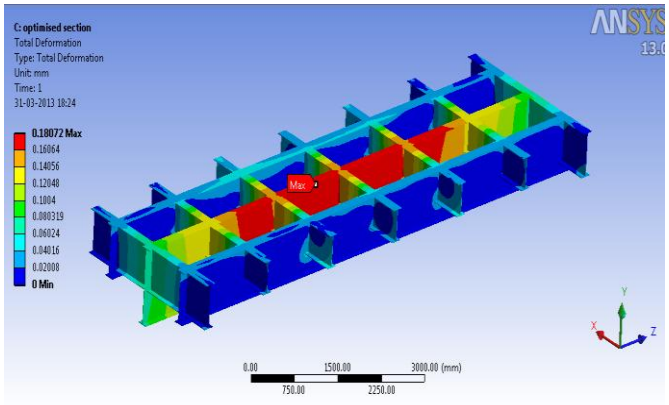


Case 2C: Results

Stress



Deformation



Result Table for Case 2

Cases	Stress	Deformation	Weight
Case 2A	30.336	0.32706	3.86
Case 2B	20.818	0.000116	4.61
Case 2C	18.974	0.18072	4.249

IV. CONCLUSION

The truck chassis design is done analytically and the weight optimization is done by sensitivity analysis. In sensitivity analysis different cross section are used for stress analysis and we find a 17% weight reduction in the truck chassis. The stress and deformation are also compared for the different cross section.

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