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# Design and Analysis of Chassis of Four-Seater Car

Murli Jha[1], Sujan Raut[2], Sanjip Pokhrel[3], Nitesh Kumar Yadav[4]
[1, 2, 3, 4] *Mechanical Engineer, Kathmandu, Nepal.*

***Abstract: The initial dimensions and weight for the vehicle is considered from the Audi A8 vehicle as a reference. The specifications for the motor and battery are considered for the Mahindra e2o electric vehicle of similar dimensions. The main objective of this paper is to model and perform static analysis on the chassis of a four-seater car.***
***The initial design for the chassis was a space frame body which is very rigid and had very less deflection. The second and final chassis is a ladder type chassis which is most common chassis type being used in Nepal and India. The difference in deflection between both the chassis type is very less, which is about 0.3235 mm for a reasonable reduction in weight which is about 120 Kg. The simulation part is carried out in ANSYS software. The result is selection of best suitable material for chassis on the basis of ANSYS and theoretically calculated result.***
***Keywords: Chassis, Structural Analysis, Optimization, Four seater car***

## I.INTRODUCTION

In modern day's passenger car, the chassis frame and main body are both combined into a single structural element. Such arrangement known as unit-body construction, the steel body shell is reinforced with braces that make it rigid enough to resist the forces. If the chassis is designed considering optimal material usage, then it will save the amount of material consumed for single time also the reduction in maintenance cost will also be economical for customer. The increase in weight reduces the energy efficiency and increases the cost due to extra added material. The design of the Chassis should have adequate stiffness and strength.
The automotive chassis holds all the components together while driving, and transferring vertical and lateral loads, caused by accelerations and braking, on the chassis through the suspension and to the wheels. The chassis of an automobile provide mounting points for the components like engine/motor, suspension system and wheels. The main functions of the chassis are to withstand static and dynamic loads without excessive deflection or distortion.

## II.METHODOLOGY

### *A. Design approach*

We are considering elements of the chassis of different cross sections such as c- channel, rectangular, square and circular tubes. The chassis is designed using both analytical calculations and simulation software (ANSYS). The output is optimized if necessary changes are required in the chassis to add or remove chassis parts to improve rigidity and lower weight. The design for other components such as suspensions, brakes, power needed, motor and battery was carried out based on result of chassis.

### *B. Static Analysis of Chassis Frame*

Here in static analysis a typical ladder type chassis is considered. Vehicles with a ladder type frame are easier to assemble. It is tough and great for carrying heavy loads for an extended period. It is used as a mounting point for the body, suspension and other components. It is easy to design, build and can be used in multiple applications with minimal modification. The different load considerations are taken for analysis. Varying materials and cross section of beam design the chassis analytically. The different cross sections are considered as

1) Rectangular Section
2) Square Section
3) Tube Section
4) C - Channel

The different materials are chosen like Aluminum Alloy, Stainless Steel, Iron, Carbon, Structural Steel etc.
Here analytical approach is considered for deciding the dimension of chassis cross section. During static condition, the chassis frame is only subjected to bending loads due to the weight of the members. By considering the equation of bending, the cross sections are decided. Then the same cross sections are analyzed by using FEM and ANSYS [11].

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The loads that are produced on the car are due to the following normal running conditions:

*a)* Vehicle transverse on uneven ground.

*b)* Manoeuvre performed by driver.

These are the basic load cases, which are commonly seen in the car chassis:

Bending load

- Torsion load
- Combined bending and torsion
- Lateral load
- Longitudinal load

## III. THEORETICAL CALCULATION

For the design purpose of the chassis, we have assumed the following parameters with the reference of Audi A8 vehicle model to calculate the strength of the chassis.

Rear overhang = 1185mm

Front overhang =989mm

Wheelbase =2998mm.

Large sized car (Audi A8) = 2000 kg.

Gross vehicle weight = 2280kg

Total load to be applied = 2280×9.81=22366.8N

Considering an overload of 1.25 of total load=22366.8× 1.25=27958.5N

As the chassis frame has two-member. Therefore, load acting on each side member is half of the total load.

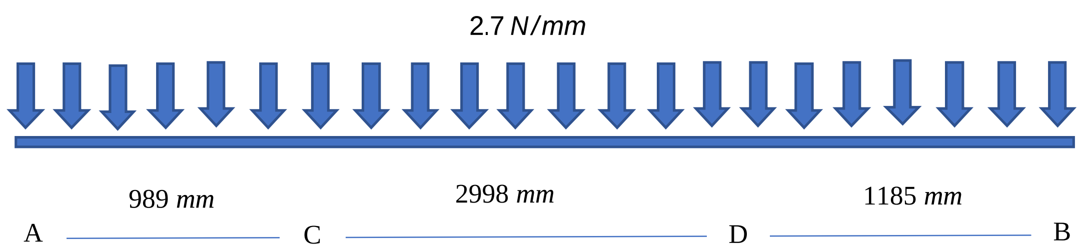
Load acting on each of member frame $=\frac{27958.5}{2} = 13979.25N$

Beam considered is a simply supported at C and D with uniformly distributed load.

Load acting on the whole beam $= 13979.25N$

Length of the beam $= 5172mm$

Uniformly distributed load $= \frac{13979.25}{5172} = \frac{2.7029N}{mm}$




### *A. Calculation of Reaction Forces*

Taking moment at C (positive as clockwise and negative as anti-clockwise)

$$2.7029 \times 989 \times \frac{989}{2} = \left(2.7029 \times 2998 \times \frac{2998}{2}\right) - (R_D \times 2998) + (2.7029 \times 3590.5 \times 1185)$$

$$1321881.625 = 12146838.01 - R_D \times 2298 + 11500143.5$$

$$R_D = 7446.66N$$

Similarly,

$$R_C + R_D = 13979.25N$$

$$R_C = 6532.58N$$

The reaction force at point C and D are 6532.58$N$ and 7446.66$N$

*Calculation of bending moment*

Let $M_A, M_B, M_C, M_D$ be the moment at point A, B, C and D respectively.

$$M_A = 0N - mm.$$

$$M_B = 0N - mm.$$

$M_C = \quad (2.7029 \times 989 \times \frac{989}{2} = \quad 1321881.625N \quad mm.$

$M_D = \left(-3987 \times \frac{3987}{2} \times 2.70029\right) + (6532.5856 \times 2998)$

$= -21482877.6 + 19584691.63$

$-1898185.971N - mm.$

Maximum bending moment acting on the beam

$= 1898185.971N - mm.$

*B. Calculation of Shear Force*

$V_1 = w \times a = 2.7029 \times 989 = 2673.1681N.$

$V_2 = R_C - V_1 = 6532.5856 - 2673.1681 = 3859.4175N.$

$V_3 = R_D - V_4 = 7446.664405 - 3202.9365 = 4243.727905N.$

$V_4 = w \times c = 2.7029 \times 1185 = 2482.3298N.$

*C. Calculation of Bending Stress*

*Hollow square cross-section*

Assume dimension (80*80*6) mm.

Moment of inertia about XX-axis

$I = \frac{bh^3}{12} - \frac{b_1}{12} h_1^3$

$= 80 \times \frac{80^3}{12} - 68 \times \frac{68^3}{12}$

$= 1631552mm^4.$

To calculate Deflection$(\delta)$

$\delta - \frac{w(b-x)}{24EI}\left\{x(b-x) + b^2 - 2(c^2 + a^2) - \frac{2}{b}[xc^2 + a^2(b-x)]\right\}$

Where

$w = 13979.25N.$

$b = 2998mm.$

$x = \frac{totallength}{2} = \frac{5172}{2} = 2586mm.$

$a = frontoverhang = 989mm.$

$c = rearoverhang = 1185mm.$

For stainless steel

$E = \frac{200000N}{mm^2}$

$I = 1631552mm^4.$

By putting all the values in above deflection equation, we get maximum deflection

$\delta = 1.91mm.$

For structural steel

$E = \frac{210000N}{mm^2}$

$I = 1631552mm^4$

By putting all the values in defection equation, we get maximum defection for aluminum alloy

$\delta = 1.82\ mm.$

*D. Hollow Rectangular Cross-Section*

Assume dimensions

$thickness, t = 6mm.$

$d = 90mm.$

$b = 60mm.$

Calculating moment of inertia about XX-axis by using formula

$$I = \frac{bd^3}{12} - \frac{b_1 d_1^3}{12} = \frac{60 \times 90^3}{12} - \frac{48 \times 78^3}{12} = 1746792mm^4.$$

To calculate deflection $(\delta)$ by using deflection formula on the beam given as

Deflection, $\delta = \frac{w(b-x)}{24EI}\left\{x(b-x) + b^2 - 2(c^2 + a^2) - \frac{2}{b}[xc^2 + a^2(b-x)]\right\}$

Where

$w = 13979.25N$

$b = 2298mm$

$x = \frac{totallength}{2} = 2586mm$

$a = front\ overhang = 989mm$

$c = rear\ overhang = 1185mm$

$I = 1746792mm^4$

Young's modulus of elasticity for stainless steel, $E = \frac{200000N}{mm^2}$

Young's modulus of elasticity for structural steel, $E = \frac{210000N}{mm^2}$

By putting all the values in above deflection equation, we get maximum deflection on the beam

Deflection on the beam for stainless steel, $\delta = 1.784mm.$

Deflection on the beam for structural steel, $\delta = 1.70mm.$

*E. Hollow Circulation Cross Section*

Assume dimensions

Thickness, $t = 6mm$

Diameter, $D = 80mm$

Moment of inertia about XX-axis is

$$I = \frac{p(D^4 - d^4)}{64}$$

Where, P=perimeter

$$I = \pi \times \frac{(80^4 - 68^4)}{64} = 960576.24\ mm^4.$$

Calculation of deflection $(\delta)$ by using maximum deflection formula of beam given as

Deflection, $\delta = \frac{w(b-x)}{24EI}\left\{x(b-x) + b^2 - 2(c^2 + a^2) - \frac{2}{b}[xc^2 + a^2(b-x)]\right\}$

Where

$w = 13979.25N$

$b = 2298mm$

$x = \frac{total\ length}{2} = 2586mm$

$a = front\ overhang = 989mm$

$c = rear\ overhang = 1185mm$

$I = 960576.24\ mm^4$

Young's modulus of elasticity for stainless steel, $E = 200000N/mm^2$

Young's modulus of elasticity for structural steel, $E = 210000N/mm^2$

Finally, by putting all the values on above deflection equation,

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We get,
Deflection on the beam for stainless steel, $\delta = 3.24mm$
Deflection on the beam for aluminum alloy, $\delta = 3.09mm$

## *F. C- Channel Cross Section*

Assume dimensions
$d = 90, b = 60, t = 6\ mm.$
Moment of inertia about XX-axis is

$$I = \frac{b \times d^3}{12} - \frac{(d - 2t) \times (b - t)}{12} = 1509516mm^4.$$

Calculation of deflection $(\delta)$ by using maximum deflection formula of beam given as

Deflection, $\delta = \frac{w(b-x)}{24EI}\left\{x(b-x) + b^2 - 2(c^2 + a^2) - \frac{2}{b}[xc^2 + a^2(b-x)]\right\}$

Where
$w = 13979.25N$
$b = 2298mm$
$x = \frac{total\ length}{2} = 2586mm$
$a = front\ overhang = 989mm$
$c = rear\ overhang = 1185mm$
$I = 1509516mm^4$
Young's modulus of elasticity for stainless steel, $E = 200000N/mm^2$
Young's modulus of elasticity for structural steel, $E = 210000N/mm^2$
Finally, by putting all the values on above deflection equation,
We get,
Deflection on the beam for stainless steel, $\delta = 2.065mm$
Deflection on the beam for aluminum alloy, $\delta = 1.97mm$

## *G. Summary of the Calculations*

*1)* The summary of the dimensions and parameters required for the design of our project, assumed and calculated are given in the table 3.1

| | |
|---|---|
| Rear overhang | 1185 |
| Front overhang | 989 |
| Wheel base | 2998 |
| total weight of car (Audi A8) Kg | 2280 |
| Total load to be applied N | 22366.80 |
| Considering an overload of 1.25 of total load | 27958.50 |
| As the chassis frame has two members .so, load acting on each side member is half of the total load. | |
| Load acting on each of member frame | 13979.25 |
| Total length of Chassis, *mm* | 5172.00 |
| uniformly distributed load, *N/mm* | 2.70 |
| Reaction at Point D | 7446.66 |
| Reaction at Point C | 6532.59 |

| Taking moment at C (positive as clockwise and negative as anti-clockwise) | | | | | | | |
|---|---|---|---|---|---|---|---|
| foh | wbs | roh | udl | Reaction at C | Reaction at D | Moment at C | Moment at D |
| 989 | 2998 | 1185 | 2.7029 | 6532.59 | 7446.66 | -1321882 | -1898186 |

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## IV.SIMULATION AND ANALYSIS

### A. *Cad Model*

The cad model is generated using Solidworks 2016 as a single body. The suspensions and side members are attached with the help of assembly tool. The reference for the dimensions of the chassis is considered from the car model Audi A8. The major dimension of the chassis are **5172 mm * 1332 mm * 290 mm**.

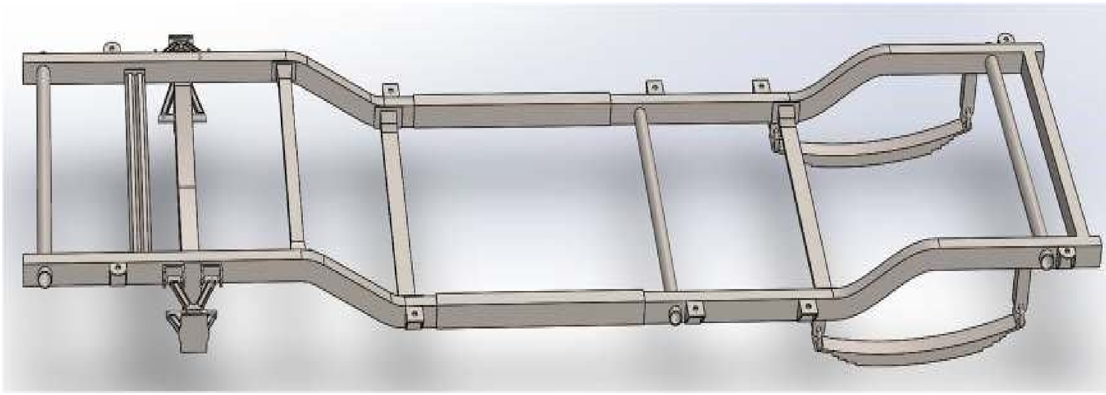

Figure 1: CAD Model of Chassis

### B. *Static Simulation*

The simulation and analysis of the chassis is performed in the ANSYS 18.1 with the following parameters as shown in the figure below. The total force of 27960 N is applied in the downward direction with respect of the horizontal plane.

*The simulation and analysis of the chassis is performed in the ANSYS 18.1 with the following parameters as shown in the figure below. The total force of **27960 N**is applied in the downward direction with respect of the horizontal plane.*

Figure 2: Parameters of the simulation in Ansys

(b)The deformed model with the stress concentration and deflection is shown in the figure with different colors. The material of the chassis is Structural steel. The maximum deflection from recent simulations is 1.3436 mm at middle of the chassis below the driver’s seats. The weight of the chassis is about 480 kg.

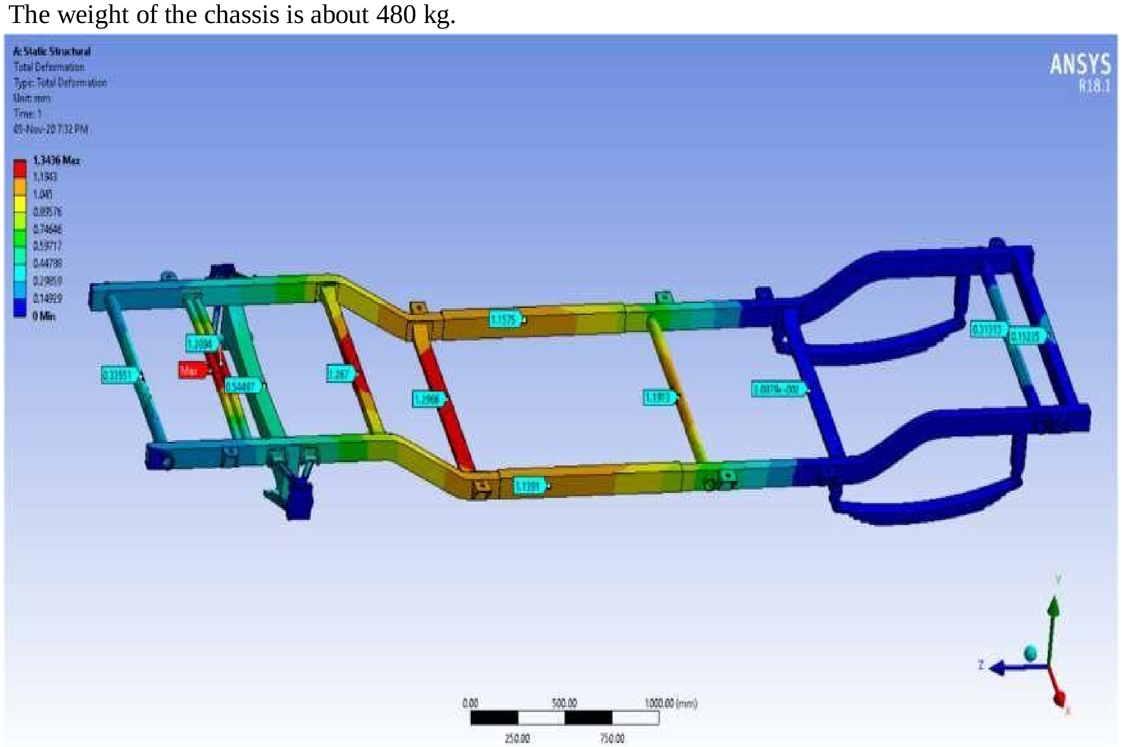


Figure 2: Static Structural Analysis (deformed (true scale))

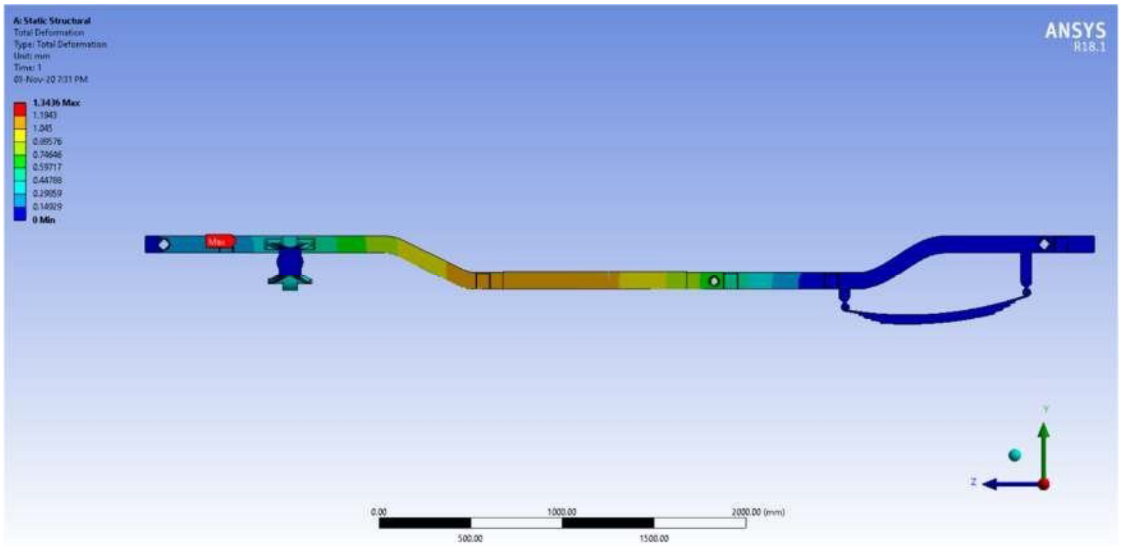


Figure 3: Static Structural Analysis (deformed (true scale))

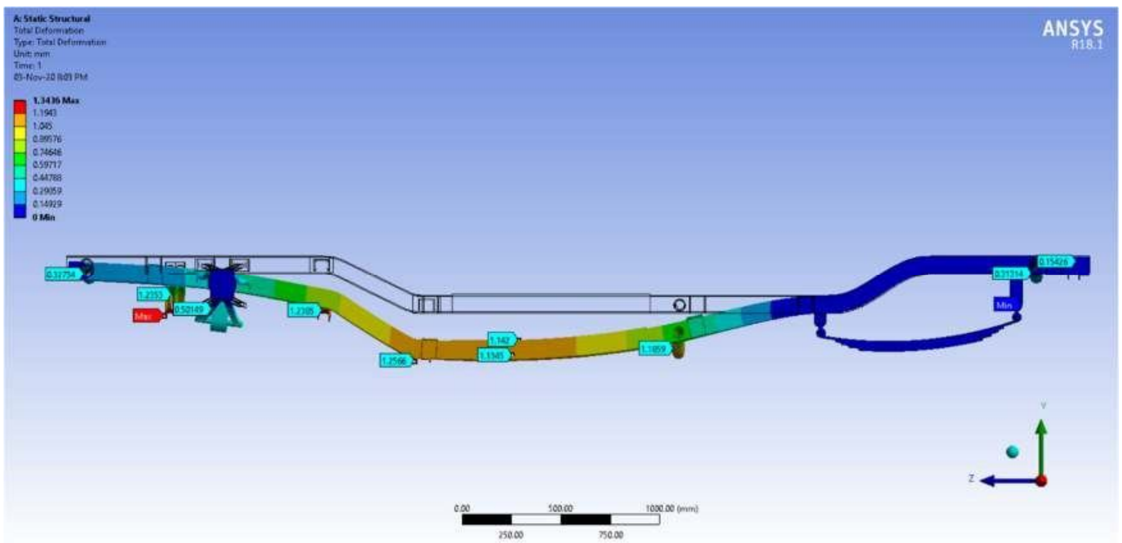


Figure 4: Static Structural Analysis (deformed (2x scale))

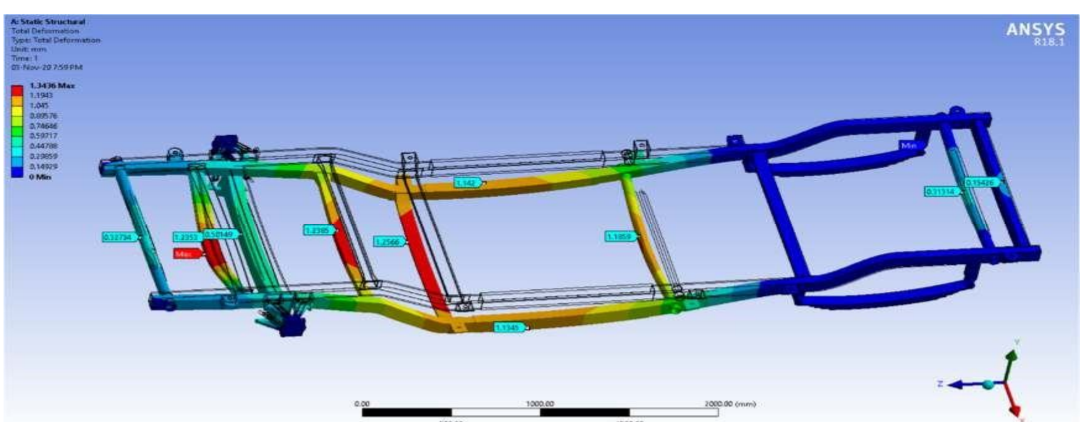


Figure 5: Static Structural Analysis (deformed (2x scale))

### *C. Equivalent Stress*

The Maximum equivalent (Von – Mises) Stress appeared in this chassis is about **201.41 MPa** which is less than the yield strength of the Structural Steel (**275 MPa**).

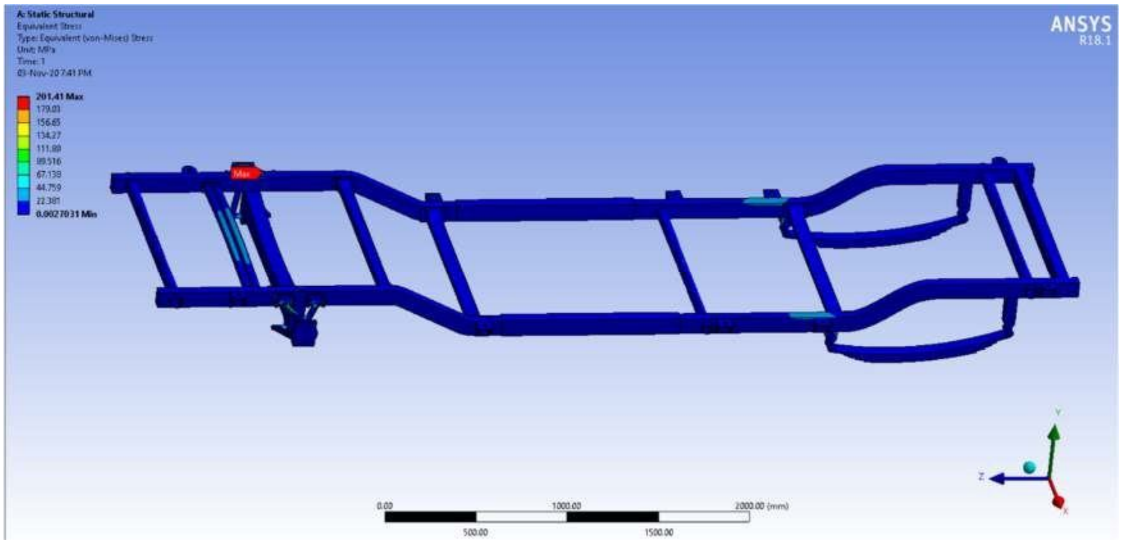


Figure 6:Equivalent (Von – Mises) Stress

## V. CONCLUSION

This paper focuses on a lightweight design of ladder frame chassis of four seater electric car. The maximum deflection of chassis is 1.3236 mm and the weight of the chassis is 480 kg. The chassis is capable of bearing the maximum static load of 27960 N. The material used for the chassis is structural steel.

This paper has also focused on the different components of the electric vehicle such as power needed, motor, steering, brake and battery. The designed gear for the steering system is rack and pinion with Ackerman mechanism, which has a turning radius of 6767.5 mm, and gear of cast iron can withstand a load of 2292.93 N.

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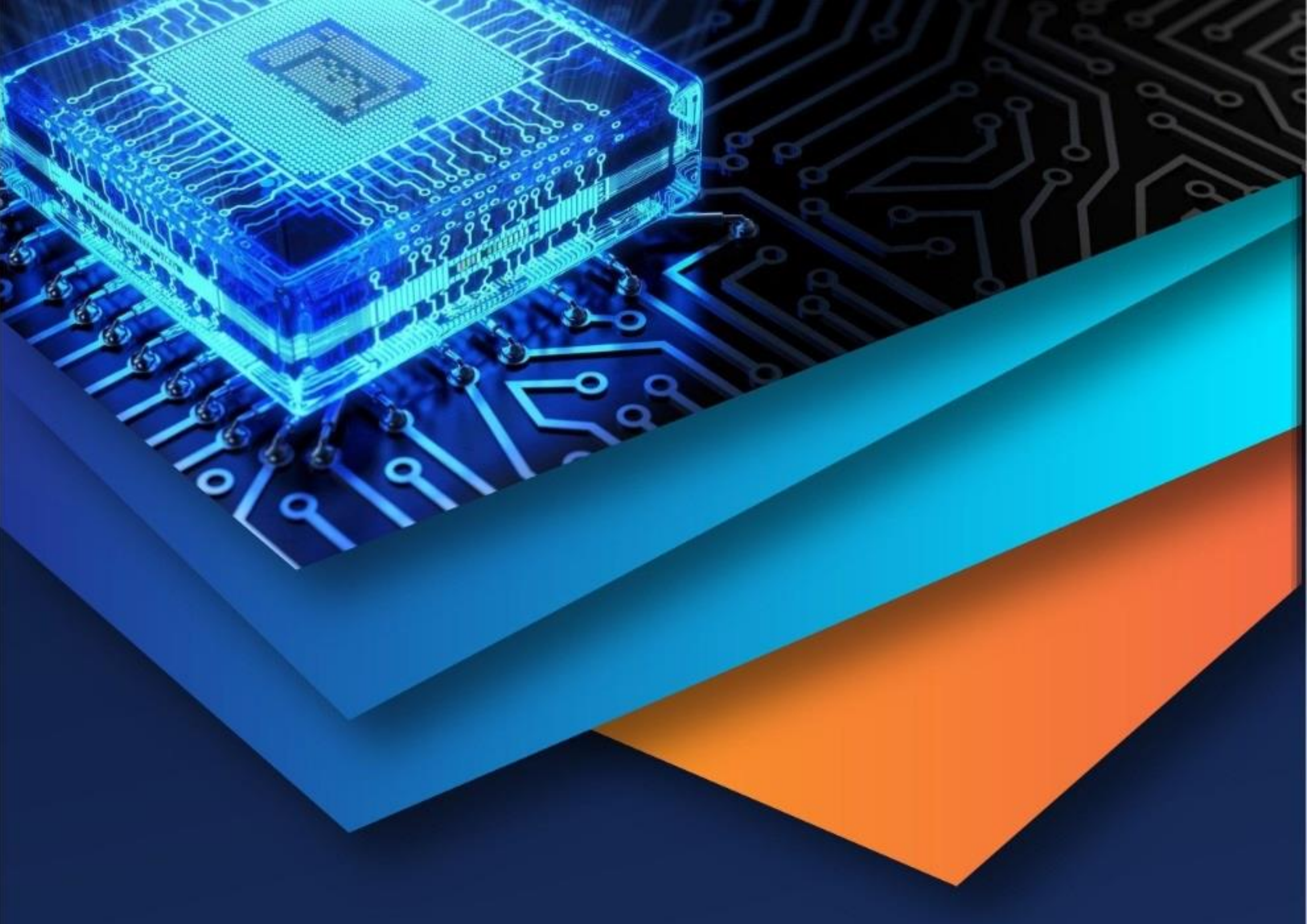


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