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STRUCTURAL OPTIMIZATION OF TRUCK LADDER CHASSIS USING FINITE ELEMENT METHOD

Syed Hasnain Muzammil, Muhammad Hussain, Muhammad Umair Khalid, Abdullah Amin
Department of Mechanical Engineering
CEME NUST, Rawalpindi, Punjab, Pakistan

Abstract— **The research aim is to find out the most suitable cross section truck ladder chassis with the factors of maximum stress and equivalent stress. The vehicle's chassis is an important component, and static loading circumstances can lead to a variety of breakdowns. Unbalanced loading circumstances exist in the design of passenger and truck trucks; the local passenger bus's real carrying capacity for unloading is lower than that of the truck. The passenger truck chassis is designed with maximum stress and maximum deflection as the primary design parameters. But the present study focus is on the stresses developed in the chassis for each type of crosssection. For our analysis the material we selected is ASTM 710 Steel. Different models of chassis have been selected with different types of cross sections that are I , C and rectangular (hollow). The solid modelling and Finite Element Analysis has been done in Ansys. In the end the analytical results are compared with the results of software.**

Keywords— **ANSYS, FEA, Stress, Automotive, Chassis**

I. INTRODUCTION

Chassis is one of the most fundamental parts of automotive vehicles. It is a study metal frame that can carry whole load of vehicle in static or dynamic conditions. It is the backbone of automotive vehicles and most of the vehicle parts are mounted on it like engine, drive train, axial assemblies including the wheels, suspension system braking system etc. A chassis not only proves to be the load carrying backbone but also keep theautomotive body rigid and stiff. Chassis is also designed to absorb and dampen the different forces generated between the road and truck and keep the contact with road all the time. Another Important factor along with the stress calculations is that the chassis should have adequate bending and shear stiffness. So, the chassis should be designed in such a way that it should bear the necessary loads as well as should be adequate to bear the bending and shear stiffness. So, stress and stiffness are two important factors in the design of chassis. Our analysis involves choosing a suitable material for the chassis that is ASTM 710 Steel and applying the analytical methods to calculate the maximum stresses in the chassis for each model of chassis (for I, C and Rectangular cross sections) and comparing it with the finite element analysis of each model. Then from the results we can select the most suitable cross section for truck chassis. The problem is well suited for a complex engineering problem and cannot be resolved without in depth engineering knowledge. The calculation of stresses surely requires the knowledge of how bending, normal and shear stresses arise within a material and how they are formulated and calculated. The stress analys isn't enough for chassis to be suited for use. Other technical issues that are involved with chassis include the correct dimensioning or the proper size of chassis to ensure proper distribution of load and other dynamic as well as static geometric parameters that should be looked before designing a chassis. So, chassis provesto be a good complex engineering problem to investigate.

Classical theories and software simulation have been used inmultiple study kinds throughout the last few decades to optimize the chassis, assess stress on the chassis, and analyze associated issues in various ways. This study encourages more chassis-related research as it applied the best load management techniques, including reducing the weight of the chassis [1] the experiment is conducted as part of his research on automobile chassis failures. During durability testing of the car suspension, a crack was developed and allowed to spread, ultimately resulting in component fracture. The failure occurred close to the bumper fastening points. He investigated the longitudinal stringer chassis failure region and employed the reinforcing model for a stringer in a different orientation to reduce stress. The conclusion of this work is that stress reduction using external reinforcement is possible without modifying the geometry.[2] This work examined several cross-sections under various loading situations to assess stress, demonstrating how stress analysis may be used in various cross section[3].Various studies have also been performed in automotive chassis and their resultant deflection and stresses are compared. [4-12].

II. DESIGN AND ANALYSIS

A. Material Specifications –

Table -1 Material Data

Density (g/cm3)	7.85
Tensile Strength (MPa)	495
Yield Strength (MPa)	415
Poisson's ratio	0.29
Young Modulus (GPa)	205
Shear Modulus (GPa)	80

B. Load Estimations –

Table -1 Specifications of Hino 814 Truck

Load Capacity of Truck	7.5 Ton = 7500 Kg = 73,575 N
Load Capacity with 1.25% more	92000 N
Weight of Body and Engine	2 Ton = 2000 Kg= 19,620 N
Total Load	111,620 N
No of beams for Chassis	2
Load Acting on one beam	55,810 N
Overall Length of Chassis (OL)	6740 mm
Wheelbase	3870 mm
Front Overhang (FOH)	1110 mm
Rear Overhang (ROH)	1760 mm
Front Width (FW)	750 mm

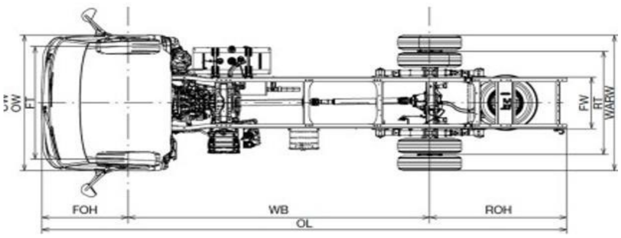


Fig. 1. Top View of Hino 814 Truck

C. Assumptions –

The chassis is clamped by shock absorber and leaf spring. So, the chassis can be simplified as simply supported beam with reaction supports at absorber and leaf spring positions. Furthermore, the load over the beam is uniformly distributed this simplify our analysis and makes the reaction and stresses easy to calculate.

D. Reaction Support Calculations –

Total Load on a single beam = 55,810 N Total length of Chassis = 6740 mm Distributed load on single beam = 8.28 N/mm

$\Sigma(M)_C = 0$

$[(8.28 \quad 6470)] \quad (3370-1110) = F_D \quad (3870)$

F_D = 32590.51 N

Also,

$F_C + F_D = 8.28 \quad 6740$

F_C = 23216.949 N

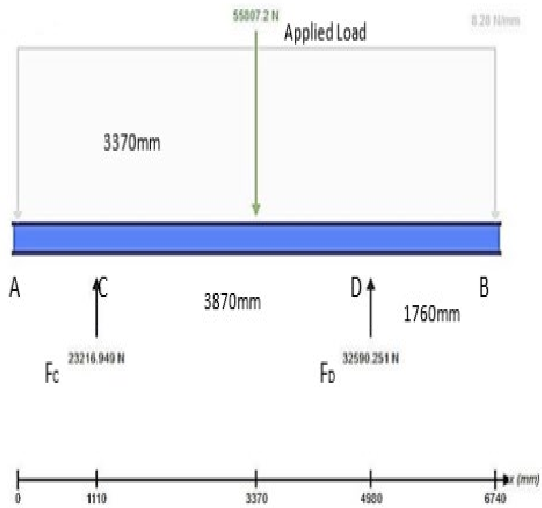


Fig. 2.Freebody Diagram for Ladder Chassis

E. Bending Moment and Shear Force –

Cut the beam at point C.

$\Sigma M_C = 0$

$(M_C)_B = (8.28 \quad 1110) \quad 555$

$(M_C)_B$ = 5.1 kNm

Cut the beam at point D.

$\Sigma M_D = 0$

$(F_C \quad 3870) = (M_D)_B + (8.28 \quad 4980) \quad (2490) \quad (M_C)_B = 12824063.37$ Nmm

$(M_C)_B$ = 12.82 kNm

$I_X = 13372380\ mm^4 I_y = 442540\ mm^4$

$J = I_X + I_y = 13814920\ mm^4$

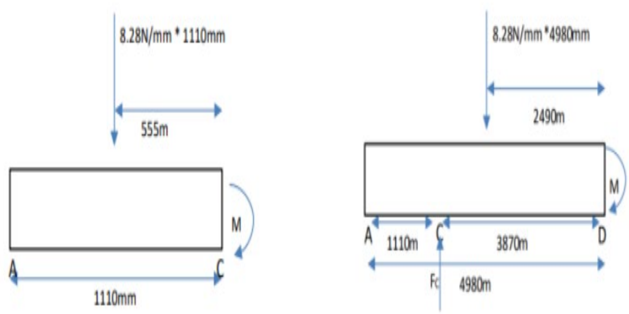


Fig. 3. Cut Sections for Bending Moment and Shear Force Calculations

The resultant bending moment diagram is as follows:

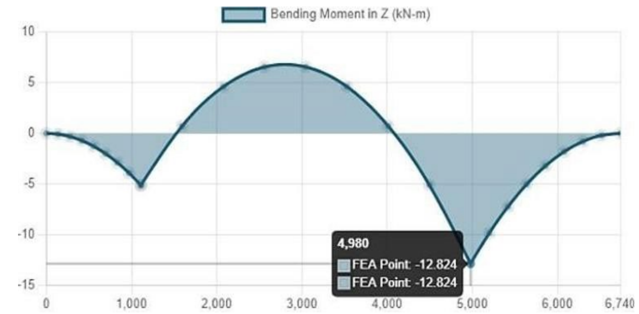


Fig. 4. Bending Moment Diagram

The shear forces are calculated as: $V_A = V_B = 0$
Vmax = VD = 18017.451 N = 18.01kN

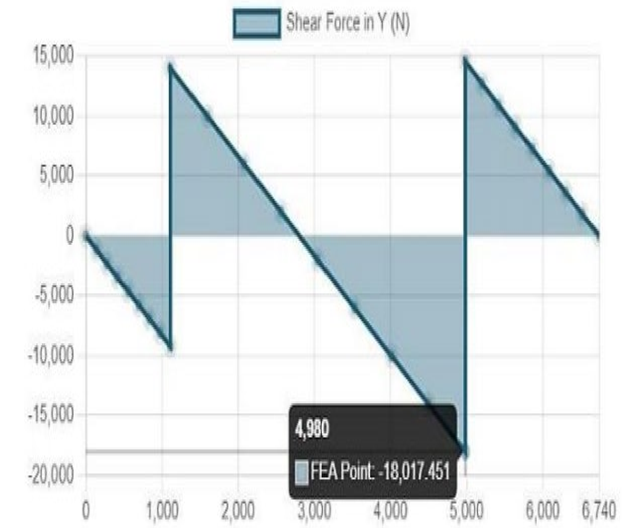
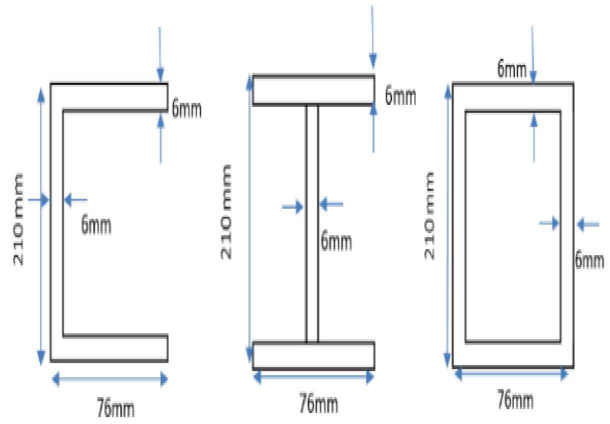


Fig. 5. Shear Force Diagram

F. Section Properties for Different Channels –
For C-Channel we have:
Using Moment of inertia formula for rectangular geometry
I = bh3 /12 (1)
Here, we subtract the moment of inertia ofsmall rectangle from whole rectangle to get the required C-shape.
Ix = 13372380 mm4
Iy = 1074560 mm4
J = Ix + Iy = 14446940 mm4

Similarly for I and Hollow Rectangular Geometry we have:
For I channel we have :
Ix = 13372380 mm4
Iy = 442540 mm4
J = Ix + Iy = 13814920 mm4

For Hollow rectangular channel we have :
Ix = 17253576 mm4
Iy = 3356700 mm4
J = Ix + Iy = 20610276 mm4



(a) (b) (c)
Fig. 6. (a) C channel (b) I channel (c) Rectangular Channel

Now for first moment of area
$Q = (A1 * y1) + (A2 * y2)$ (2)
Therefore, we have :
QC = 75915mm3
QI = 75915mm3
QR = 105318mm3

G. **Bending, Torsion and Tranverse Shear Stress –**
The formulas for Bending, Torsion and Transverse shear stressare given by:
σB =(M *y) /I (3)
τTorsion =(G*J*φ) /L (4)
τTrasnverse =(V*Q)/(I*t) (5)

Now For C channel:
σB = 100.69 MPa
τTorsion = 155.36 Mpa
τTrasnverse = 17.04 Mpa

Now For I channel:
σB = 100.69 MPa
τTorsion = 155.36 Mpa
τTrasnverse = 17.04 Mpa

Now For Rectangular channel:
σB = 78.043 MPa
τTorsion = 155.36 Mpa
τTrasnverse = 9.615 Mpa

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Now for equivalent Von Misses we have:

Now,
Von Misses = $(\sigma^2+3\tau^2)^{1/2}$ (6)
And the boundary conditions are given by:

Von Misses$_C$ = 287.316 Mpa
Von Misses$_I$ = 287.316 Mpa
Von Misses$_R$ = 280.18 Mpa

III. EXPERIMENT AND RESULT

For FEA we used Ansys. Both the solid modelling, and FEA have been done in Ansys. The solid models were created in Space Claim geometry option and were analyzed in the model option.

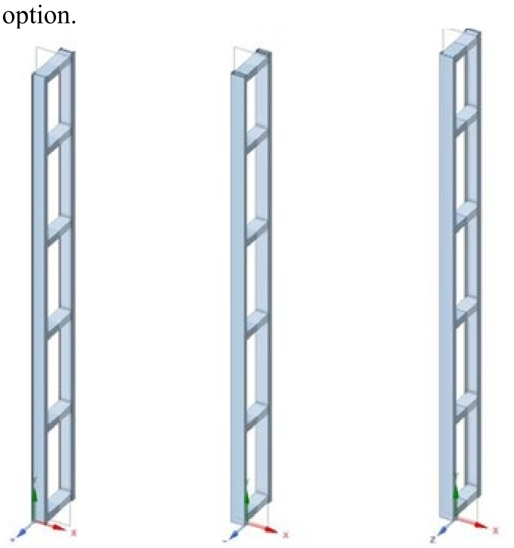


Fig. 7. Solid Models for Truck Ladder Chassis

The total meshing has been done with 67148 modes and 34130 tetrahedral elements. The following figures show meshing and the boundary conditions.

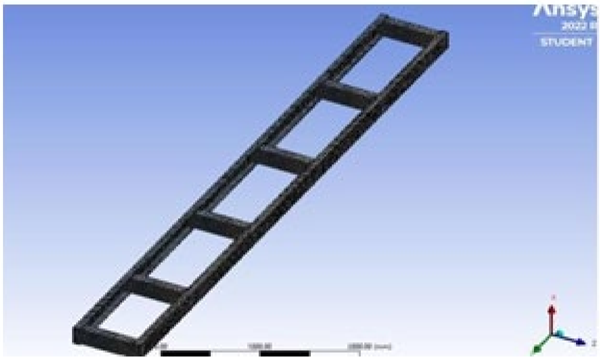


Fig. 8. Meshed Model for Chassis

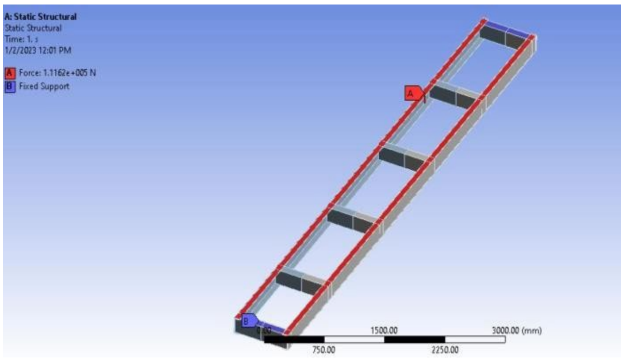
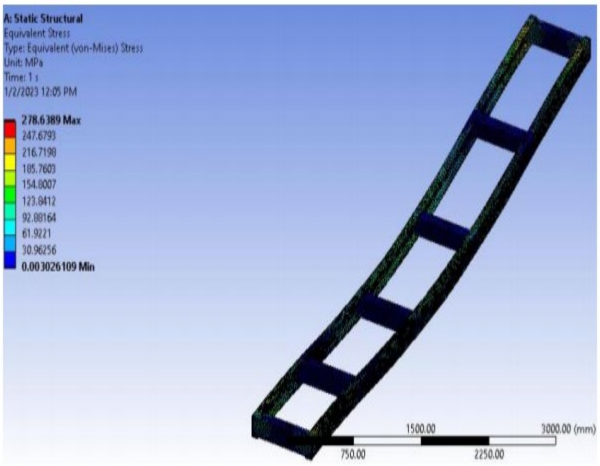
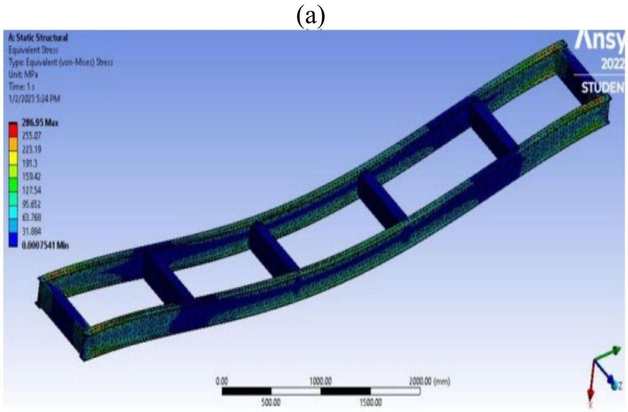


Fig. 9. Boundary Conditions

The Final Results are yielded as follows:



(a)



(b)

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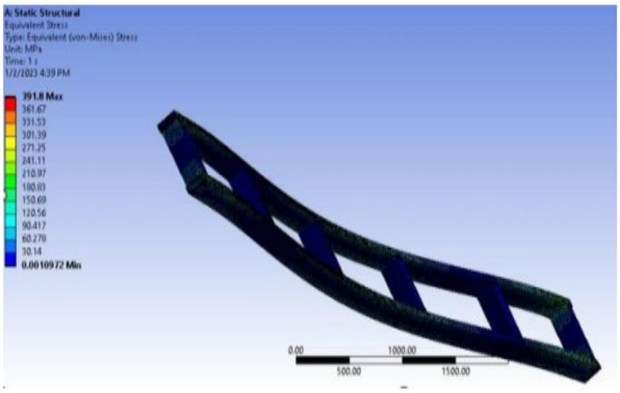
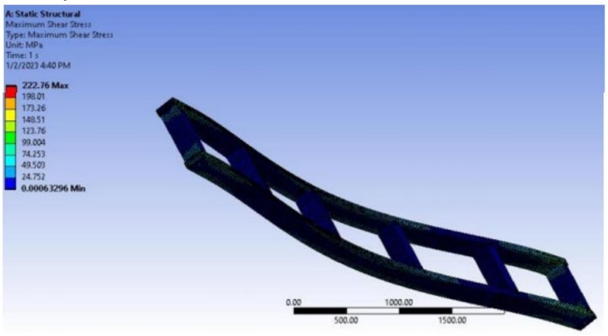


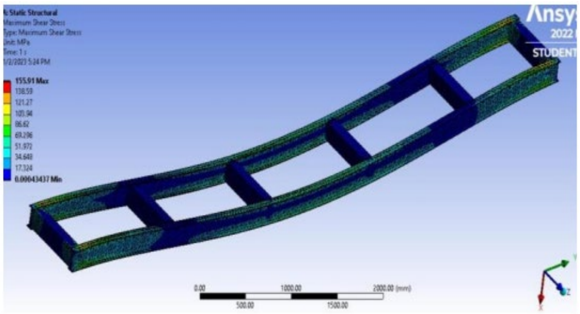
(c)

Fig. 10. (a) C Channel (b) I Channel (c) Hollow Rectangle

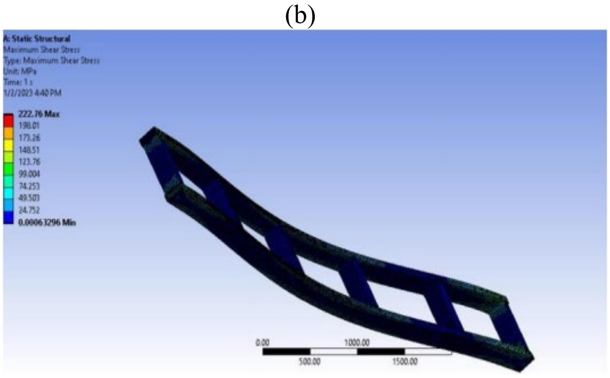
Similarly the Shear Stresses are as follows:



(a)



(b)



(c)

Fig. 11. (a) C Channel (b) I Channel (c) Hollow Rectangle

Now for FEA results of stresses it is pretty evident that the results are very similar to that of theoretical stresses with a very little error. The table for theoretical and FEA stresses can give us a good understanding of the whole scenario. Also, the Factor of safety is calculated using maximum energy distortion theory.

Table -1 Theoretical Results

Cross Section	Von Misses	Shear Stress
C channel	287.316	163.31
I channel	287.316	163.31
Hollow Rectangle	280.18	160.19

Table -2 FEA Results

Cross Section	Von Misses	Shear Stress
C channel	278.3689	148.5
I channel	286.95	155.91
Hollow Rectangle	391.8	222.76

Table -3 Theoretical Factor of Safety

Cross Section	Factor of Safety
I channel	1.44
C Channel	1.44
Rectangular Channel	1.48

Table -4 FEA Factor of Safety

Cross Section	Factor of Safety
I channel	1.49
C Channel	1.45
Rectangular Channel	1.0045

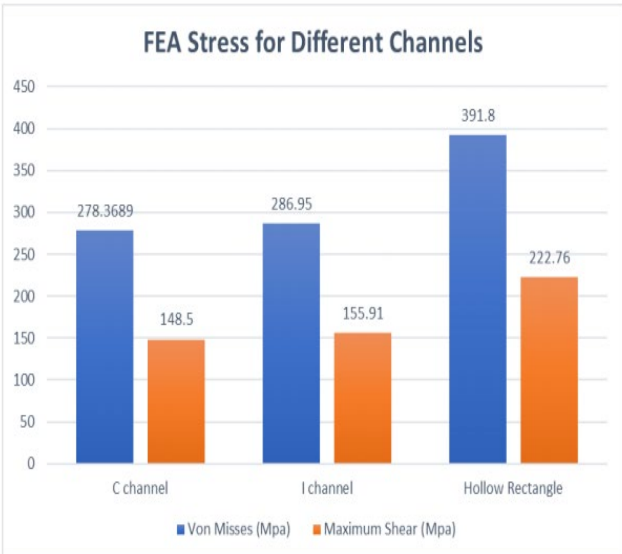


Fig. 10. FEA Results

IV. CONCLUSION

The report involved the analysis of Hino 840 Series truck ladder chassis. The results prove that the minimum stresses occur in C channel chassis and the maximum occur in the Hollow rectangular channel chassis as per the Finite Element Analysis result. Following are the points which conclude our result:

I. All the geometries are safe under the loadassumptions.
II. The analytical result shows that the factor of safety is greater for hollow rectangle and the analytical result showed that the factor of safety is greater for C channel.
III. Maximum shear stress is the lowest for C channelboth in analytical and FEA results.
IV. The Von Misses stresses are also the lowest for C channel as per FEA results,

As per our Analysis the best section for ASTM 710 Steel Chassis is the C channel Ladder chassis. The C channel Truck Ladder Chassis has low Von misses and Shear stresses and hasa good factor of safety.

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