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Structural Integrating Of Ladder Type Heavy Load Automotive Chassis and Its Optimization

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Abstract - *Chassis is used to denote the frame parts or main structure of vehicle, which is now, denotes the whole vehicle except body in case of heavy vehicles. The present study has analyzed the various literatures. After a careful analysis of various research studies conducted so for it has been found that there is the scope of optimizing different factors like weight, stress-strain values and deformation etc. by creating a slot in the chassis frame we can reduce the weight of the chassis. This paper describes the design and Structural analysis of the heavy vehicle chassis with constraints of maximum stress and deflection of chassis under maximum load. In the present work, the dimension of the Mercedes-Benz-Truck chassis is used for the structural analysis of the heavy vehicle chassis by considering "C" type section subjected to the Loading. A three dimensional solid Modeled in the CAE software CATIA and analyzed in ANSYS. The numerical results are validated with analytical calculation considering the stress distribution and deformation. After Validation, we create a slot in the Chassis frame to reduce the weight of the chassis frame. In Ansys software optimization of the slot is carried out.*

Key Words: **Heavy truck chassis frame, CATIA, ANSYS, FEM, stress, deformation.**

1. INTRODUCTION TO CHASSIS

Chassis is the French word was used to denote the frame parts or main structure of vehicle, which is now, denotes the whole vehicle except body in case of heavy vehicles (that is vehicle without body is called chassis). In case of light vehicles of mono construction, it denotes the whole vehicle except additional fittings in the body.

Types of Chassis

a. Ladder Chassis
b. Tubular Space Frame
c. Monocoque
d. ULSAB Monocoque
e. Backbone Chassis
f. Glass-Fiber body
g. Carbon-Fiber Monocoque
h. Aluminum Space Frame
i. Lotus Elise

In this project we consider the Ladder type Chassis for analysis and modification.

2. METHODOLOGY

2.1 FEA PROCEDURE IN CATIA AND ANSYS

1) The geometry details of the Chassis are obtained by the 3D model giving by the company.
2) The preliminary changes are made using CATIA-V5R20
3) The preliminary geometry is again
Refined by giving proper fillets and
champers and the CAD model is finalized. 4) This CAD model is exported in the form of neutral file such as step.step.igs and parasolid file.
5) This neutral file is imported into preprocessing software like ANSYS for meshing.
6) Once the geometry is imported into an ANSYS, initially geometry cleanup is done i.e, Removing small fillets less than 2mm and holes less than 10 mm diameter to arrive at a better mesh.
7) An average element length of 5 – 6 mm is considered for meshing.
8) Wherever the features are important, (at a stress construction region) a fine mesh up to 2 mm of element size is maintained.
9) The quality parameter like war page and Jacobean are checked and maintained appropriately to give better results.
10) Material properties of steel such as young's modulus, poison's ratios and density are assigned to the structure (meshed parts).
11) Loads and boundary conditions are defined on the meshed parts by using analysis panel in the ANSYS.
12) Solve the meshed model in Ansys solver for the Von-misses stress and the Deformation
13) The Results are noted and compared with Theoretical Values.

2.2 Analytical Calculation

Physical Property of the ST37:-

Modulus of Elasticity = 210 GPa
= 2.10 x 105 N / mm^2
Density = 7850 kg/m^3

Ultimate Tensile Strength = 460 MPa
= 460 N / mm^2
Yield Strength = 260 MPa .
= 260 N / mm^2
Poisson Ratio = 0.29

S.N	Parameter	Values
1	Total length of the chassis	8436.64mm
2	Wheel Base	5715.765mm
3	Front Overhang	1214.63mm
4	Rear Overhang	781.22mm
5	Payload	25Ton's

Table: 1 Specification of Existing Mercedes-Benz-Truck Chassis frame

Side bar of the existing chassis frame are made from "C" Channels with Height (H) = 290 mm, Width (B) = 100mm, Thickness (t) = 12 mm

Basic Calculation for Chassis Frame

Engine Weight + Gear Box Weight = 265.989Kg
Payload = 25000Kg
Fuel Tank + Oil Tank + Hydraulic Tank = 494.36Kg
Total Weight = 25760.34Kg
= 252708.93 N
Load acting on the single frame
= Total Load acting on the chassis / 2
= 252708.93 N/ 2
Load on each the single frame = 14.97 N/mm

Load Condition

Load acting on Entire span of the beam is 252708.93 N.
Length of the Beam is 8436.64 mm.
Uniformly Distributed Load is 252708.93 / 8436.64 = 14.97 N/mm
According to loading condition of the beam, a beam has a support of three axle means by three wheel axles C, D and E.
Total load reaction generated on the beam is as under:-
After calculation for Reactions, Bending Movement we have,

For C- Section

b =100mm, h =290mm, b1 =88mm,
h1 =266mm,
y = h /2 = 290 /2 = 145 mm
I xx = [bh^3- b1 $h1^3$] / 12
= [100* 290^3- 88* 266^3] / 12
= 65220296mm4
Z xx = I xx / y = 65220296/ 145
= 449795.144 mm3

Stress produced on the Beam

$\sigma = \frac{M}{Z}$ = -71.60 Mpa

We have E & I values as
E=2.10*e15 N/mm^2, I=65220296 mm^4

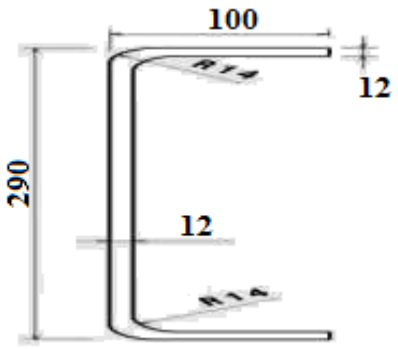

Fig-1 Main "C" section

Y_{max}= Y= $\frac{-1.097225*e14}{2.10*e15*65220296}$= -8.0112 mm

2.3 METHODOLOGY FOR MODELING AND ANALYSIS

Chassis Geometry

We Create a Chassis Geometry or Import the Chassis Geometry to the Catia Software and any modification or any unwanted parts are removed for analysis purpose.

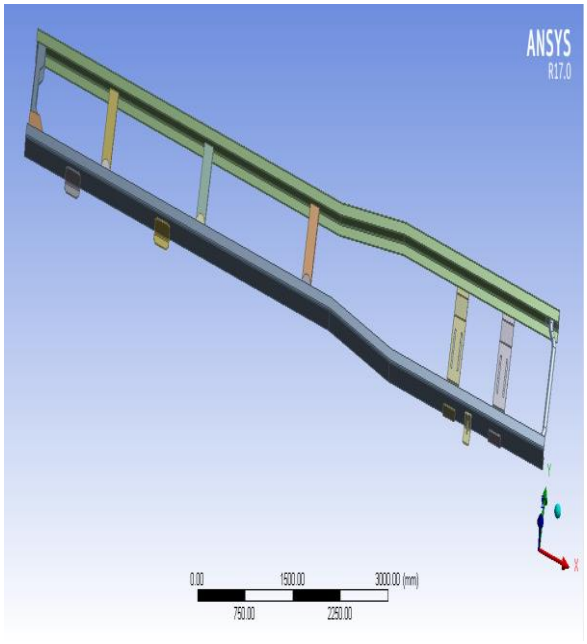

Fig-2 Chassis Geometry in Ansys

Again the Chassis geometry is import to Ansys software and removes the bolt holes and other unwanted slots and edges to get an accurate analysis.

Chassis without slot analysis

For comparing the results of theoretical and software we need to analyze only chassis without any other attachments. We remove the cross beams attached to it and only single beam is taken in to account.

A. Single Beam Geometry

Only Single Beam is considering for analysis purpose.

1. Importing geometry file into Design Modular.
2. Identifying geometry corruptions/issues.
3. Geometry repair and defeaturing.
4. Modification on extracted flow volume for ease in meshing.

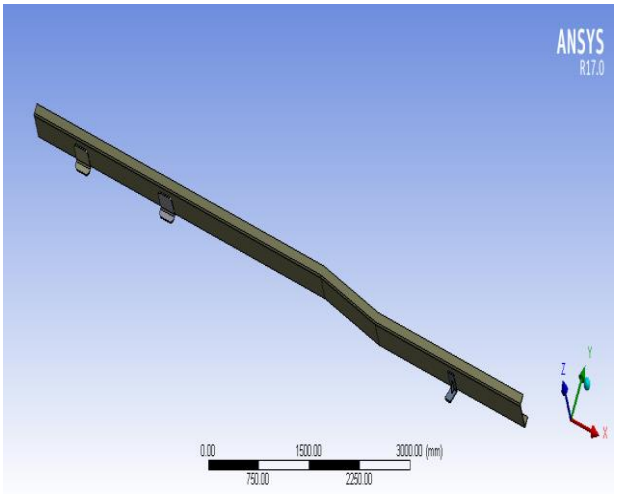

Fig-3 Single Beam Geometry

B. Meshing

Generation of meshing on component is highly complicated task but the clean meshing is not covered by other software, but the Ansys created a way for clean mesh with easy process and with approximate densities. If component has to loaded the number nodes has to known and for the better result the density has to be high for better approximation.

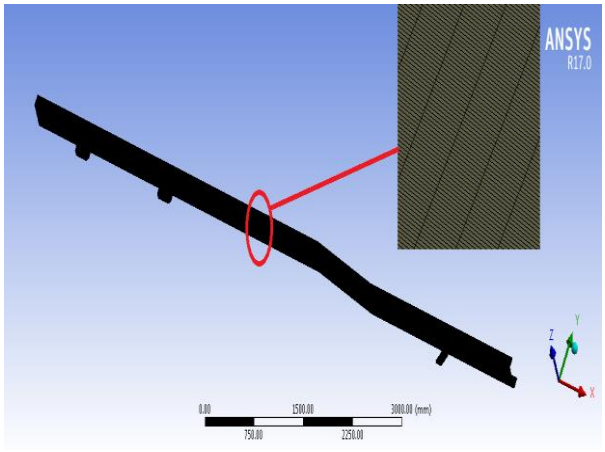

Fig-4 Meshed part in Ansys

C. Apllying Boundery Condition

a. Fixed Support

Here we fix three supports where the suspension system is attached to the chassis.

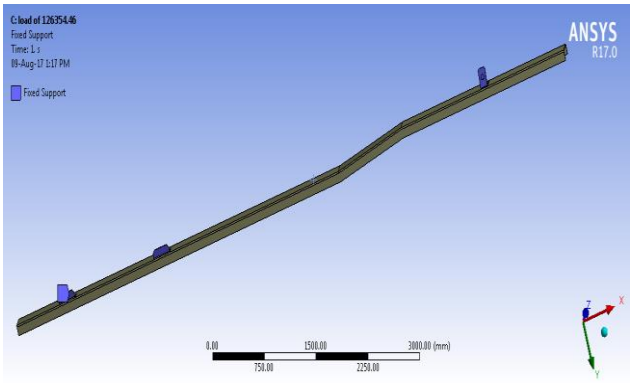

Fig-5 Fixing the Chassis

b. Load/Applying Force

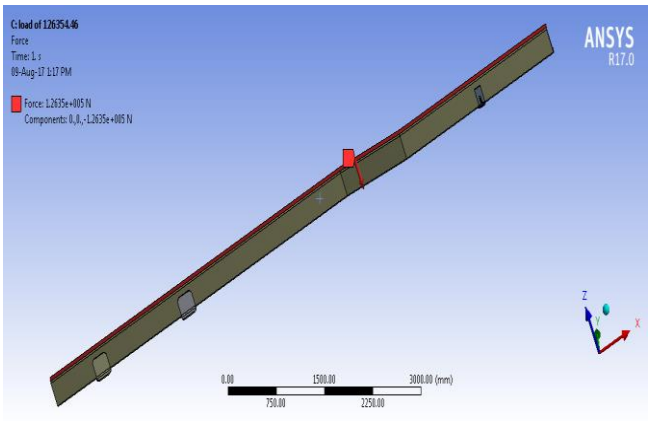

Fig-6 Load Applied on Chassis

Once the system is fully designed, the next task is to burden the system with constraints, such as supports and physical loadings. Applying a Load of 126354.465 N in the downward direction as the whole load of the Vehicle is acted on the Chassis.

D. Deformation in Chassis

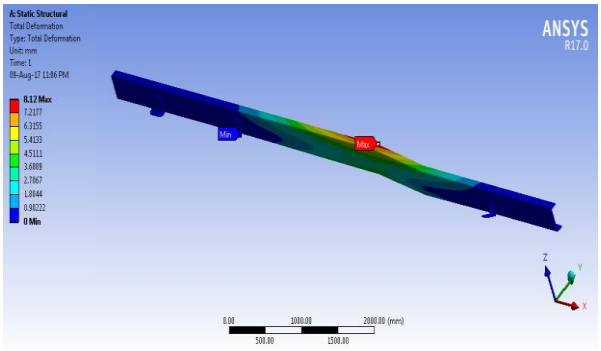

Fig-7 Deformation in Chassis

By analyzing the single beam in Ansys by applying a load of 126354.465 N we get a deformation of 8.12mm.

E. Stress in Chassis

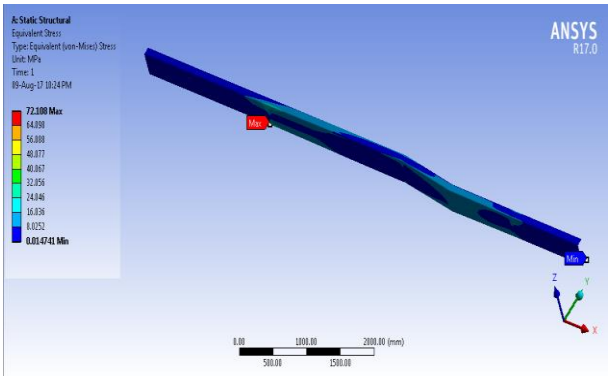

Fig-8 Stress in Chassis

We get the stress in the beam as 72.108 MPa for the load of 126354.465 N in single beam. By comparing the analytical calculated values with the analysis results.

Than the modification is carried out in the chassis to reduce the weight without effeccting to the Deformation of the chassis.

S.N	Parameter	Analytical	Ansys	% Error
1	Deformation	8.011mm	8.12mm	1.36
2	Stress	71.60MPa	72.108MPa	0.7095

Table: 2 Comparision of Results

Chassis analysis with modified chassis With slot

We are looking for reducing the Mass of the Chassis, We make a slot in the chassis where the deformation in the chassis is minimum, we create a slot which will not effect to the deformation of the Chassis.

In this process the chassis is considered with cross beams and for simplification of analysis we make a symmetry of the chassis. When we consider whole chassis there is a complecity in meshing of chassis and the analysis of the problem. But in an analysis ansys will consider the symmetry part and shows the results.

A. Modified Chassis

Geometry is modified by creating the slot in the Chassis where the deformation is Minimum.

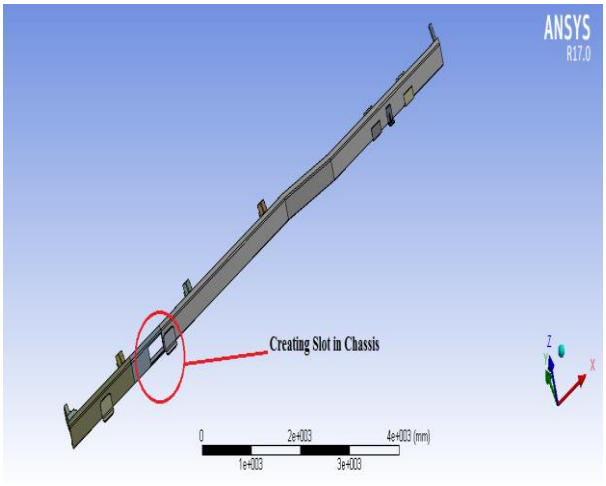

Fig-9 Modified Geometry of Chassis

B. Meshing

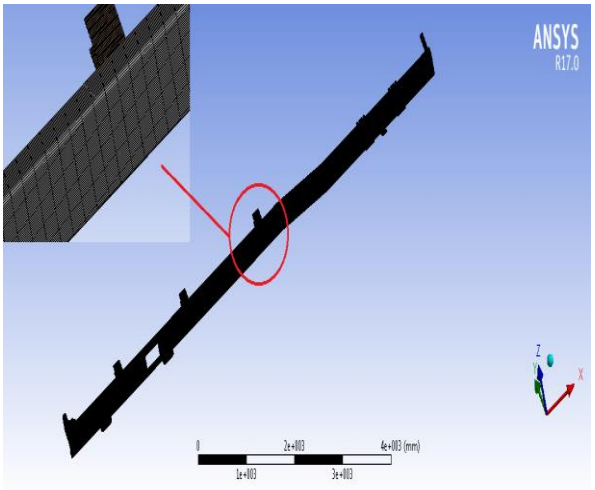

Fig-10 Meshing of Chassis

Fine Meshing is done on the beam to get accurate results.

A. Apllying Boundery Condition

a) Constaning or Fixing

Fixing the three supports where the suspension system attached to Chassis.

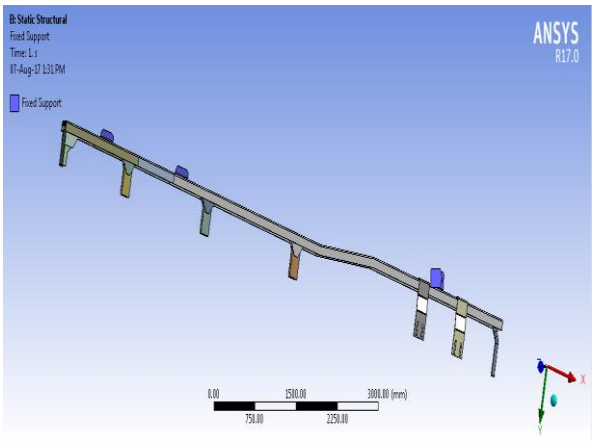

Fig-11 Fixing of Chassis

b) Loading/Applying force

Load of 126354.465 N is applied on the beam in downward direction as the whole weight acting on the chassis.

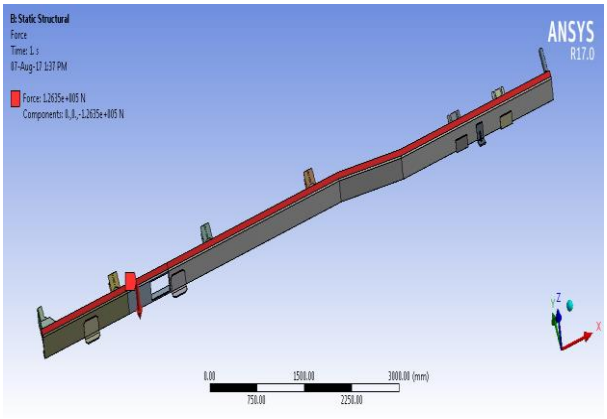

Fig-12 Loading on Chassis

3. RESULTS

Deformation in Chassis

By analyzing the beam with slot we get deformation of 5.65mm. the deformation in the chassis is less compared to single beam analysis because of the cross members consideration.

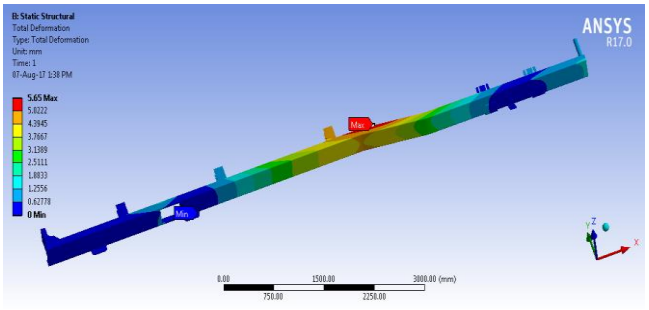

Fig-13 Deformation of Chassis

Varying the Length and Width of slot in chassis

We know vary the length and width of the slot by the use of Design Experiment in Ansys software.

Table of Schematic C2: Design of Experiments (Central Composite Design : Auto Defined)

	A	B	C	D	E
1	Name	P2 - Plane20.V6 (mm)	P6 - Plane31.H1 (mm)	P4 - Total Deformation Maximum (mm)	P5 - Geometry Mass (kg)
2	1	2	475	6.2665	457.08
3	2	1	475	5.6888	485.26
4	3	3	475	7.0018	428.69
5	4 DP 7	2	300	6.2288	460.24
6	5	2	650	6.2652	453.92
7	6 DP 3	1	300	5.65	488.74
8	7 DP 11	3	300	6.9647	431.54
9	8	1	650	5.6877	481.79
10	9	3	650	7.0002	425.85

Table: 3 Design Experiment

Optimization

Table of Schematic D2: Optimization

	A	B	C	D
1	Optimization Study			
2	Minimize P4; P4 <= 13 mm	Goal, Minimize P4 (Default importance); Strict Constraint, P4 values less than or equals to 13 mm (Default importance)		
3	Minimize P5	Goal, Minimize P5 (Default importance)		
4	Optimization Method			
5	Screening	The Screening optimization method uses a simple approach based on sampling and sorting. It supports multiple objectives and constraints as well as all types of input parameters. Usually it is used for preliminary design, which may lead you to apply other methods for more refined optimization results.		
6	Configuration	Generate 30 samples and find 3 candidates.		
7	Status	Converged after 30 evaluations.		
8	Candidate Points			
9		Candidate Point 1	Candidate Point 2	Candidate Point 3
10	P2 - Plane20.V6 (mm)	2.965	2.825	2.755
11	P6 - Plane31.H1 (mm)	549.46	596.96	406.96
12	P4 - Total Deformation Maximum (mm)	6.9735	6.8584	6.7978
13	P5 - Geometry Mass (kg)	428.47	431.66	436.8

Table:4 Optimization

This table gives the points which are best in reducing the mass of the chassis without much effecting to the total deformation of the chassis. We can see that an Ansys is suggested three points for the modification
in the slot which is created in the chassis.

4. VALIDATION

In this validation process we consider single beam without any attachment for the simplification of problem.
We can see the deformation in the slotted beam is below the single beam deformation because of cross beam consideration.

S.N	Parameter	Analytical	Ansys	% Error
1	Deformation	8.011mm	8.12mm	1.36
2	Stress	71.60MPa	72.108MPa	0.7095

Table:5 Validation

Mass of the chassis by Ansys software

S.N	Conditions	Mass(Kg)
1	Chassis without Slot	1018
2	Chassis with slot	873.6

Table: 6 Mass Comparison

Choosing the candidate point 3 in the optimization we get the weight of the chassis as 873.6Kg. We can see that the weight of the chassis is reduced by 144.4 Kg.

5. CONCLUSION

By the analysis of the single beam of the chassis in Ansys software and comparing with the analytical solution, Calculation is done by an indeterminate method.

After comparing the results our aim is to reduce the weight of the chassis by removing the material by it.

We find the area where the deformation of the chassis is zero and created a slot by removing the material from the chassis. We solve the modified design mode by Ansys software and noted done the results.

We can do the design optimization of the slot by design experiments. Or by varying the length and width of the slot. By selecting the suitable value of the slot we can design the chassis with reduced mass of 144.4 Kg.

Feature Work

a. Model analysis of modified chassis.
b. We can do the vibration analysis on the Modified chassis.
c. Fatigue Analysis of modified chassis.

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