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Design and Static Analysis of Heavy Vehicle Chassis with Different Alloy Materials at Different Optimum Load Conditions

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Abstract – *The chassis is one of the most important parts of an automotive. It is made up of an internal frame that is used to carry the vehicle under the stipulated conditions that it encounters throughout its operation. The supporting structure on which body of an engine and axle assembly are mounted is the backbone of any car. As a result, it is the most important component that provides strength and stability to the vehicle in a variety of settings. These chassis are mostly made of steel frames that support the body and engines of a vehicle. The term "chassis" refers to the frame or basic structure of a vehicle. The purpose of this work is to investigate the designing and statically structural analysis of a big vehicle chassis utilizing various alloy materials at various ideal loads. This heavy vehicle chassis will be designed in Fusion 360, CATIA V5, and structural analysis will be performed in Ansys workbench. The project's purpose is to build a better chassis that reduces total vehicle weight while increasing the performance of a big vehicle under ideal circumstances.*

Key Words: **Heavy vehicle chassis, static structural analysis, modelling, CATIA V5, Design, Fusion 360**

1. INTRODUCTION

The chassis is regarded as the most important component of a car. And it is the most important element in providing strength and stability to the vehicle under a variety of situations. The chassis, often known as the 'Frame,' is the vehicle's main support structure. It bears all of the vehicle's stresses in both static and dynamic circumstances. Every vehicle has a chassis-frame, whether it is a two-wheeler, a car, or a truck. However, its shape clearly varies depending on the vehicle type. It supports all vehicle components such as the engine, gearbox, vehicle chassis, propeller shaft, axles, tiers, fuel tank, and so on. It has cross members with varying cross sections depending on the vehicle type. I-section, C-section, and Box-type cross sections are the most common cross sections used in heavy vehicle chassis. A structural study utilizing ANSYS workbench may be used to determine the most suitable cross section for a large vehicle.

1.1 Types of Chassis:

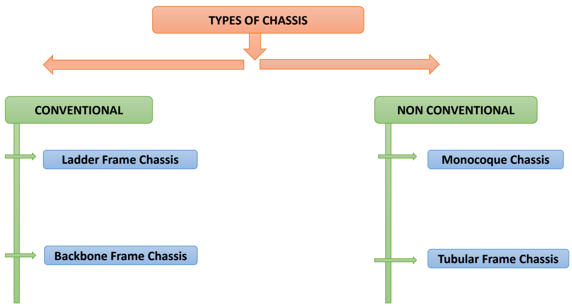

Fig -1: Chassis Types

1.2 Main Objectives:

a) 1. To analyze the different types of chassis and their selection of material
b) 2. To construct a new design from an existing one which minimizes the overall weight of the vehicle with excellent load bearing capacity
c) 3. To do static structural analysis using ANSYS workstation
d) 4. To observe the varied load circumstances.

2. METHODOLOGY AND MATERIAL SELECTION:

2.1 Methods used:

A static analysis: Static analysis is mostly used to conduct an analysis by considering the dynamic conditions and this method is used to determine various factors such as stress, deflection, strain, strain energy, volume, weight etc.
Modal Analysis: Modal analysis is the process of applying Different load conditions to the model by fixing at different locations (fixed joints were made at that place).Conditions such as front end impact, Rear impact and Central impact Front end and Rear end Twisting.

2.2 Selection of Material:

Aluminum-Alloy, Cast Iron, and Structural Steel are the materials under consideration for design and analysis. The design criteria were chosen and investigated with the goal of minimizing design outcomes in areas where aluminum is often used in the vehicle industry, such as chassis and body building. The using of aluminium is an advantage to reduce the overall weight vehicle.
Steel alloys are much harder and stronger than aluminium but steel alloys are heavier in weight compared to other alloys, It is a major disadvantage for steel alloys and steel alloys are not suitable for low light vehicles. 7075 aluminum alloy (AA7075) is an aluminum alloy using zinc as the main alloying element. It possesses exceptional mechanical properties, including high ductility, strength, toughness, and fatigue resistance.

3. DESIGN:

3.1 Specifications:

1. Chassis length : 6355mm
2. chassis width : 700mm
3. Front overhung : 935mm
4. Rear overhung : 1620mm
5. Cross section dimensions : 210×76×6

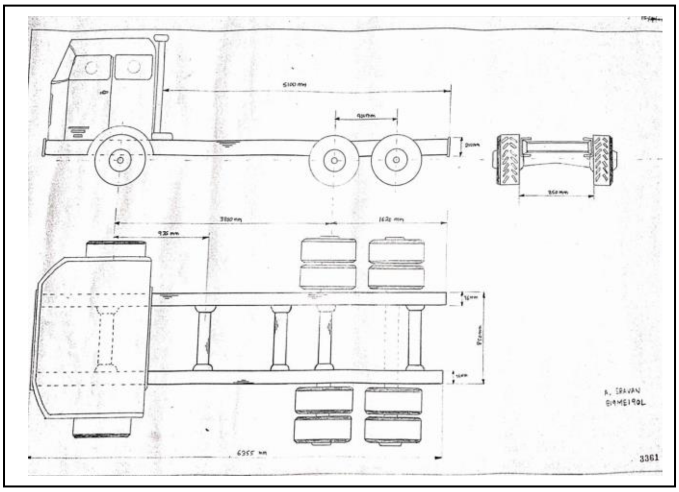

Fig -2: Isometric drawing of the Chassis

3.2 Design Calculations:

Material & Geometry of the Truck made with C - type Chassis with the following dimensions
210 mm x 76 mm x 6 mm
Material of chassis is ASTM A710 Steel
Front Overhang (a) = 930.0 mm
Rear Overhang (c) = 1620.0 mm

wheel base [b] = 3810 mm
Young's modulus, [E] = 2.15 x 10^5 N / mm2
Poisson's Ratio = 0.287
Capacity of vehicle = 8.2 tons = 8200kg =79480 N
Capacity of vehicle with 1.25% = 98100.0 N
Weight of the vehicle = 2 ton = 2000 kg = 19620 N
Total load acting on chassis = Capacity of Chassis + Weight of body and engine
= 98100 + 19820
= 117740 N

a)Calculation of Reactions:

Load acting on the beam = 58660 N
Beam Length = 6345 mm
Uniformly distributed load = 58660/ 6345
= 9.36N/mm

Considering the moment about C and the reaction load generated at the support D, we obtain the load at reaction C & D.

Moment about *C*:

$9.26\times935\times935/2 = (9.24\times3800.0\times3800.0/2) - (R_d\times3800.0) + (9.24\times1620.0\times4610.0)$

$R_D = 34757.650$ N

Total load acting on beam $= 9.26 \times 6355.0 = 58847.305$ N

$R_C + R_D = 58857.36$

$R_C = 24119.645$ N

b)Calculation of SF and BM:

Shear force calculations:

$F_A = 0$ N

$F_C = (-9.24\times936) + 24200.66 = 15462.66$ N

$F_D = (-9.26\times4735)+34727.65+2411 = 115008.40$ N

$F_B = 0$ N

BM calculations:

$M_A = 0$ N mm

$M_C = (-9.26\times5\times934.0)/2 = -4047661.705$ N mm

$M_D = [(-9.26\times4735.0\times4735.0)/2] + (24119.65\times3800.0) = -12150971.075$ N mm

$M_B = 0$ N mm

c) Calculation of Shear Stress:

M.I. about X-X axis (I) = $(BH^3-bh^3)/12 = 13372380$ mm^4

Bending stress from bending equation $M/I = f_s/y = E/R$

$M_{max} = 12150971$ N mm

Bending Stress $f_s = 95$ N/mm^2

Shear stress from Torsion equation $T/J = \tau/r = G\theta/L$

Shear stress $\tau = 482.7$ N/mm^2

Von Mises Stress = $\sqrt{(f_s^2+3\tau^2)} = 448.5$ Mpa

4. DESIGN AND MODELLING:

Fusion 360 software was used to design the chassis. Fusion 360 is an interactive three-dimensional application. It's a solid modeling program that combines 3D parametric features with 2D tools, as well as addressing the whole design to production process. Fusion gives you the option to see your designs in 3D.

The following are the steps required in designing a chassis using Fusion360:

1. Using the draw command, draw the separate parts of the part in 2D.
2. Using the dimensions command to set the dimensions for each line.
3. Using the extrude command, convert the 2D drawing to 3D.
4. Using the material command, change the material to aluminum.
5. Assemble the component parts in the part drawing.

4.1 Design using Fusion360 (C-cross section):

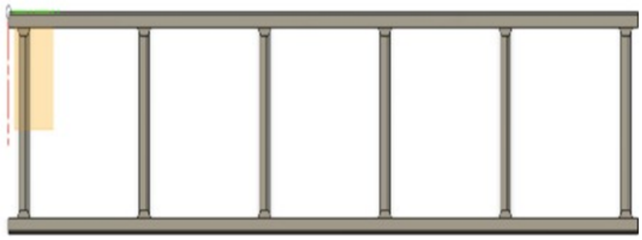

Fig-3: Top View

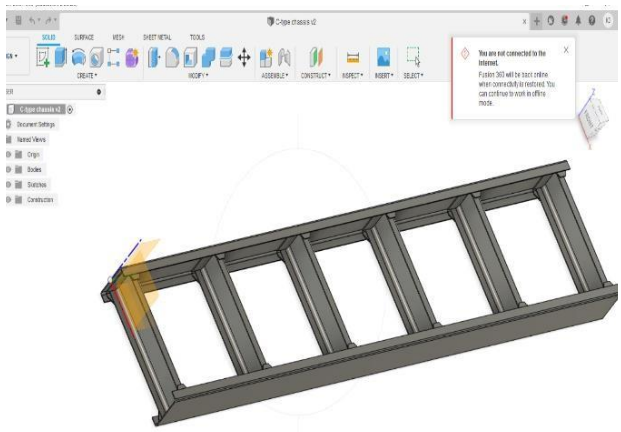

Fig-4: 3-D View

4.2 Design using Fusion360 (I-section):

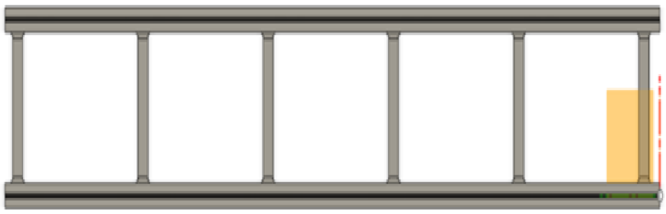

Fig-5: Top View

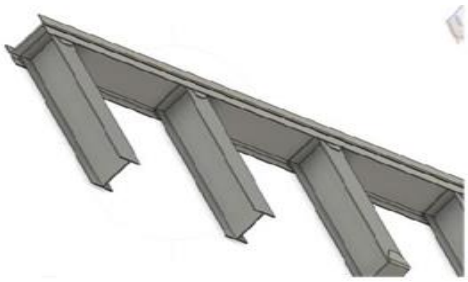

Fig-6: Sectional View

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Fig-7: 3-D View

4.3 Design using Fusion360 (Rectangular Section):

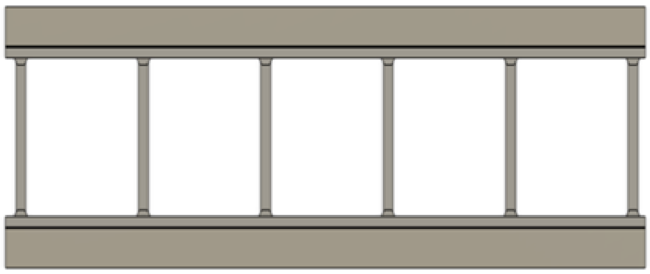


Fig-8: Top View

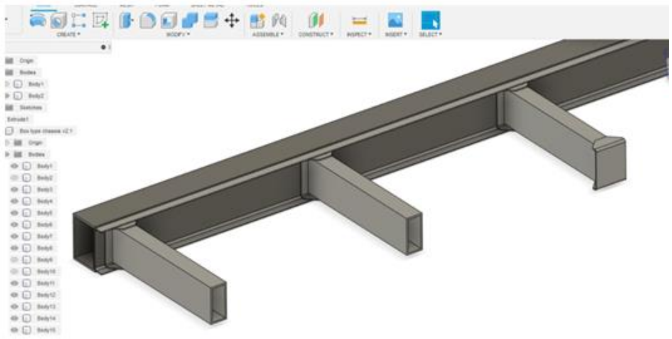


Fig-9: Sectional View

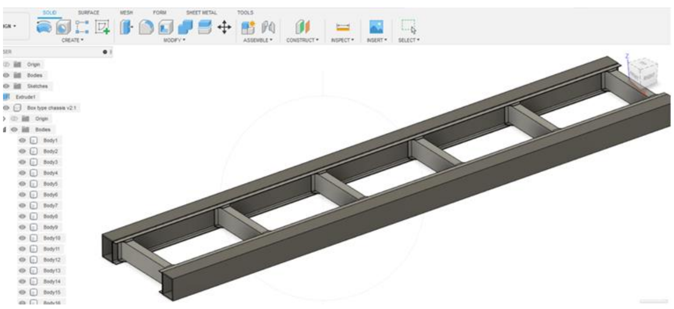


Fig-10: 3-D View

5. ANALYSIS USING ANSYS WORKBENCH:

Ansys 19.2 is a powerful simulation program that allows us to do a variety of analyses, including static, dynamic, fluid flow, and thermal analysis. The chassis design is saved as IGS/IGES format, which can imported into the ANSYS software.

5.1 Steps involved in Static Analysis:

a) Engineering data
b) Geometry Setting
c) Model importing
d) Meshing part
e) Analysis part
f) Results obtained

5.2 Meshing and Load setup:

The meshing is done on a 3516 node model with 180282 cubical and tetrahedral components. The static forces from the truck body and the load on the truck chassis model For this kind, the max loaded weight of the vehicle + body is 12,000 kg. The load is expected to be distributed evenly, with the max loaded weight divided by the whole length of the chassis frame. A finite element model with boundary conditions represents the chassis.

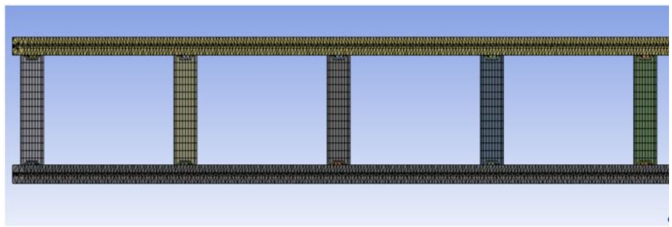


Fig-11: Meshing

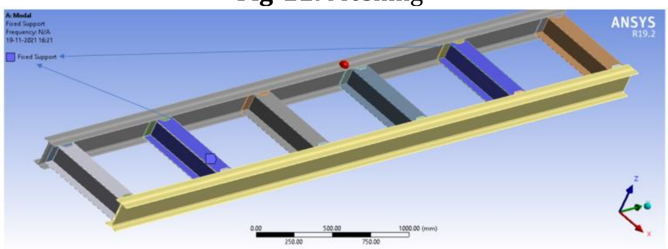


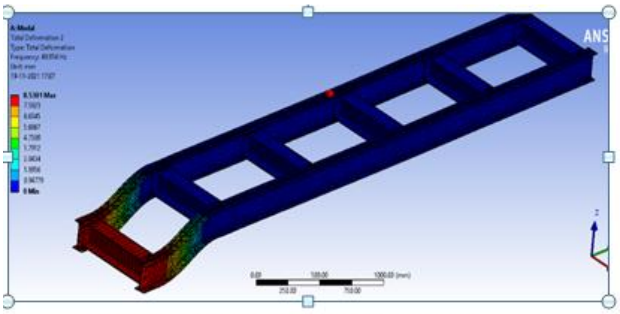
Fig-12: Boundary Conditions

5.3 Static Analysis of Chassis using ANSYS:

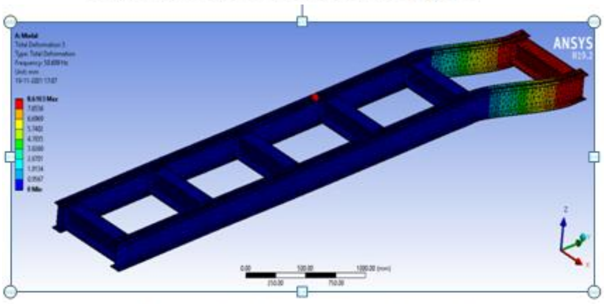
Initially the engineering data is set as per the requirement of material ,units, other properties. Then the geometry is imported into the ansys workbench , click on edit model a new tab will be opened

The more intricate a mesh, the more realistic the 3D CAD model, enabling for high quality simulations. Meshing, also known as mesh production, is the process of creating a two-dimensional and three-dimensional grid.

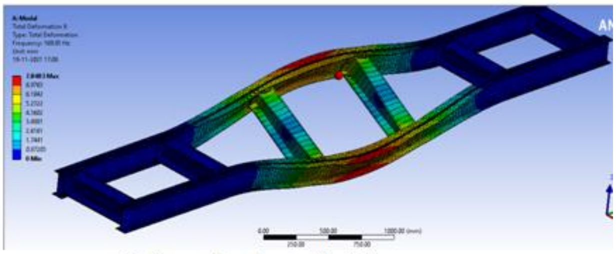
5.4 ANSYS results of I-Section Chassis



Deformation due to front end impact

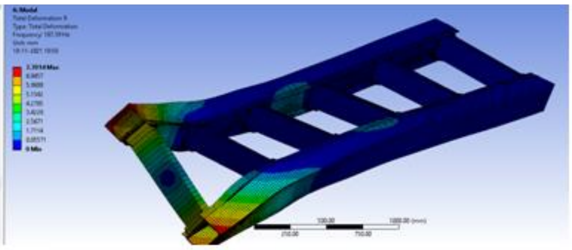


Deformation due to rear end impact

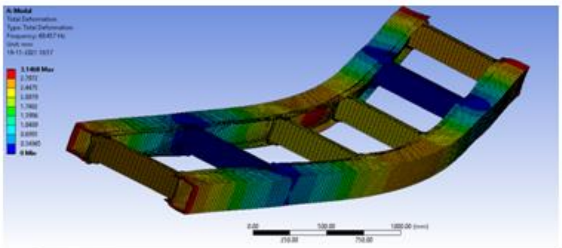


Deformation due to Twisting

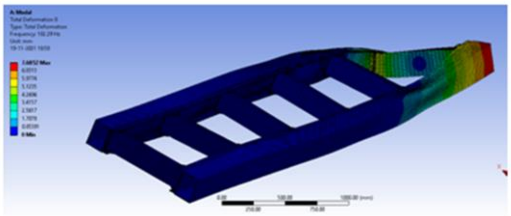
5.5 ANSYS Results of Rectangular cross section



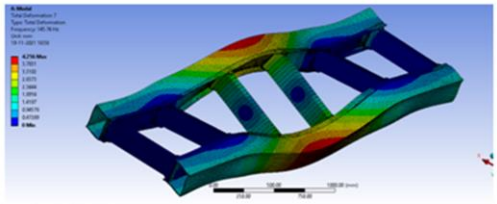
Deformation due to front end impact



Deformation due to central impact

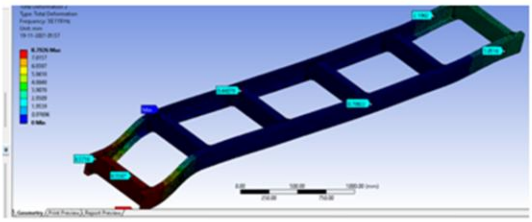


Deformation due to rear end impact

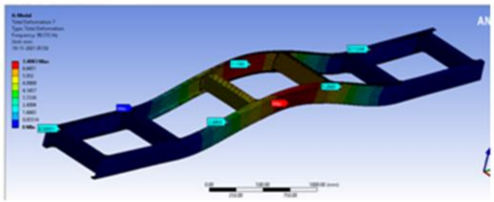


Deformation due to Twisting

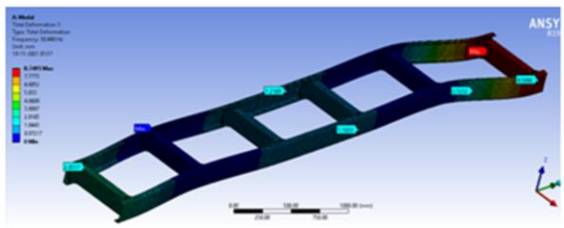
5.6 ANSYS Results of C-section Chassis



Front impact deformation



Central impact deformation



Rear impact deformation

6. RESULTS:

6.1 Results for I-Section Chassis

material	Von - mises stress (Mpa.)	Maximum Shear stress (Mpa.)	Deformation mm
ASTM A710 steel	430	242	2.36
ASTM A302 alloy steel	326	185	2.6
aluminium alloy 6063-T6	166	90	7.2

6.2 Results for rectangular section Chassis

Material	Von-mises stress (Mpa)	Maximum Shear stress (MPa)	Deformation (mm)
ASTM A710 steel	440	252.3	2.84
ASTM A302 alloy steel	335	190.75	2.57
aluminium alloy 6063-T6	168	92.75	7.9

6.3 Results for C-Section Chassis

Material	Von Mises Stress (Mpa)	Max. Shear Stress (Mpa)	Deformation (mm)
ASTM A710 steel	434	250	2.064
ASTM A302 alloy steel	328	188.5	2.015
Aluminum alloy 6063-T6	158	84	6.35

6.4 ANSYS Results for I-Section Chassis

material	Von Mises Stress (Mpa)	Max. Shear Stress (Mpa)	Deformation (mm)
ASTM A710 steel	160	88	7.4
ASTM A302 alloy Steel	154	81	10.2
Aluminum alloy 6063 - T6	141	76	14.6

6.5 ANSYS Results for Rectangular Section Chassis

material	Von-mises stress (Mpa)	Maximum Shear stress (MPa)	Deformation mm
Astm A710 steel	70	15	2.1
Astm A302 alloy steel	59.6	11	3.5
Aluminium alloy 6064 - T6	56	6.1	7.2

6.6 ANSYS Results for C-Section Chassis

Material	Von-mises stress (Mpa.)	Maximum Shear stress (Mpa.)	Deformation mm
ASTM a710 steel	150	78	6.8
ASTM a302 alloy steel	140	71	9.3
Aluminium alloy 6063-T6	112	63	14.6

7. CONCLUSIONS

In this work, the ANSYS 20.1 software was utilized to assess a ladder type chassis construction for a vehicle. According to the research, the C-section is stronger than the Rectangular and I Cross-section varieties of Ladder Chassis. For Aluminum Alloy 6063-T6, the C- Cross-section Ladder Chassis has the least deflection, 2.96 mm, as well as the lowest Von Mises stress and Maximum Shear stress, 54.31MPa and 5.98MPa, respectively. Finite element analysis is a strong technique for tackling the conception and formulation stages of design. Based on the present work's analytical results, the following conclusions may be drawn.

a) The component is safe under the given loading conditions.
b) The shape has been adjusted to allow stress levels to be dropped slightly below the yield limit in order to enhance performance.
c) The Von Mises Stress and Maximum Shear Stress produced are less than permitted value, demonstrating that the design is safe for all three materials.
d) Shear stresses were determined to be lowest in aluminum alloy 6063-T6 and largest in ASTM A710 steel at defined boundary conditions.
e) Von Mises stresses were determined to be lowest in aluminum alloy 6063 - T6 and largest in ASTM A710 steel at defined boundary conditions.
f) The Rectangle Cross-section Kind of Chassis has the lowest deflection, Von Mises stress, and Greatest Shear stress for Aluminium alloy 6063-T6 in all three materials among three distinct cross section kinds of Ladder Chassis.

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9. AUTHOR BIOGRAPHIES

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