Static and Modal Analysis of 2W Electric Vehicle Chassis Frame

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***Abstract* - Fuels such as petrol and diesel are limited and are coming out day after day. So now the world is turning to renewable energy for the future. Fuels such as gasoline and diesel are limited and are on the verge of extinction by the day. The main objectives of this work is to model the motorcycle chassis by considering static loading conditions to check the strength of the chassis frame. In the present work for analysis of central structure of an electric motorcycle considered called as chassis, as it carries the maximum load in the vehicle. The modelling of chassis is done by using Catia V5 software. Analysis is carried by Hyper mesh-Optistruct. Modal analysis is carried to know the frequency of the material, so that the best material for chassis is selected. Analysis is carried out to know the deformation and stress developed in the chassis for the two different materials AISI 4130 and Al7075. Then the design optimization is done for the better material to select. In this work the analysis results are compared with the analytical results.**

***keywords* - Chassis, Catia V5 Tool, Hypermesh - Optistruct, Modal Analysis, Optimization, AISI 4130, Al7075, Modelling**

1. INTRODUCTION

Fossil fuels are becoming limited and days passed. So now it is the time to switch more to renewable energy sources non-contagious and even non-polluting. Electricity is one of the main sources of energy emerged with great growth. With this electricity means of transport are also emerging in the market with an increase capacity range. A chassis is the main structure which supports all the components of the vehicle. Chassis is made up of the circular and rectangular tubes which are hollow inside.

1.2 COMPONENTS OF 2W ELECTRIC VEHICLE

Chassis: Chassis is also called as frame which holds all the components such battery, controller, motor. It also should be strong and stiff to withstand all the forces acting on it.

Motor: Motor is one of the components in vehicle which converts the electric energy to mechanical energy and the energy is transmitted to rear wheel through belt drive. It offers excessive transmission performance and high-speed ratio.

Battery: Battery is the soul of the electrical vehicles. There are two styles of batteries that are lead acid and lithium ion which can be rechargeable and replaceable.

Controller: Controller is the device that receives electrical power from the battery and sends it to the motor which runs the vehicle. Power sent by the controller depends on the acceleration of the throttle given by the driver. It also senses all the voltages and shut it down whenever the voltage crosses the safety limit to protect the electric vehicle.

Suspension: Suspension is one of the fundamental parts in vehicles which minimizes the jerks by changing over the shock into Kinetic energy. There are two kinds of suspension utilized in vehicles in front adjustable suspension is utilized it could be straight one and in back suspension springs are utilized whether mono suspension is used and other type is twin suspension two spring suspensions are used in the back side of vehicle.

2. LITERATURE REVIEW:

In this chapter the studies carried out by the number of researchers on design and analysis of 2-wheeler electric bike are summarized.

Vignesh, Arumugam et al 2019 [1] accomplished the technology of Electric bikes and performed the analysis on static analysis and torsional analysis for sudden impacts . In the present study, optimum design for an electric bike has been modeled and analyzed for stress and failure rate for commercial purpose. The material used is of AISI 3410 standard. The analysis showed of static analysis and torsional analysis for sudden impacts of all the components in the frame. It was concluded AISI 3410 material displayed good results against static and impact loads acting on the frame.

P. N. V Balasubramanyam, A.Sai Nadh et al 2019 [2] designed the electric vehicle frame for the material AISI4130 to determine the three impact analysis on the frame. Side impact, Frontal impact and the combined impact analysis for the speeds of 30 Kmph, 60 Kmph and 80Kmph. The results showed that frame not gives better strength but it also provides better mounting of the components. The results also showed that the design is safe for even the maximum speed 80 Kmph.

Suraj Kudale, Pranav Diyewar et al 2020 [3] designed a new model for the motorcycles chassis and found the modal properties of the structure and compared them between experimental modal analysis and finite element analysis. Modal properties are also included the natural frequency and mode shapes of each mode. As well, this experiment also compared with the results of Finite element analysis (FEA) in order to get the accurate and correct modal properties of each and every mode.

Prathama's nigam, Deepak sahu et al 2020 [4] has designed and developed the modern electric bike. Due to increase of automobiles the fuel costs are rapidly increasing to overcome the situation they designed an alternative electric bike. The model of bike frame was designed in CAD software and analysis is done in ANSYS workbench. The chassis frame of the motorcycle was tested for its strength considering the motorcycle is with the driver. The project shows a review and improvement process of affordable electric bike to reach the market standards.

Jeyapandiarajan.Pa, Kalaiarassan Ga et al 2017 [5] work endeavored to plan the case for electric engine driven bike for road lawful transportation. We know beyond all doubt that the stress is just a property of force and doesn't rely upon the material. The upsides of stress in our examination are steady with the reality. From the investigation, obviously AISI 4340 has the greatest FOS to 4.06. The deformation is likewise the least (0.5 mm). Be that as it may, the FOS of Aluminum 6063 is the least with the element of wellbeing being simply in the required range. Assuming light weight is a significant figure the edge, Aluminum 6063 can be utilized. Yet, it ought to be noticed that the assembling cost of Aluminum 6063 edge will be fundamentally more than different cases since just TIG welding works for Aluminum which requires refined apparatus and abilities. Subsequently, we suggest AISI 4340 as the material for mass production.

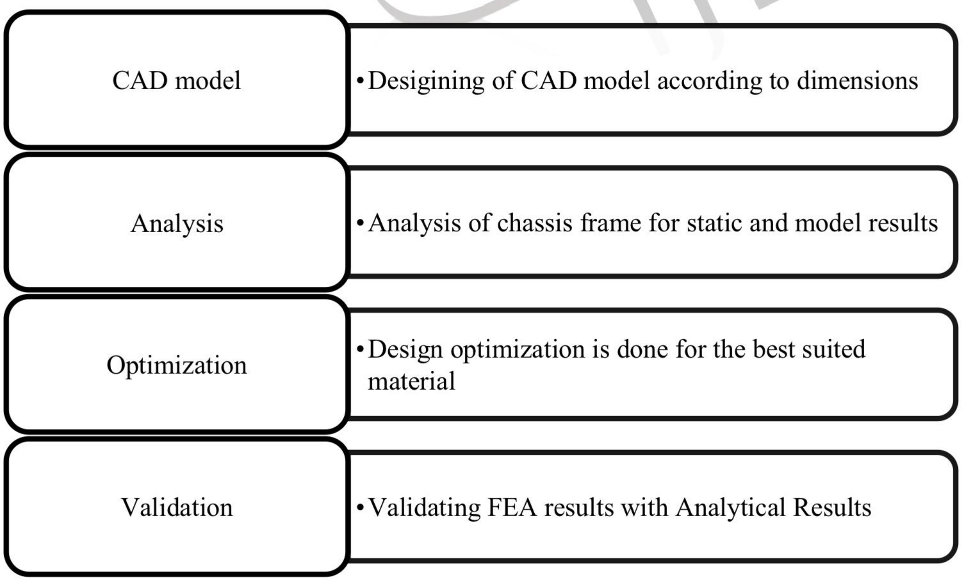
SaurabhRege, Chirag Khatri, Mrudul Nandedkar, NoopurWagh et al 2017 [6] they pointed toward planning the chassis of a bike, two-seater vehicle for an electric versatility reason, while thinking about strength, safety and optimum performance of the vehicle. They concentrated and study on has been completed with a twostep methodology. The initial step incorporates demonstrating of model according to primary and ergonomic contemplations, the design requirements represented by the front and back suspension, steering and transmission frameworks and gatherings as well as the assurance of loads following up on the chassis. The subsequent step is the stress investigation involving finite element analysis software and plan alterations for weight decrease without influencing primary strength. It was clear from the investigation that the deformation during most terrible burden cases was well inside limits. The fundamental parts like the battery pack and the engine are protected from the critical forces following up on the chassis.

3. OBJECTIVE:

- The main objective of this project is determining the best suited material for chassis between AISI 4130 and Al 7075.
- It is done by determining the Stress, Displacement and Frequency.
- Optimization of the best selected material from the AISI 4130 and Al 7075.
- Analytical calculations for the stress, deformation and frequency
- And at last, comparing the Finite element analysis results with the Analytical Results and finding the percentage of error.

4. METHODOLOGY:

After going through various research papers in our project the correct path is determined. First step is to modelling of the CAD model using the Catia V5. Meshing and Analysis is done through the Hyper mesh.



4.1 SELECTION OF MATERIALS:

The two materials selected in our project the first one is AISI 4130 and another material selected is Al 7075.

4.1.1 AISI 4130 ALLOY STEEL:

AISI 4130 grade is a low-alloy steel contains 1% of chromium and 0.2% of molybdenum which acts as agents of strengthening. The steel has good strength and toughness. It can be easily welded and machined. AISI 4130 is alloy with best atmospheric corrosion resistance and reasonable strength. The material has the following properties.

Properties	Metric
Density	7.85 g/cm^3
Melting Point	1432°C

Table 1: Physical Properties of AISI 4130

Properties	Metric
Tensile strength, ultimate	560 MPa
Tensile strength, yield	435 MPa
Modulus of elasticity	190-210 GPa
Bulk Modulus	140 GPa
Shear Modulus	80 GPa
Poission's ratio	0.27-0.30

Table 2: Mechanical Properties of AISI 4130

4.1.2 ALUMINIUM 7075 ALLOY:

The primary alloy in the aluminum 7075 is zinc and it has the strength levels comparable with steel alloys so it considered in our project with AISI 4130 steel. It is light weight compared to other elements. Most used material after the steel is aluminium.

Properties	Metric
Density	2.81 g/cm^3
Melting Point	477°C

Table 3: Physical Properties of Al 7075

Properties	Metric
Tensile strength, ultimate	572 MPa
Tensile strength, yield	503 MPa
Modulus of elasticity	71.7 GPa
Fatigue Strength	159 MPa
Shear Modulus	26.9 GPa
Poission's ratio	0.33

Table 4: Mechanical Properties of Al 7075

5. Design and analysis of Chassis:

5.1 Modelling of Chassis:

The model is developed in Catia V5 software. The design developed satisfies the maximum loading conditions and safety of the rider. Three types of cross sections are used in that two are circular and another one is rectangular cross section. 21.3mm diameter with 2.3 mm thickness and another with 50mm diameter with 5 mm thickness. And rectangular section with 30 mm of length and breadth with thickness of 2.6mm.

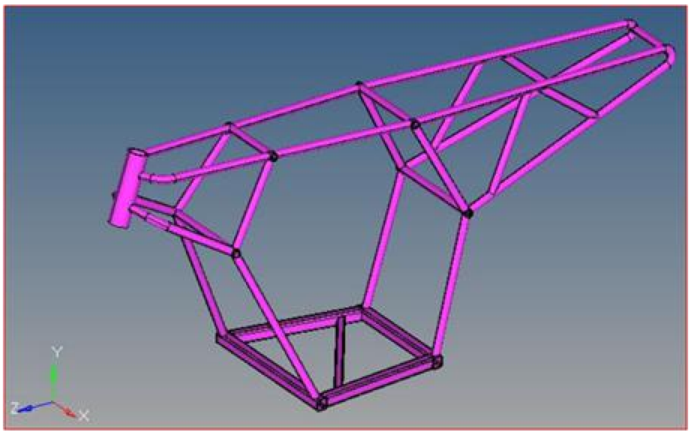


Fig 1: CAD model of chassis

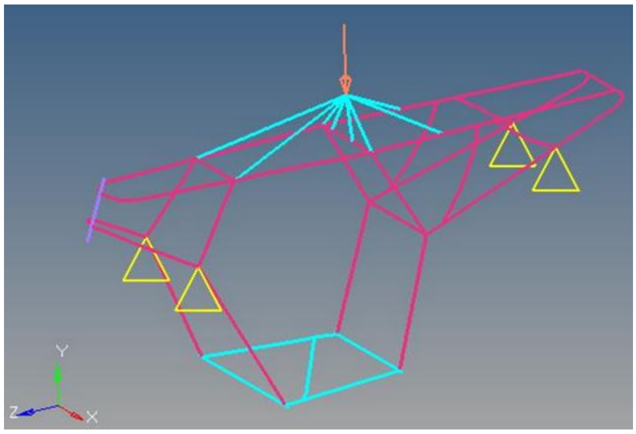


Fig 2: Boundary Conditions

5.1.1 OPERATIONAL LOAD CALCULATION:

- Conventional 2W electric vehicle chassis Designed for Total Payload of 300kg.
- It also includes Average Rider Mass of 100kg.
- Total Force Acting on the 2W electric vehicle chassis is = m*g.
- M=300kg
- F=300*9.81 = 2943N
- Force F is applied at CG point which is connected to Chassis Frame using RBE 3 Elements.

5.2 STATIC ANALYSIS AND MODAL ANALYSIS:

5.2.1 AISI 4130:

The mass of chassis when we consider the material AISI 4130 steel alloy is 15.36 Kg. Maximum stress developed in AISI 4130 is 105 MPa with deformation of 0.5 mm. And the natural frequency at the mode 7 is 85.9 Hz.

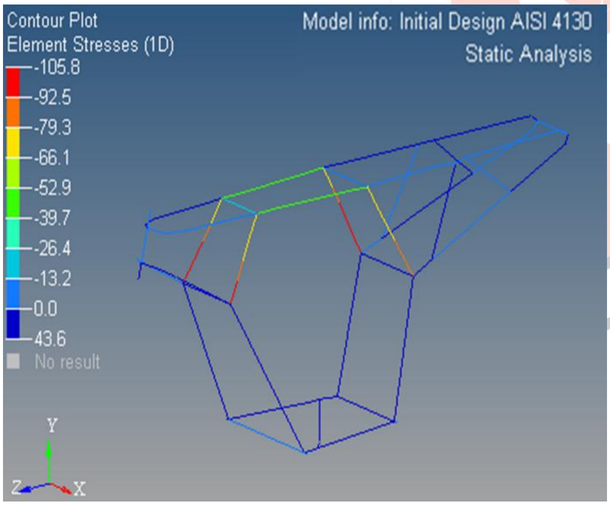


Fig 3: Stress in AISI 4130

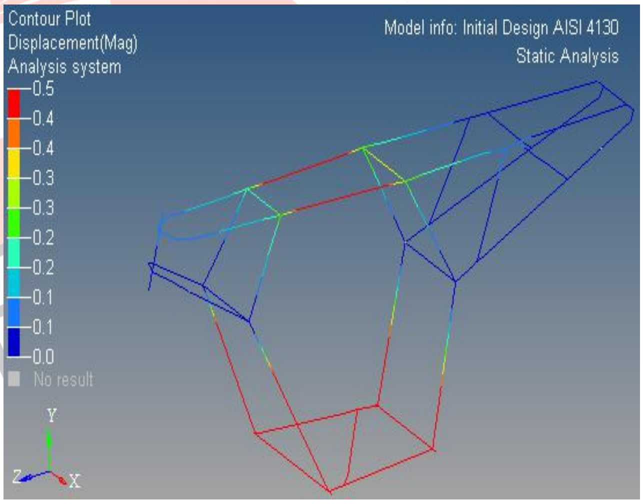


Fig 4: Deformation in AISI 4130

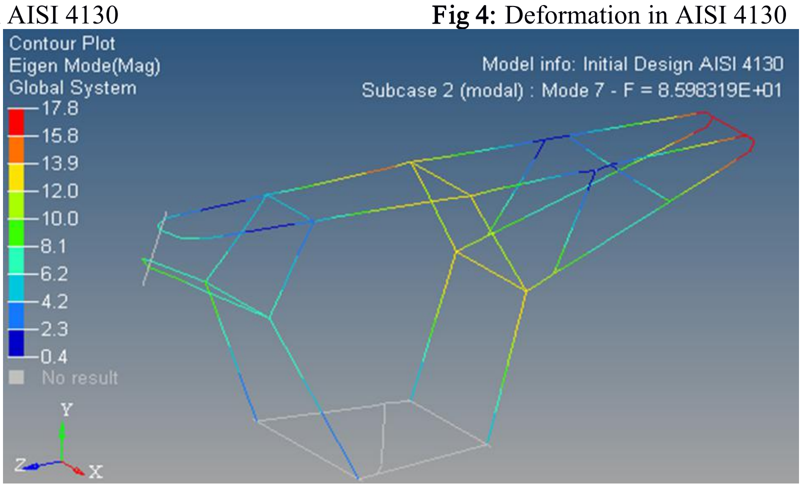


Fig 5: Frequency of AISI 4130 at Mode 7

5.2.2 ALUMINIUM 7075:

The total mass of chassis is 5.51 Kg. Maximum stress developed in Al 7075 is 105 MPa with deformation of 1.5 mm. And the natural frequency at the mode 7 is 83.5 Hz.

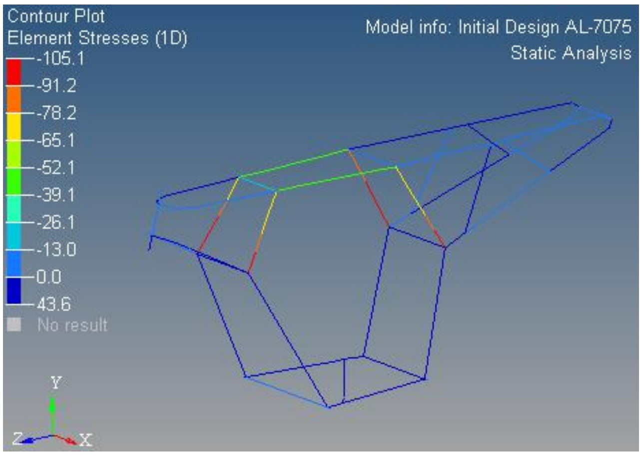


Fig 6: Stress in Al 7075

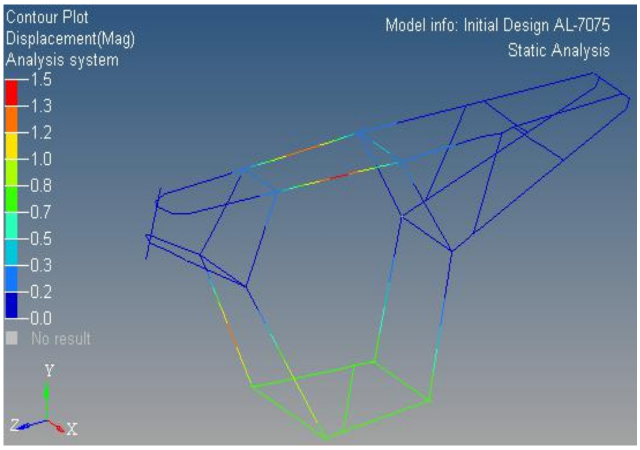


Fig 7: Deformation in Al 7075

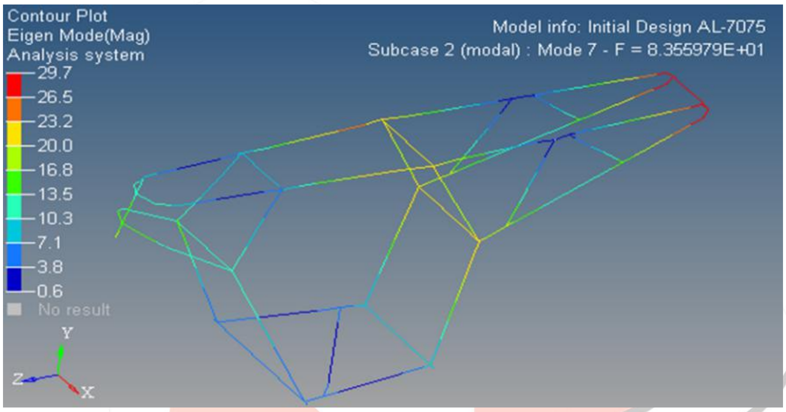


Fig 8: Frequency of Al 7075 at Mode 7

When we compare between these two materials Aluminium 7075 has the displacement of 1.5 but the AISI 4130 has the displacement of 0.5 mm only. So, for the further design optimization we consider only AISI 4130 and also compare them with the analytical solution.

Material	Stress (MPa)	Displacement (mm)	Frequency (Hz)
AISI 4130	105.8	0.5	85.98
Al 7075	105.1	1.5	83.55

Table 5: Results of AISI 4130 and Al 7075

5.3 OPTIMIZATION OF AISI 4130 MATERIAL DESIGN:

When the AISI 4130 material is optimized then the weight of the chassis is reduced to 12.27 Kgs. Circular cross section has 21.3mm diameter with 1.65 mm thickness and another with 50mm diameter with 4 mm thickness. And rectangular section with 30 mm of length and breadth with thickness of 2.4 mm.

Maximum stress developed in the optimized design is 352.3 MPa and the deformation developed is 0.9 mm with the natural frequency of 88.17 Hz.

Factor of safety of optimized design is

FOS = Yield Stress / Stress Induced

FOS = 435 /353.3

FOS =1.23

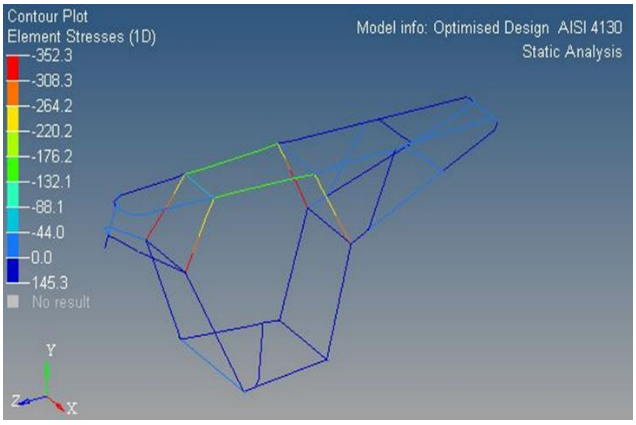


Fig 9: Stress in Optimized AISI 4130

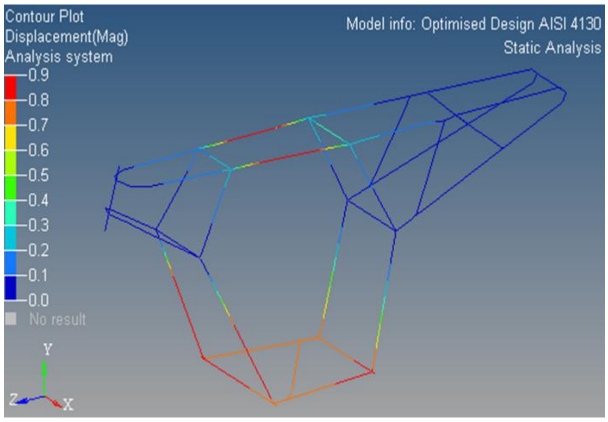


Fig 10: Deformation in Optimized AISI 4130

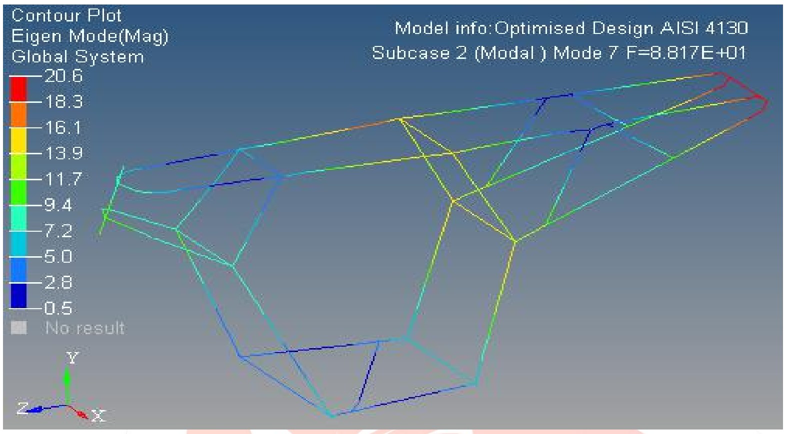


Fig 11: Frequency of Optimized Al 7075 at Mode 7

5.4 ANALYTICAL CALCULATIONS:

5.4.1 ASSUMPTIONS:

Analytical Calculations of actual model is done by considering the following assumptions.

- This problem is treated as a cantilever beam of Hollow Circular Section (cross section) subjected to gravity load at CG point A.
- Stress values are assumed to be within elastic limit (Linear case).
- Principal of superposition is applied for getting effective deformation and stress values of the Chassis Tubes for Applied Load.
- Welded connections are not taken into the consideration for calculations.
- Material Behaviour Assumed to be Linear Elastic and Isotropic.

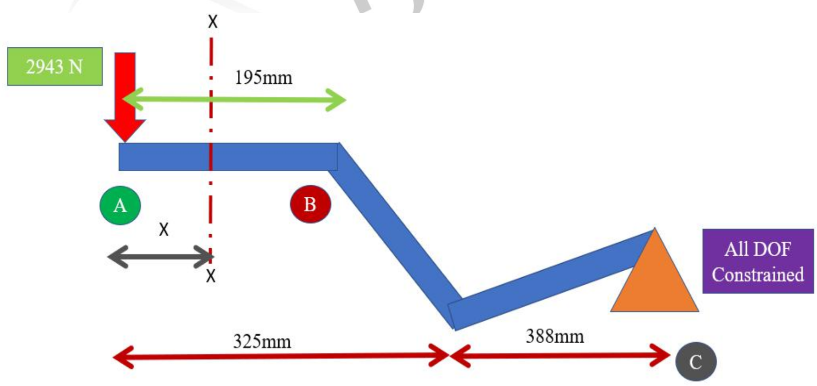


Fig 12: Line Diagram

5.4.2 DEFORMATION CALCULATIONS OF CHASSIS:

The deformation is calculated for the optimized design for the material AISI4130. The effective deformation of Frame Tubes under given load of 2943 N acting at CG Point A. Consider the section A to B, $0 \leq X \leq 195$. Section B to C $195 \leq X \leq 713$.

$$\delta eff = \int_A^B \left[\frac{M}{EI}\right] dx + \int_C^B \left[\frac{M}{EI}\right] dx \quad (1)$$

$\delta_{eff} = \delta_a + \delta_b$
$\delta_{eff} = \int (2943*x) /(EI) + \int [2943 * (713 - x)]/ (EI)$
Where, M = Moment
E=210000Mpa, Young's modulus of the material.
I = 4.95 e03 Kg/m^2, Moment of Inertia of Tubular sections

After solving the above integral equation
We get, δ_{eff} =8.6564 e9 / EI = 8.6564 e9 / (2.1e05 * 4.95e03)
δ_{eff} = 0.827 mm.

5.4.3 STRESS CALCULATION OF CHASSIS:

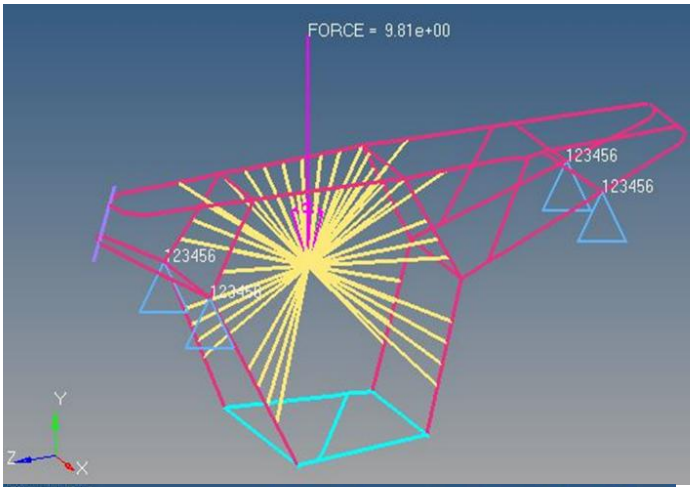
The effective Stress of Chassis Frame Tubes under given load of F=2943 N acting at CG Point A. Consider the Bending Equation along the section A to B, $0 \leq X \leq 195$ and Section B to C $195 \leq X \leq 713$.

$$\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}, \ \sigma = \frac{M}{Z}, \ Z = \frac{I}{y} \quad (2)$$

$M_{eff} = \int_A^B F^* dx + \int_C^B F^* (713 - X) dx$
$M_{eff} = M_a + M_b$
$M_{eff} = \int (2943*x) + \int 2943 * (713 - x)$
Where, M = Moment
I_a=Area MOI
I_m=Mass MOI
E=210000Mpa, young's modulus of the material,
I =Mass Moment of Inertia of Tubular sections
R = Radius of curvature of neytral axis
Z = section modulus
$I_m = I_a / \rho * t$ (3)
After solving the above integral equation
$Z = I_m / y$
We get, $\sigma_{eff} = M_{eff} / Z$
σ_{eff} = 8.234 e7 /(2.54e05) = 324.2 Mpa.

5.4.4 FREQUENCY CALCULATION:

For the Frequency calculation we have to consider the center point of the vehicle with the load of 9.81N. The CG point is taken for the chassis. We can observe from the analysis that 1.5e^{-3} mm of deformation is developed in the chassis.



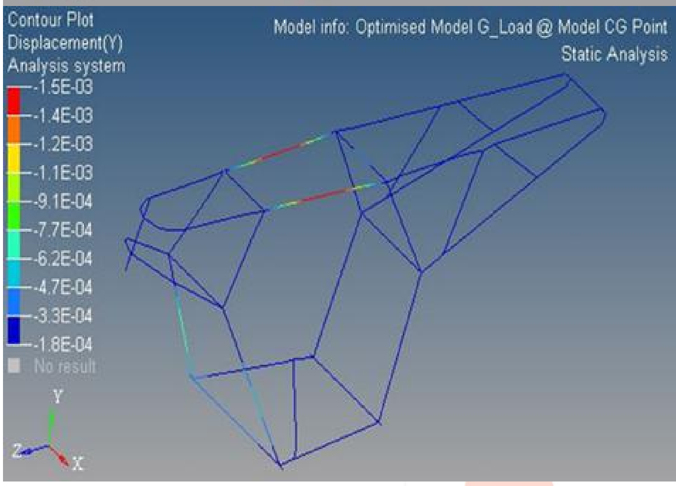


Fig 13: CG point of Vehicle

Fig 14: Displacement at CG point

$$\text{Frequency, } \omega = \sqrt{g/\delta} \qquad (4)$$

ω = Natural Frequency

g = Acceleration due to gravity

δ = Deformation at CG

$\omega = \sqrt{9.81/1.5e\text{-}03}$

$\omega = \sqrt{6540}$

ω= 80.87 HZ

6. RESULTS AND DISCUSSION:

The comparison of initial design with the optimized design is done below in the table 5 for the material AISI 4130. The table 5 shows that the initial design has the weight of 15.36 Kgs and it is reduced to 12.27 Kgs when the design optimization is done. An we got the Factor of safety of 4.1 which is for the initial design of AIS 4130 and the when the design is optimized by reducing the thickness of the material the Factor of safety got is 1.2 within the industrial standards.

Sl.no	Design model	Mass (Kg)	Stress (MPa)	Displacement (mm)	FOS
1	Initial Design	15.36	105.8	0.5	4.1
2	Optimized Design	12.27	352.3	0.9	1.2

Table 6: Comparison of Initial and optimized design

The stress developed for the initial design is 105.8 MPa and after the optimization of design through thickness reducing the stress got to be 352.3 MPa which is well less than the yield stress of the AISI 4130 steel alloy material.

Results	FEA	Analytical	% Difference
Stress (MPa)	352.3	324.2	7.98
Displacement (mm)	0.9	0.827	8.11
Frequency (Hz)	88.1	80.87	8.21

Table 7: Comparison between FEA and Analytical results for AISI 4130

In the above table 6 FEA results are compared with the Analytical results the percentage difference between the both FEA and Analytical results are well within the limits that is less than the 10 percentage. And the difference of up to 10 percentage is allowed according to the industrial standards.

7. CONCLUSION:

Thus, chassis frame has designed and developed for materials AISI 4130 and Al7075. Static analysis and Modal analysis has been carried out for the maximum stress, deformation and frequency. The AISI 4130 has come out to be the better design. Because it has less deformation when compared to the aluminium 7075. And the design optimization is continued for AISI 4130 steel alloy and found to be have the factor of safety is within the industrial requirements.

Finally, the difference between FEA results and Analytical results are not greater than the 10%. The results of both FEA and Analytical are relatively equal.

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