Design Modification of Ladder Chassis Frame

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***Abstract-* Research work describes analysis of ladder chassis frame for Ashok Leyland truck Model No. IL super 3118. Practically load distribution on the chassis is not uniform across its total area, so according to the intensity of load it is possible to vary the area of ladder chassis. Analyzing the effect of reduction in cross section area with constrains of bending stress, shear stress and deflection, reduction in area will save amount of material required for ladder chassis. Four different cases are considered and in each case height is reduced for some specific span of chassis where intensity of load is less. Reduction of area for some specific span will distribute nearly uniform stresses across its whole area. The research work is carried out on side member of ladder chassis particularly.**

Index Term- Cross section area, Ladder chassis, Side member, Weight Reduction.

I. INTRODUCTION

Automotive chassis is a skeletal frame on which various mechanical parts like engine, tires, axle assemblies, brakes, steering etc. are bolted. The chassis is considered to be the most significant component of an automobile. It is the most crucial element that gives strength and stability to the vehicle under different conditions. Automobile frames provide strength and flexibility to the automobile. The backbone of any automobile, it is the supporting frame to which the body of an engine, axle assemblies are affixed. Automotive frames are basically manufactured from steel. It provides strength needed for supporting vehicular components and payload placed upon it. It is usually made of a steel frame, which holds the body and motor of an automotive vehicle. At the time of manufacturing, the body of a vehicle is flexibly molded according to the structure of chassis.

A. Ladder Frame

So named for its resemblance to a ladder, the ladder frame is one of the simplest and oldest of all designs. It consists of two symmetrical beams, rails or channels running the length of the vehicle and several transverse cross members connecting them. [8]

B. Backbone tube

A backbone chassis is a type of automobile construction chassis that is similar to the body-on-frame design. Instead of a two-dimensional ladder type structure, it consists of a strong tubular backbone (usually rectangular in cross section) that connects the front and rear suspension attachment areas. A body is then placed on this structure. [8]

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C. Monocoque

Monocoque is a structural approach whereby loads are supported through an object's external skin, similar to an egg shell. The technique may also be called structural skin. The word monocoque is a French term for "single shell". Monocoque Chassis is a one-piece structure that prescribes the overall shape of a vehicle. This type of automotive chassis is manufactured by welding floor pan and other pieces together. Since monocoque chassis is cost effective and suitable for robotized production, most of the vehicles today make use of steel plated monocoque chassis. [8]

II. LITERATURE REVIEW

P. S Madhu., T. R. Venugopal RADIOSS is used as solver for the analysis, they found that location of maximum Von Misses stresses and maximum shear stresses are just near the support and at the joining portion of connecting plates and side rail. These stresses can be minimized by relocating the position of the cross members and deflection of the chassis side members can be reduced considerably. [1]

H. Patel, K. C. Panchal and C. S.Jadhav has work performed towards the optimization of the automotive chassis with constraints of maximum shear stress, equivalent stress and deflection of chassis. For optimization of chassis different cross sections are selected by changing the height and width of side members and cross members. [2]

K. I. Swami, Prof. S. B. Tuljapure considered Eicher 20.16 ladder chassis and they have studied the effect of varying thickness on chassis. They found that at the free end of beam highest deformation has occurred leading to lowest stresses. Deformation and stresses are directly proportional to load applied. As the thickness of cross members increases there is decrease in von misses stress and deformation. [3]

J. S. Nagaraju, U. H. Babu has replaced the traditional material of chassis i.e. steel & Aluminum with Composite Material Carbon Epoxy and E glass Epoxy. By observing structural Analysis results the stress values for Carbon Epoxy and E glass Epoxy are less than their respective allowable stress values. So using composite for chassis the weight of the chassis reduced 4 times than by using steel because density of steel is more than the composites. [4]

H. B. Patil, S.D. Kachave and E. R. Deore have selected ladder chassis of truck. They have selected different thicknesses for cross members and side members of truck. They have suggested that in order to achieve a reduction in the magnitude of stress at critical point of the chassis frame, side member thickness, cross member thickness and position of cross member from rear end were varied. Finally they have suggested that to change the thickness of cross member at critical stress point than changing the thickness of side member and position of chassis for reduction in stress values and deflection of chassis. [5]

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K. Rajasekar, Dr. R. Saravanan study reviewed the literature on chassis design. After a careful analysis of various research studies they found that sufficient studies have not been conducted on variable section chassis concept. [6]

A. Singh, V. Soni, A. Singh has carried out study on ladder chassis for higher strength. The research paper describes Structural analysis & optimization of vehicle chassis with constraints of maximum shear stress and deflection of chassis under maximum load. The dimensions of an existing vehicle chassis of a TATA LP 912 Diesel BS4 bus is taken for analysis. The four different vehicle chassis have been modeled by considering four different cross-sections. Namely C, I, Rectangular Box (Hollow) and Rectangular Box (Intermediate) type cross sections. From the results, they observed that the Rectangular Box (Intermediate) section is having more strength full than the conventional steel alloy chassis with C, I and Rectangular Box (Hollow) section. [7]

III. PROBLEM STATEMENT

From the literature survey it is observed that strength is prime important point for vehicle chassis design if possible with reduced weight. The load acting on the chassis is not uniform across its total area. Due to non-uniform loading on the chassis generated stresses are not uniform across its total area. But where the intensity of load is less unnecessarily extra material is provided.

IV. OBJECTIVE

The objective of research work is design the ladder chassis according to the application of load on it. It is observed that some area of the chassis comes under heavy load and remaining part of it under low load. The generation of stresses will be according to the applied load on the chassis i.e. in some area of chassis magnitude of stresses will be high and remaining portion of chassis will be under low stresses.

Consider these conditions.

1. Design the chassis by considering its existence dimensions. It will give the magnitude of stresses and deflection which is generating in the chassis.
2. Reduce the area where intensity of stress is less.
3. Generated stresses and deflection after reducing area must be less than its allowable limit.
4. Calculate amount of weight reduction after reducing the area.

V. METHODOLOGY

In order to achieve objective the following methodology is selected.

1. Ashok Leyland truck Model No. IL super 3118 considering here for design.
2. Basically work of this research is concentrated on side member of ladder chassis.
3. Need to find maximum and minimum load intensity on the chassis.
4. By taking existing dimensions of chassis, need to find its bending stresses, shear stresses and deflection under the application of applied load.
5. Need to make necessary changes in cross section area of chassis according to applied load. And redesign changed cross section chassis for bending stress, shear stress and deflection. For safe design generated stresses and deflection should be less than allowable limit.

VI. CASE STUDY

A. Input Data

Material of Chassis is steel 52

Young's Modulus = 2 X 10^5 N/mm^2

Poisson's Ratio = 0.3

Density = 7860 kg/m^3

Yield Strength = 250 N/mm^2

Factor of Safety = 2.5

Allowable Bending Stress = 250/2.5 = 100 N/mm^2

Allowable shear stress = 55 N/mm^2

The load is calculated using figure.1

Kerb Weight = 6990 kg

Payload = 24010 kg

Total Load Carrying Capacity of Ladder Chassis = 31000 kg

Consider overload of 25% on span AE= 31000 X 1.25

= 38750 kg

Total Load on one side member for the span AE

= 38750/2 = 19375 kg =190068.75 N = 190.06 kN

UDL = 25.89 kN/m

Total load on Span EG = 6990 Kg

Consider overload of 25% on span EG

Total load acting on span EG = 6990 X 1.25 = 4368.75 kg

Total load on one side member = 6990/2 = 3495 kg

= 42857.43 N = 42.85 kN

UDL = 19.84 kN/m

B. Case-I

Moment of inertia for the section X-X is calculated using figure. 2

I_{x-x} = 7.725X10^{-5} m^4

Moment of inertia for the Section N-N is calculated using figure. 3

I_{N-N} =3X10^{-5} m^4

Bending Moment Calculations

Apply the theorem of three moments for each span in side member and find out the bending moments

M_A= 0

M_B = 33.13 kN-m

M_C = -7.82 kN-m

M_D = 21.59 kN-m

M_E = 12.28 kN-m

M_F = 2.78 kN-m

M_G= 0

Support Reaction

R_B = 92.29 kN

R_C= -23.65 kN

R_D = 83.14 kN

R_E = 65.20 kN

R_F = 15.9 kN

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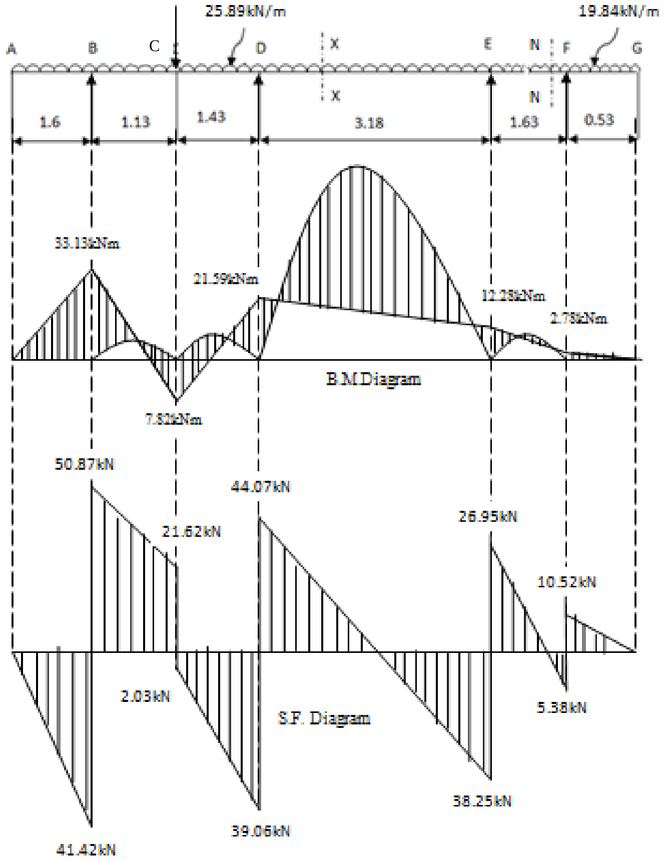

Figure.1 Distribution of load on side member

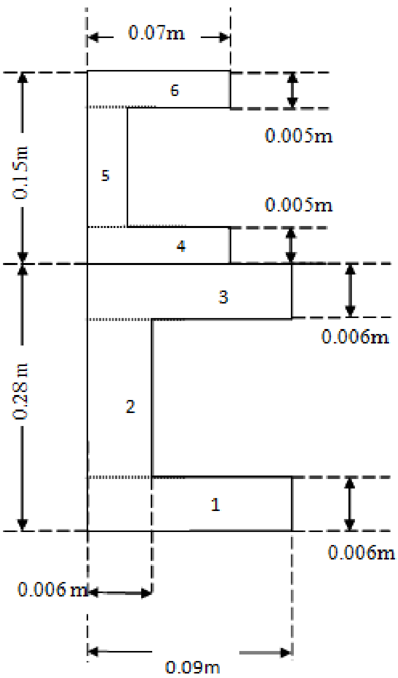

Figure.2 Section X-X of the span AE

Shear Analysis
S.F. at A = 0
S.F. on LHS of B = - 41.42kN
S.F. on RHS of B = 50.87kN
S.F. on LHS of C = 21.62kN
S.F. on RHS of C = -2.03kN

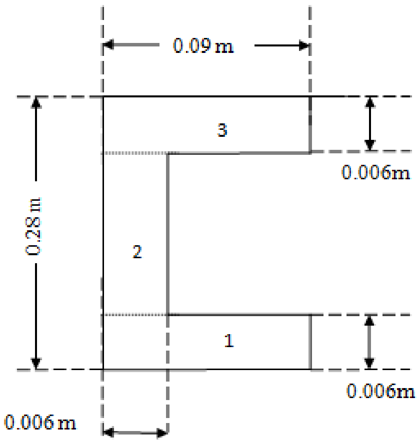

Figure.3 Section N-N of the span EG

S.F. on LHS of D = -39.06kN
S.F. on RHS of D = 44.07kN
S.F. on LHS of E = -38.25kN
S.F. on RHS of E = 26.95kN
S.F. on LHS of F = -5.38kN
S.F. on RHS of F = 10.52kN
S.F. at G = 0
Stress Calculations
Bending stress for span AE = 93.06 N/mm^2
Shear stress for span AE= 12.46 N/mm^2
Bending stress for span EG = 57.53 N/mm^2
Shear stress for span EG = 14.27 N/mm^2
Deflection Calculations
Deflection of span DE = 2.23mm
Deflection of span EF = 0.0003 mm
Deflection of Cantilever FG = 0.032 mm
All values for stresses and deflection are within limit.

C. Case-II

The result of first case it shows that the generated stresses in span AE are much closer to the allowable limit of stresses so do not have scope to make any modification for span AE (i.e cross section X-X in first case) but for span EG generated stresses and deflection are much less than allowable limit of stresses and deflection. So it is possible to reduce the area for span EG (i.e cross section N-N in first case).

Reduce height of span EG from 0.28m to 0.19m so section N-N becomes section P-P in second case and section X-X will be same for span AE.

Moment of inertia for the section X-X is calculated using figure. 2

$I_{x-x} = 7.725X10^{-5}\ m^4$

Moment of inertia for the Section P-P is calculated using figure. 5

$I_{P-P} = 1.185 \times 10^{-5}\ m^4$

Bending Moment Calculations

Apply the theorem of three moments for each span of side member and find out the bending moments

$M_A = 0$
$M_B = 33.13$ kN-m
$M_C = -8.17$ kN-m
$M_D = 22.82$ kN-m
$M_E = 8.86$ kN-m
$M_F = 2.78$ kN-m

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$M_G = 0$

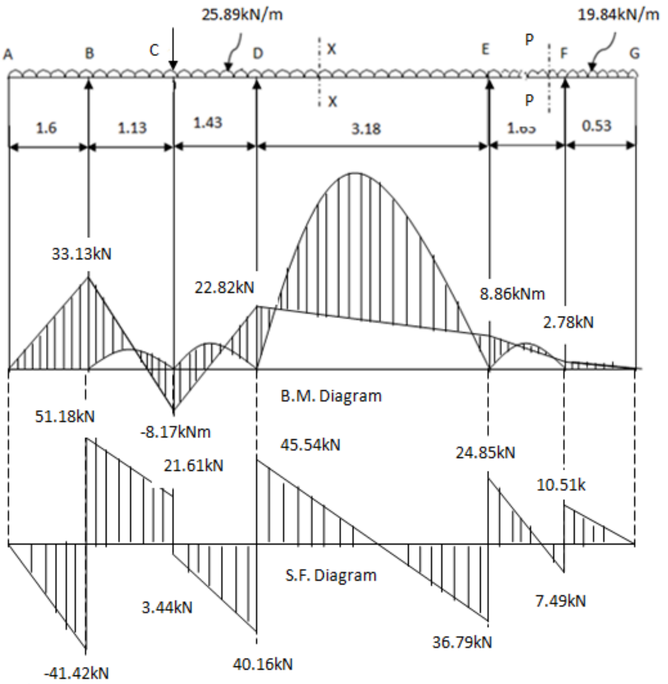

Figure.4 Distribution of load on side member

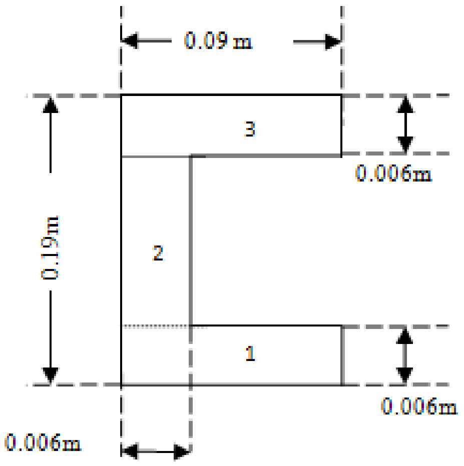

Figure.5 Section P-P of the span EG

Support Reaction

R_B = 92.60 kN

R_C = -25.06 kN

R_D =85.70 kN

R_E = 61.64 kN

R_F = 18kN

Shear Analysis

S.F. at A = 0

S.F. on LHS of B = -41.42 kN

S.F. on RHS of B = 51.18 kN

S.F. on LHS of C = 21.61 kN

S.F. on RHS of C = -3.44 kN

S.F. on LHS of D = - 40.16 kN

S.F. on RHS of D = 45.54 kN

S.F. on LHS of E = -36.79 kN

S.F. on RHS of E = 24.85 kN

S.F. on LHS of F = -7.49 kN

S.F. on RHS of F = 10.51 kN

S.F. at G = 0

Stress Calculations

Bending stress for span AE = 93.06 N/mm^2

Shear stress for span AE = 12.54 N/mm^2

Bending stress for span EG = 71.02 N/mm^2

Shear stress for span EG =17.12 N/mm^2

Deflection Calculations

Deflection for span DE = 2.23 mm

Deflection for span EF = 0.769 mm

Deflection for cantilever FG = 0.082 mm

All values for stresses and deflection are within limit.

D. Case-III

Reduce height of span EG from 0.19m to 0.15m so section P-P becomes section R-R in third case and section X-X will be same for span AE.

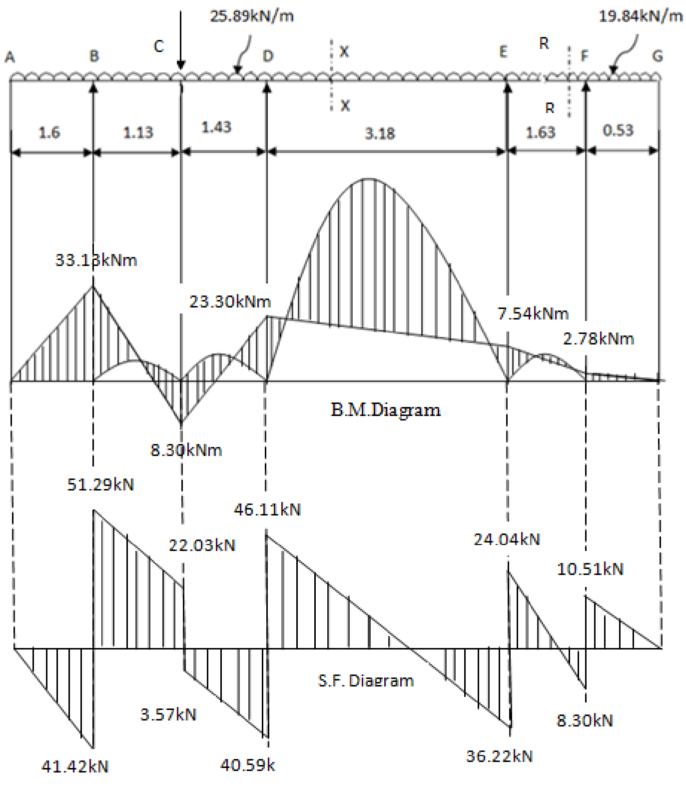

Figure.6 Distribution of load on side member

Moment of inertia for the section X-X is calculated using figure. 2

$I_{x\text{-}x} = 7.725 \times 10^{-5}\ m^4$

Moment of inertia for the section R-R is calculated using figure. 7

$I_{R\text{-}R} = 7.01 \times 10^{-6}\ m^4$

Bending Moment Calculations

Apply the theorem of three moments for each span of side member and find out the bending moments

$M_A = 0$

M_B = 33.13 kN-m

M_C = -8.30 kN-m

M_D = 23.30 kN-m

M_E = 7.54 kN-m

M_F = 2.78 kN-m

$M_G = 0$

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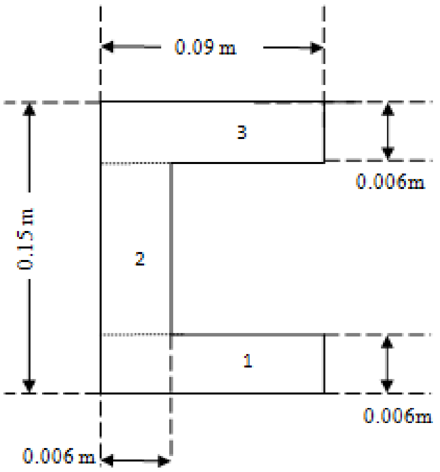

Figure.7 Section R-R of the span EG

Support Reaction
R_B = 92.71 kN
R_C = -25.60 kN
R_D =86.70 kN
R_E = 60.26 kN
R_F = 18.81 kN
Shear Analysis
S.F. at A = 0
S.F. on LHS of B = - 41.42kN
S.F. on RHS of B = 51.29kN
S.F. on LHS of C = 22.03kN
S.F. on RHS of C = -3.57kN
S.F. on LHS of D = - 40.59kN
S.F. on RHS of D = = 46.11kN
S.F. on LHS of E = -36.22kN
S.F. on RHS of E = = 24.24kN
S.F. on LHS of F = - 8.30
S.F. on RHS of F = 10.51kN
S.F. at G = 0
Stress Calculations
Bending stress for span AE = 93.06 N/mm^2
Shear stress for span AE = 12.57 N/mm^2
Bending stress for span EG = 80.67 N/mm^2
Shear stress for span EG =18.98 N/mm^2
Deflection Calculations
Deflection for span DE = 2.23 mm
Deflection for span EF =1.3 mm
Deflection for cantilever FG = 0.13 mm
All values for stresses and deflection are within limit.

E. Case-IV

Reduce height of span EG from 0.15m to 0.12m so section R-R becomes section S-S in third case and section X-X will be same for span AE.
Moment of inertia for the section X-X is calculated using fig. 2.
$I_{x\text{-}x}$ = 7.725X10^{-5} m^4
Moment of inertia of section S-S is calculated using fig. 9
$I_{S\text{-}S}$ = 4.15 X 10^{-6} m^4
Bending Moment Calculations
M_A= 0
M_B = 33.13 kN-m
M_C = - 8.39 kN-m
M_D = 23.62 kN-m
M_E = 6.66 kN-m
M_F = 2.78 kN-m
M_G= 0
Support Reaction
R_B = 92.79kN
R_C = -25.97kN
R_D =87.37kN
R_E = 59.34kN
R_F = 19.35kN

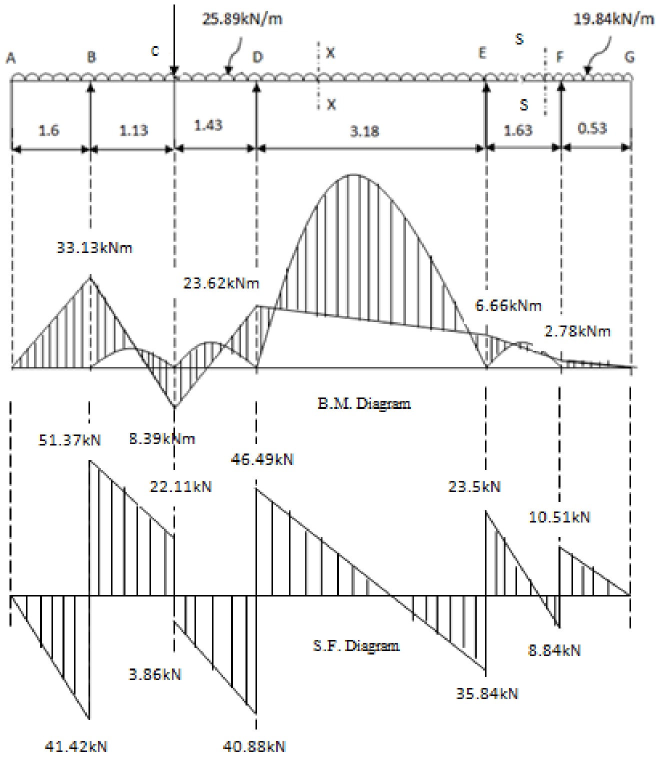

Figure .8 Distribution of load on side member

Shear Analysis
S.F. at A = 0
S.F. on LHS of B = - 41.42kN
S.F. on RHS of B = 51.37kN
S.F. on LHS of C = 22.11kN
S.F. on RHS of C = -3.86kN
S.F. on LHS of D = - 40.88kN
S.F. on RHS of D = 46.49kN
S.F. on LHS of E = -35.84kN
S.F. on RHS of E = 23.50kN
S.F. on LHS of F = - 8.84
S.F. on RHS of F = 10.51kN

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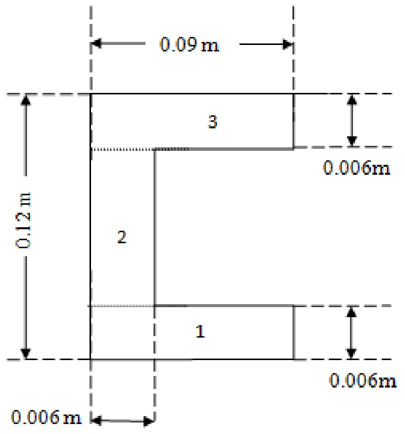

Figure. 9 Section S-S of the span EG

S.F. at G = 0
Stress Calculations
Bending stress for span AE = 93.06 N/mm^2
Shear stress for span AE = 12.59 N/mm^2
Bending stress for span EG = 96.28 N/mm^2
Shear stress for span EG = 20.74 N/mm^2
Deflection Calculations
Deflection for span DE = 2.23 mm
Deflection for span EF = 2.19 mm
Deflection for cantilever FG = 0.23mm
It is observed from fourth case that generated stresses in side member of the ladder chassis are much closer to the permissible stresses. More reduction in area lead to unsafe design of it, so maximum reduction in area is possible up to fourth case only i.e it is possible to reduce the height of side member from 0.28m to 0.12m for the span EG.

VII. WEIGHT REDUCTION

As area is decreasing from case-I to case-IV reduction in weight is possible. Which ultimately save the required material of the chassis.
Weight of Existing cross section for the side member of chassis (Case-I)
Volume of the span AE = Length X Area
= 7.34 X (4.088 X 10^{-3})
= 0.03 m^3
Volume of the span EG = Length X Area
= 2.16 X 2.68 X 10^{-3}
= 5.80 X $10^{-3} m^3$
Total Volume of unchanged cross section
= 0.03 + (5.80 X 10^{-3}) = 0.0358 m^3
Mass Density = Mass/ Volume
7860 = Mass/ 0.0358
m = 281.38 kg…………….(m= Mass)
Weight of changed cross section for the side member of chassis (Case-IV)
Volume of the span AE = Length X Area
= 7.34 X (4.088 X 10^{-3})
= 0.03 m^3
Volume of the span EG = Length X Area
= 2.16 X 1.728 X 10^{-3}
= 3.73X $10^{-3} m^3$
Total Volume = 0.03 + (3.73 X 10^{-3})
= 0.033 m^3
Mass Density = Mass/ Volume
7860 = Mass/ 0.033
m = 259.38 kg
Mass of changed section in percentage
= 259.38 / 281.38 = 92.18%
Percentage saving in mass = (100-92.18) = 7.81%

VIII. RESULT

Results shown below are only for span EG where change in cross section area is observed in each case. For span AE no any changes in cross section because generated stresses are already much closer to the allowable stress limit. So generated stresses will be same in second, third and fourth cases as observed in first case (original cross section) for span AE.

TABLE.I
Comparison of Results

Sr No	Cases	Bending Stress (N/mm^2)	Shear stress (N/mm^2)	Deflection (mm)	
				Span EF	Span FG
1	I	57.53	14.27	0.0003	0.032
2	II	71.02	17.12	0.769	0.082
3	III	80.67	18.98	1.3	0.13
4	IV	96.28	20.74	2.19	0.23

IX. CONCLUSION

a) Comparison of results revel that as area is decreasing the generated stresses in side member of ladder chassis are increasing but it is within allowable limit of stresses.
b) The deflection values calculated are within limit.
c) Reduction in height of span EG is possible up to fourth case i.e from 0.28m to 0.12m.
d) It helps to reduce the area for the span EG and finally material saving is possible up to 7.81%.

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REFERENCES

[1] P. S .Madhu and T. R. Venugopal, "Static Analysis, Design Modification and Modal Analysis of Structural Chassis Frame," *International Journal of Engineering Research and applications*. Vol.4, pp.06-10, Issue 5 (Version 3), May2014.
[2] H. Patel, K. C. Panchal and C. S. Jadhav, "Structural Analysis of Truck Chassis Frame and Design Optimization for Weigh Reduction," *International Journal of Engineering Advanced Technology (IJEAT)*, Volume-2, Issue -4, April-2013.
[3] K. I. Swami and Prof. S. B. Tuljapure, "Effect of Torque on Ladder Frame Chassis of Eicher 20.16," *Int. Journal of Engineering research and Applications*, Volume 4, Issue 2(Version 1), February 2014.
[4] J. S. Nagaraju, U. H. Babu, "Design and Structural Analysis of Heavy Vehicle Chassis Frame Made of Composite Material by Varying Reinforcement Angles of layers," *International journal of Advance Engineering research and studies*, Vol.1, Issue 2, January-March, 2012.

[5] H. B. .Patil, S. D .Kachave and E. R. Deore, “Stress Analysis of Automotive Chassis with Various Thicknesses,” IOSR *Journal of Mechanical and Civil Engineering (IOSR-JMCE),* Volume 6, PP 44-49, Issue 1 (Mar. - Apr. 2013).

[6] K. Rajasekar and Dr. R. Saravanan, “Literature Review on Chassis Design of On-Road Heavy Vehicles” *International Journal of Innovative Science, Engineering & Technology*, Vol. 1 Issue 7, September 2014.

[7] A. Singh, V. Soni, A, Singh, “Structural Analysis of Ladder Chassis for Higher Strength,” *International Journal of Emerging Technology and Advanced Engineering,* Volume 4, Issue 2, February 2014.

[8] Strength of Materials by S. Ramamrutham.

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