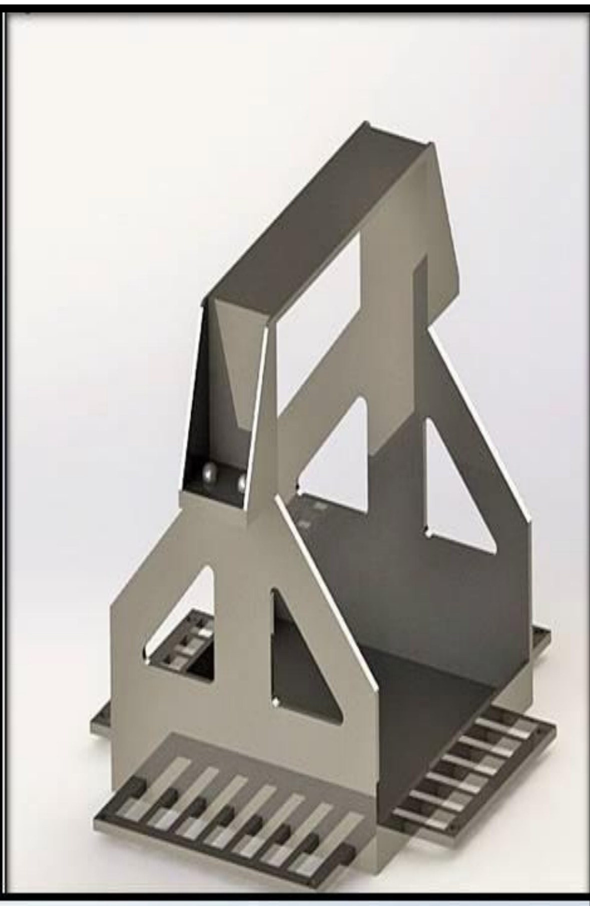
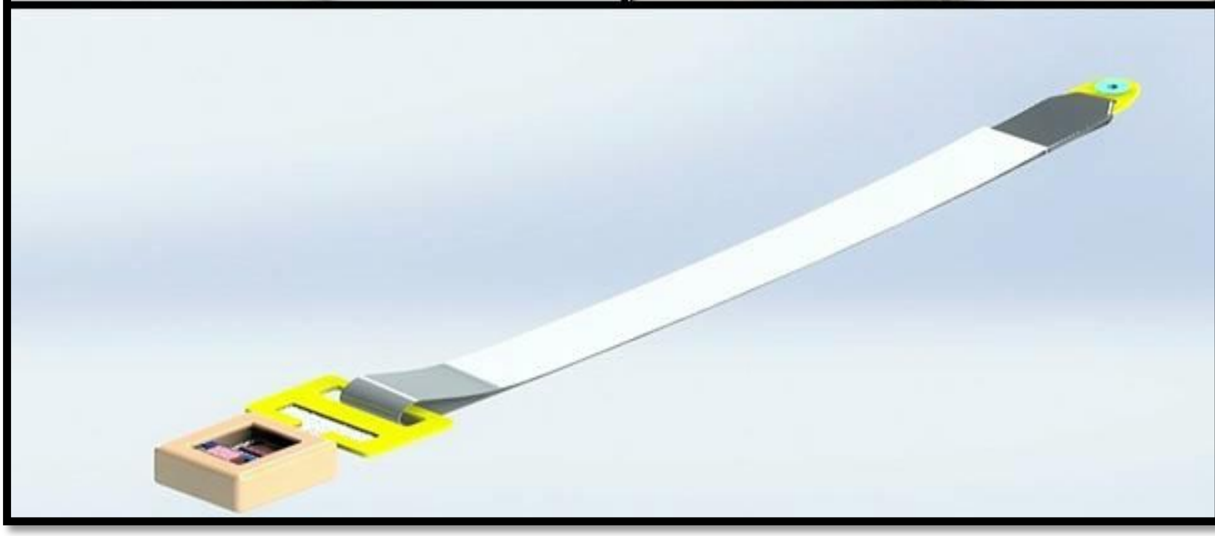
ENGINEERING DESIGN REPORT

REPORT

ON

DESIGN OF BRAKING SYSTEM , MOTOR & BATTERY MOUNTING & SEAT BELT





LIST OF FIGURES

LIST OF TABLES

ENGINEERING DESIGN REPORT

INTRODUCTION

Evolocity is an electric car racing event under which engineering students form groups then design , manufacture an electric racing car then use that car for racing competition .In this report main parts of electric racing car is design by using theoretical calculations and software simulation . Electric racing car vehicle used on any type of road conditions , so the vehicle must be design to work in worst road condition .This vehicle should be design to the factor of safety of 1.5 to 2 because the shock/vibration act on this vehicle may double the value of applied load .This report consist of designing of main parts of car .The major parts includes braking system of car , motor- battery mounting frame and seat belt . All the aspect is considered while designing these parts like load act upon it ,factor of safety , shear force & bending moment diagram , strain energy and optimum material selection .For electric car , disc braking system is used under which hydraulic pressure is used to stop/ slow the racing car .This type of braking system is most efficient to stop the fast moving car in least time and distance .The battery/motor mounting frame is design by considering all loads on angle and design is sufficiently safe .The seat belt is also design to keep the driver safe from shocks and accidents .[1].

CAR BRAKING SYSTEM

The braking system in automobile is used to stop the vehicle or reduce its speed .Design of braking system is completely depend upon the top speed of vehicle and weight of vehicle .In off road vehicle ,as speed of vehicle is very high and less friction obtain from dusty road ,so tyre diameter and type of braking system used is playing an important role in stopping the vehicle .

ENGINEERING DESIGN PROCESS

Here the disc braking system is designed for electric racing car .

PRINCIPAL

The principal on which braking system work is Pascal law .This law states that " when pressure exerted on any incompressible liquid contained in control volume then that pressure will equally distributed in all other direction "[2].

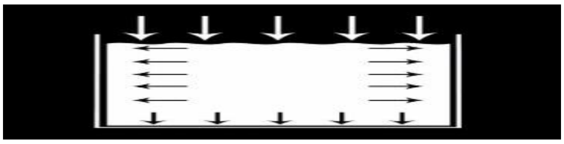


Figure :-1.1 (Pascal law)

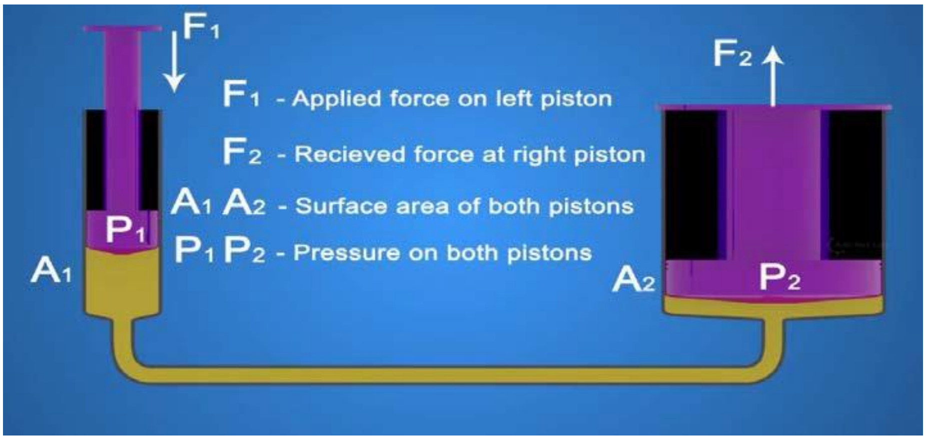


Figure :-1.2 (Pascal law formula)

The above system is used to flow hydraulic fluid from master cylinder to disc brake. According to above figure ,pressure will be same in both cylinder as A2 area is more than area A1 If force applied on F1 is x Newton , then obtained force F2 will be more .F1 is pedal force applied F2 is force act on disc brake of wheel [3].

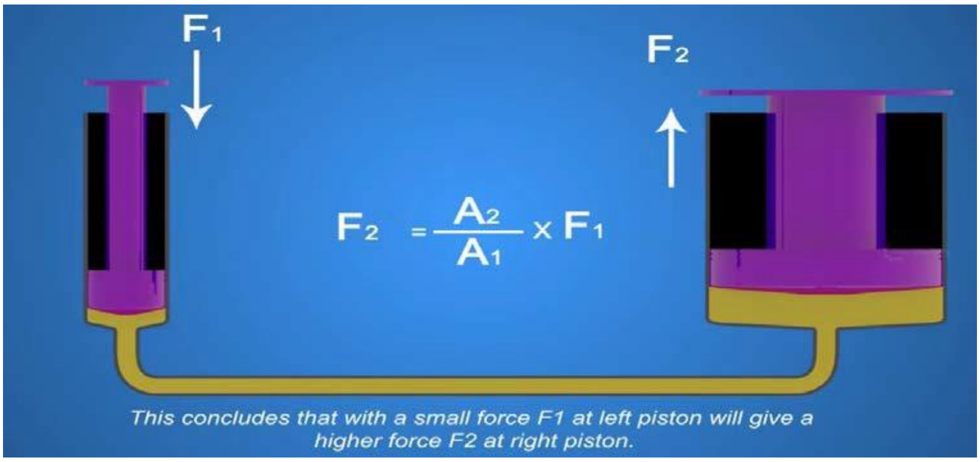


Figure :-1.3 (fluid flow in brake)

WORKING

The arrangement of braking system is shown below . The pedal is connected with vaccum chamber which is further connected to the master cylinder . Master cylinder is connected with the fluid reservoir at its top .In the master cylinder , 2 piston and spring system is present .The master cylinder is connected with the tubes carrying fluid .These tubes transfer the fluid at high pressure to the disc brake -rotor-tyre arrangement .

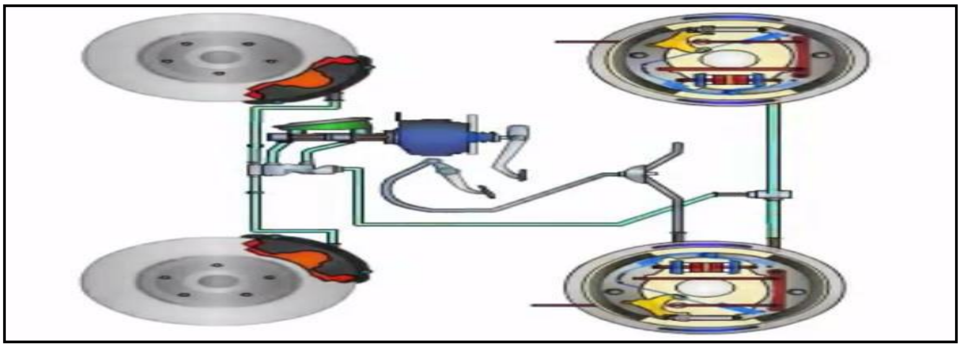


Figure :-1.4 (Parts of braking system)

The rotor is coupled with the hub of tyre , the rotor rotate with the wheel of car .The calliper present on the rotor which slides in horizontal direction due to the application of pressure from the fluid [5] .

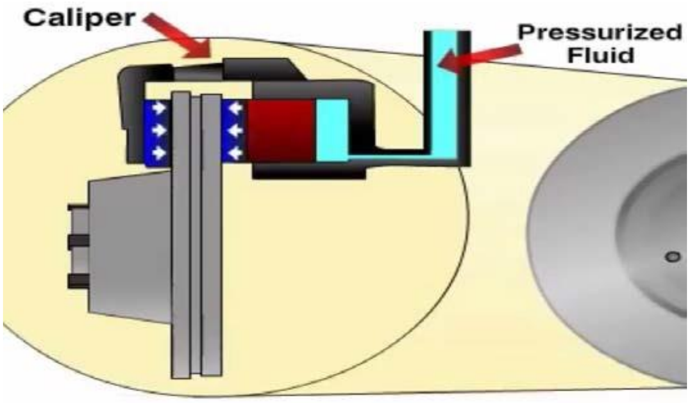


Figure :-1.5 (braking system)

Due to friction between bush of calliper and rotor ,the car stops . The piping system , rotor and calliper are present in front wheels .

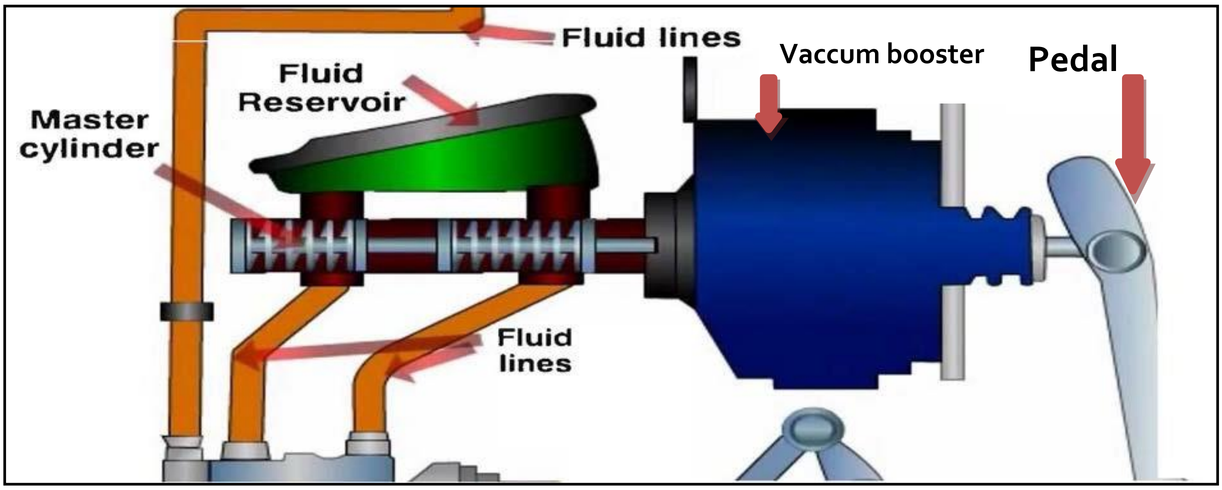


Figure :-1.6 (Parts of braking system)

When the brake is applied then the applied force cause the pressure exerted on vacuum chamber .This vacuum chamber multiplies the applied pressure according to pascal law .The vacuum chamber applied pressure on the first piston then second piston .Pressure in piston cause spring to contract .This enable the fluid from the reservoir to flow in tubes .From the tubes ,these high pressure fluid apply force on calliper , which slides from both sides horizontally and reduce the speed rotor. Rotor coupled with the wheel tyre ,as rotor speed reduce then tyre speed also reduce then both stops [6] .

As the force on brake pedal removes then spring on the master cylinder expands and pistons moves to right side to block the flow of fluid from the fluid reservoir .

THEORETICAL CALCULATION

This section provides a summary of the design decision reached through applying well known theory on brake design .The brake is created for evolocity with wheel diameter of 16'' and maximum car weight of 300 Kg .

Input values

Tyre diameter Dw = 16 Inch or 400 mm

Car weight =300 Kg

Considered values (From wilwood.com)

Rotor diameter Dr =8 Inch or 200 mm

Master cylinder diameter Dm =28.6 mm

Piston diameter Dp =28 mm

mechanical leverage m = 5:1

CALCULATION

In the calculation part by assuming nominal pedal force applied by driver , maximum braking torque to stop the car is calculation .For this calculation ,forces , cross section area and pressure generated across master cylinder , piston ,rotors are calculated .

Suppose a 50 Kg force applied on pedal .Consider Acceleration due to gravity g =10 m/s^2

Pedal force Fp =50*10 =500 N

Due to usage of vacuum chamber , mechanical advantage is obtained at 5:1 at master cylinder .

Force on master cylinder Fm =m x Fp

Fm =5 x 500 =2500 N

Master cylinder area Am =3.14*(28.6^2)/4

Am =642.09 mm^2

Pressure generated at master cylinder p = Fm/ Am

p=2500/642.09 = 3.9 MPa

Double piston calliper is considered .

Force on piston 1

Fp1 =p x Ap1

Piston area Ap1 =3.14*(28^2)/4 =615.75 MPa

Fp1 =3.9x 615.75 =2398 N

Total Force by 2 pistons

FpT = 2398 X 2

FpT=4795 N

Total force on disc/rotor

FD =µ x FpT

µ = coefficient of friction = 0.6

FD =0.6 x 4795

FD = 2877 N

Braking torque

TB= Dr/2 x FD

TB= 200/2 x 2877/1000

TB= 287.7 Nm

Braking force act on the disc/rotor

FB= TB/(Dw/2)

FB= 287.7 /(400/2) *1000

FB= 1438.5 N

It is considered that weight of vehicle = 300kg

Weight act on one wheel = 300 /4 = 75 kg

Now consider the factor of safety of 2 , Weight acted on one wheel = 75 x 2 = 150 Kg

Load on one wheel FT1= 150 x10 =1500 N

Maximum braking toque act to stop the vehicle

TB= Dr/2 x FT1

TB= 200/1000 X 1500

TB= 300 Nm

It is concluded by comparing two values that 50 to 60 Kg load on pedal is enough to stop the vehicle completely .

Minimum distance in which car stops

On applying brakes, kinetic energy must be converted to work .

Maximum speed 50km/hr

Total kinetic energy =Braking force x distance covered(d)

$$\frac{1}{2}mv^2 = F_b * d$$

1/2 x 300 x $(50\ XX\ 5/18)^2$ = 1438.5 X d

28936 = 1438.5 x d

d = 20 .11 meters

So car completely stop from 50KMPH in 20.11 meters [8]

Maximum time in which car stop and Heat generated by brakes

Force F

$F = \mu * m * g$

F = 0.6 X 300 X 9.81 = 1765.8 N

$F = a * m$

$a = \frac{F}{m}$

$a = \frac{1765.8}{300}$

$a = 5.886\ m/\sec^2$

time in which car stops after applying brakes

$t = \frac{v}{a}$

$tt = \frac{13.88}{5.886}$

$t = 22.33\ s$

So car stops in 2.359 sec

$\frac{1}{2} mv^2 = K.E$

$K.E = \frac{1}{2} * 300 * 13.88^2$

$K.E = 28935.18\ J$

Heat generated by brakes to overcome this kinetic energy

$H.E = \frac{K.E}{t} * \mu$

$H.E = \frac{28935.18}{2.359} * 0.6$

$H.E = 7360\ W$

So total heat generated on both sides of disc is 7360 W

DESIGNING USING SOFTWARE

Designing of brake system is done using solidworks .The main part of brake system design is wheel-disc-calliper assembly .So only this part is designed using solidworks .According to the size of wheel , the rotor is available in the market .So rotor is purchased from the market and its specifications are taken from vendor for design evaluation .

The description of main parts of brakes is provided below:-

1) Disc/Rotor

For car braking , disc braking system is used .Disc/rotor is circular part which is coupled to wheel of tyre , So both wheel of car and disc rotate with same rpm .

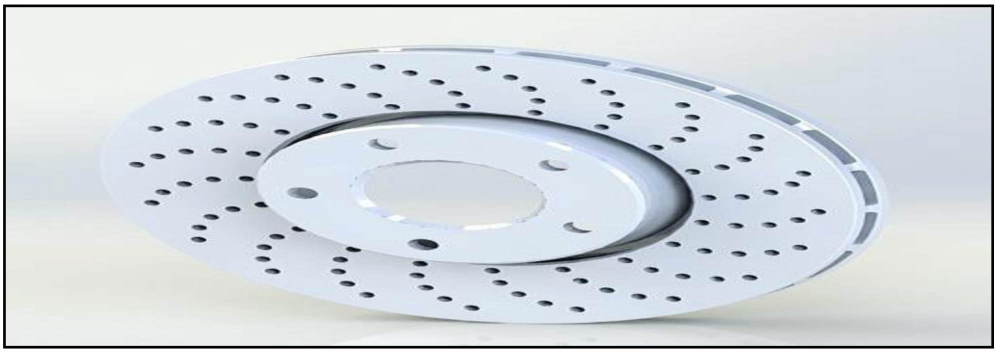


Figure :-1.7 (Disc/rotor)

Manufacturing process :-

The disc is made up of casting process .The mould is prepared similar to shape required for rotor. Liquid metal pour into mould till it solidify. Final product is obtained after grinding the surface of rotor to achieve appreciable surface finish .

Material used :- Grey Cast Iron

By comparing the different material for rotor , major requirement for material is its castability , high temperature resistant ,high torsional strength and machanibility properties .So comparing with mild steel and aluminium , grey cast iron consist all these properties [7] .

Major properties of Grey cast iron is shown below

Elastic Modulus	67	GPa
Poisson's Ratio	0.27	Not Applicable
Shear Modulus	50	GPa
Mass Density	7200	kg / mm^3
Tensile Strength	152	MPa
Thermal Conductivity	45	W / (m · K)

Table :-1.1 (Grey cast iron material properties)

2) Calliper

Calliper is mounted on the rotor. Calliper is connected with fluid tubes on ends of calliper bush . Calliper consist of multiple parts like frame , carbon bush , brass screws and sliding part . Structural steel is used as the rotor frame should be sufficiently strong to stop the high speed rotating disc .Due to fluid pressure, the carbon bush slides horizontally in opposite direction to oppose the rotation of rotor .Calliper also purchased from market .

Manufacturing process

The calliper is complex part , it is also manufactured from casting process . The mould is prepared similar to shape required for calliper. Liquid metal poured into mould cavity untill it solidifies. Final product is obtained after grinding the surface to achieve appreciable surface finish .

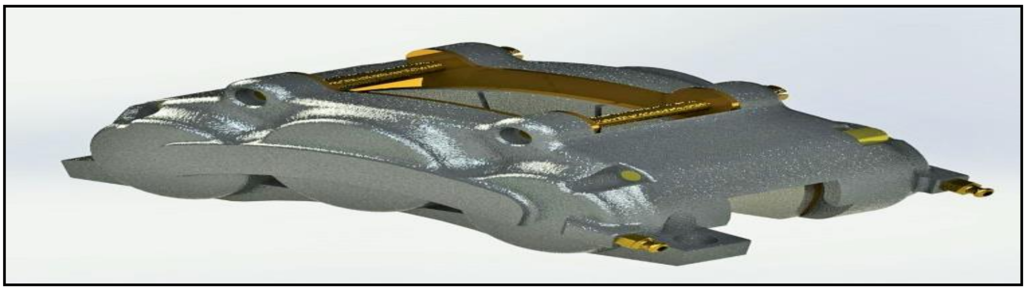


Figure :-1.8 (Calliper)

Material used :- Structural Steel

Major properties of Structural Steel is shown below

Properties	Value	Units
Elastic Modulus	210	GPa
Shear Modulus	7.9	GPa
Mass Density	7850	kg / mm^3
Tensile Strength	400	MPa
Yield Strength	220	MPa
Thermal Conductivity	43	W / (m · K)
Specific Heat	440	J / (kg · K)

Table :-1.2 (Structural steel material properties)

3) WHEEL TYRE ASSEMBLY

Wheel & tyre assembly provide the rotational motion to the vehicle . To stop the vehicle , rotational motion of tyre need to be reduced . As rotor and wheel coupled together , so material of both will be same and material of tyre is natural rubber.

Figure :-1.9 (Tyre wheel)

Material used :- Plain carbon steel/Mild steel

By comparing the different material for tyre wheel , major requirement for material is its castability , high torsional strength and machanibility properties .So comparing with cast iron and aluminium , mild steel consist all these properties .

Major properties of plain carbon steel is shown below

Elastic Modulus	210	GPa
Poisson's Ratio	0.28	N A
Shear Modulus	7.9	GPa
Mass Density	7800	kg / m^3
Tensile Strength	400	MPa
Yield Strength	220	MPa
Thermal Conductivity	43	W / (m · K)

Table :-1.3 (Plain carbon steel material properties)

ASSEMBLY

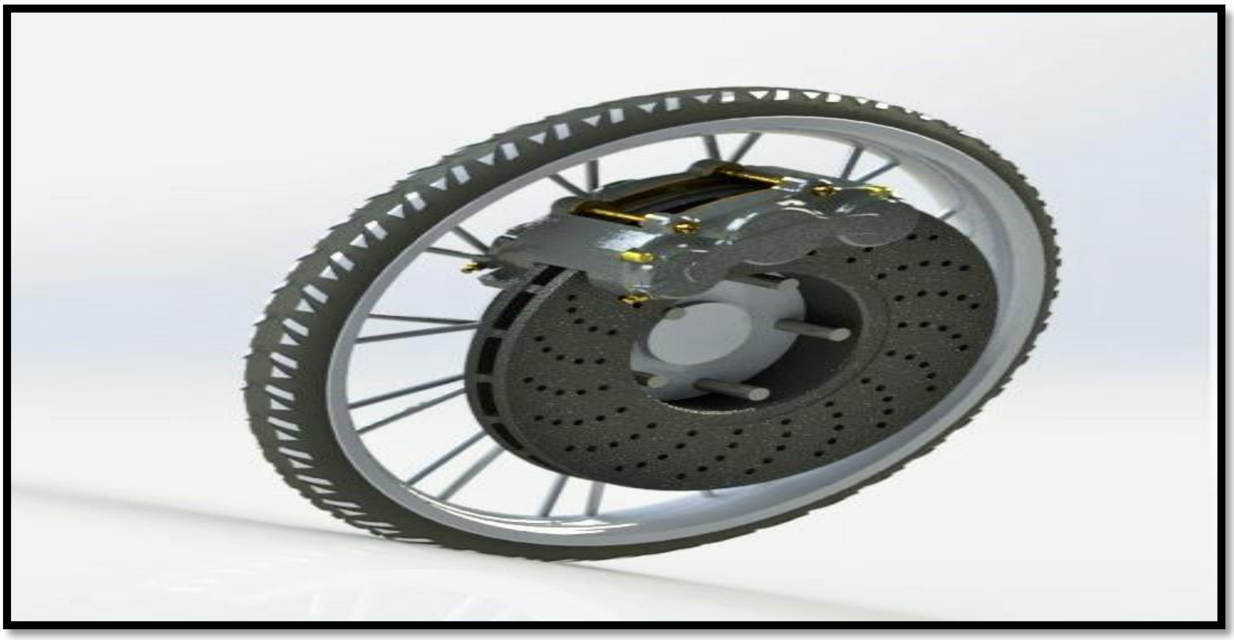
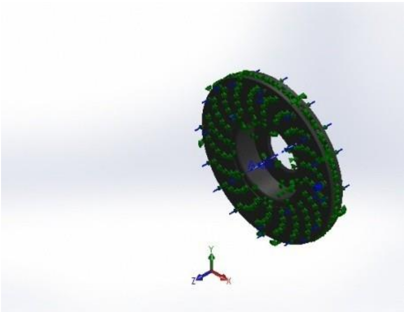


Figure :-1.10 (Wheel Assembly)

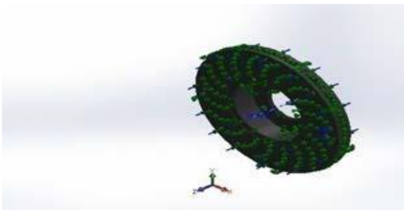
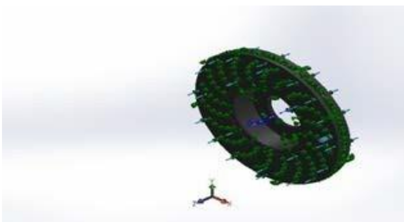
THERMAL SIMULATION ON DISC BRAKE FOR HEAT DISSIPATION

Effect of heat dissipated from the disc while applying brake

Material Properties

Model Reference	Properties
	Name: **Gray Cast Iron** Model type: **Linear Elastic Isotropic** Default failure criterion: **Mohr-Coulomb Stress** Thermal conductivity: **45 W/(m.K)** Specific heat: **510 J/(kg.K)** Mass density: **7200 kg/m^3**

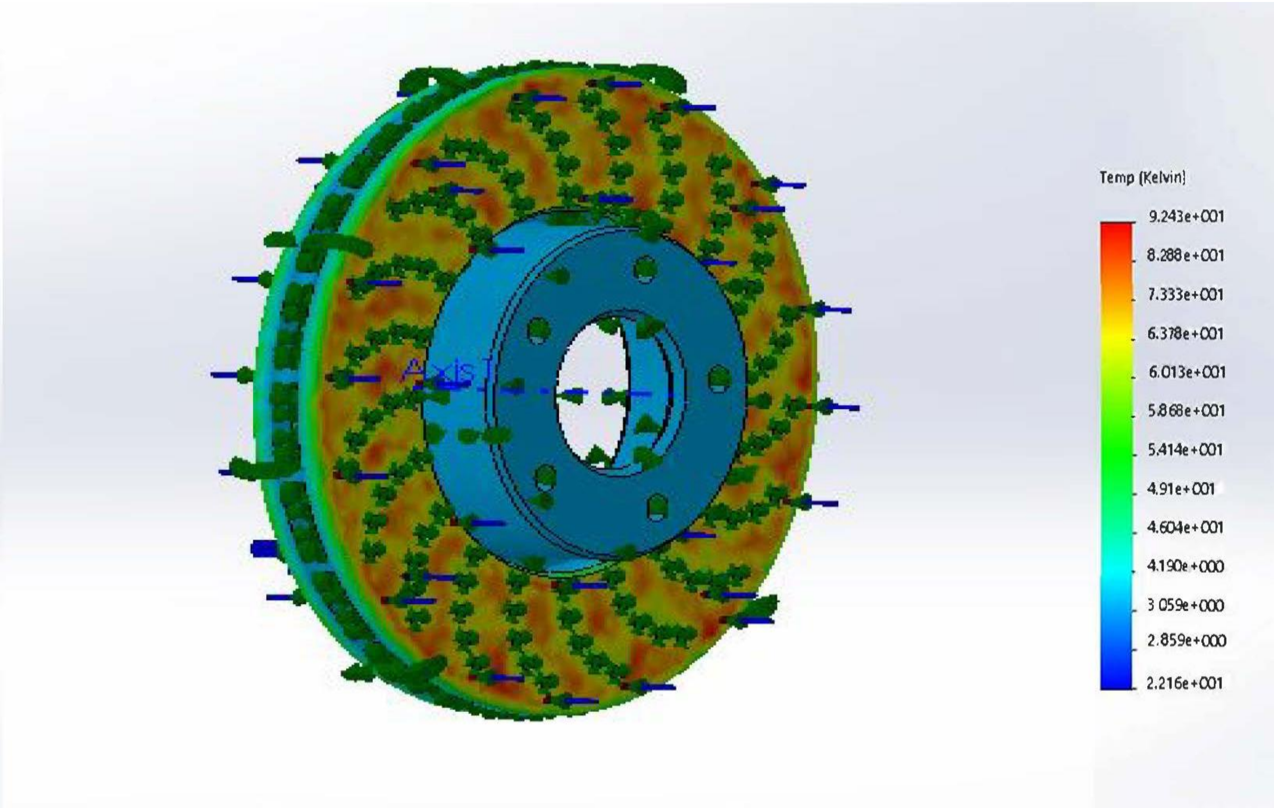
Thermal Loads

Load name	Load Image	Load Details
Convection-1		**Entities:** **310 face(s)** **Convection Coefficient:** **90 W/(m^2.K)** **Bulk Ambient Temperature:** **293 Kelvin**
Heat Power-1		**Entities:** **2 face(s)** **Heat Power Value:** **7360 W** **Time variation:** **on**
Temperature-1		**Entities:** **2 face(s)** **Initial temperature:** **293 Kelvin**

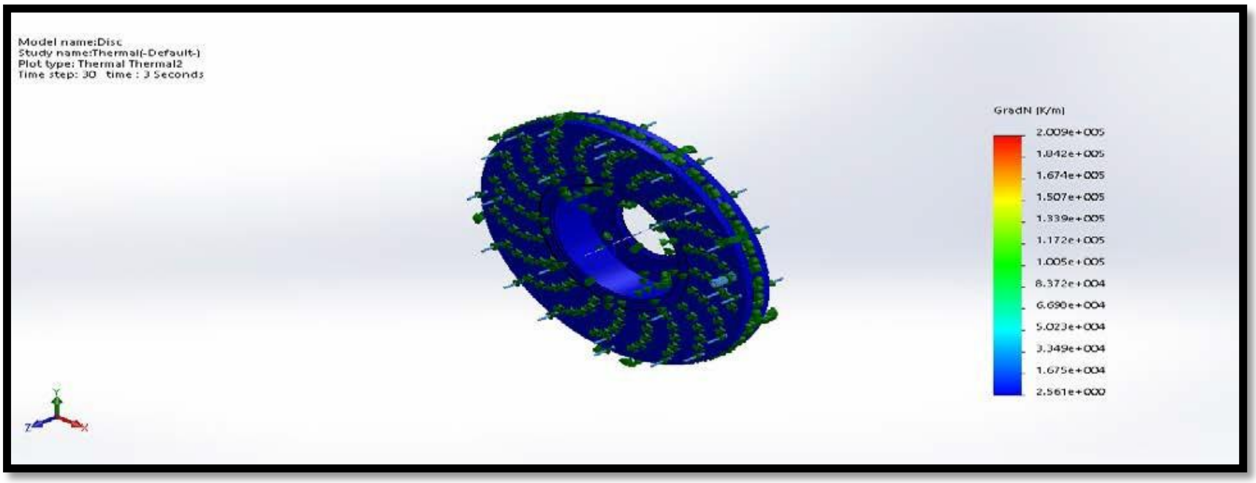
- In the above table , heat transfer coefficient of air around the rotor surface is considered as h=90 W/㎡k .Heat transfer coefficient is responsible for the transfer of heat by convection method .
- From theoretical calculation heat generated while applying brakes is 7360 W .This generated heat is applied on the both surface of rotor .
- The initial temperature of rotor before applying brakes is 293Kelvin.
- From these above input ,temperature variation in rotor is observed .

Study Results

Name	Type	Min	Max
Thermal1	TEMP: Temperature change at Step No: 6(0.6 Seconds)	22.1558 Kelvin Node: 189	92.4276 Kelvin Node: 4325



Name	Type	Min	Max
Thermal2	GRADN: Resultant Temp Gradient at Step No: 30(3 Seconds)	2.56097 K/m Node: 45799	200922 K/m Node: 3238



- From the heat generated, temperature variation in rotor is shown above, maximum temperature change in rotor is 92.4 Kelvin for grey cast iron material .
- The value of temperature change is very less and this will not overheat the rotor so our rotor design is safe .

STATIC SIMULATION ON WHEEL RIM FOR WEIGHT OF VEHICLE

As the total load of vehicle is act upon the wheels .
It is considered that weight of vehicle = 300Kg

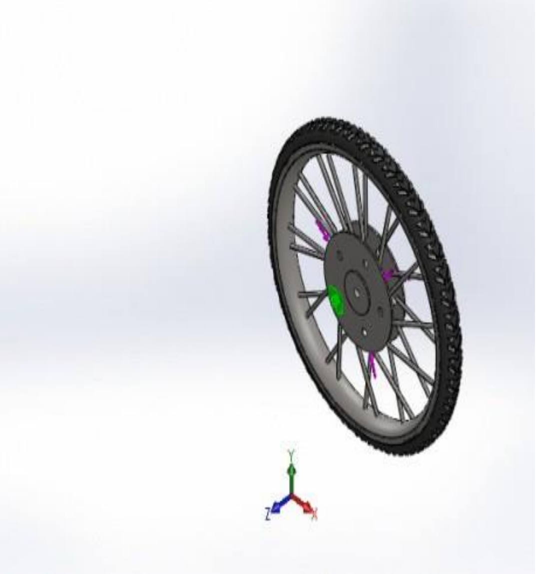
Weight act on one wheel = 300 /4 = 75 Kg

Now consider the factor of safety of 2 , Weight acted on one wheel = 75 x 2 = 150 Kg

Load on one wheel FT1= 150 x10 =1500 N

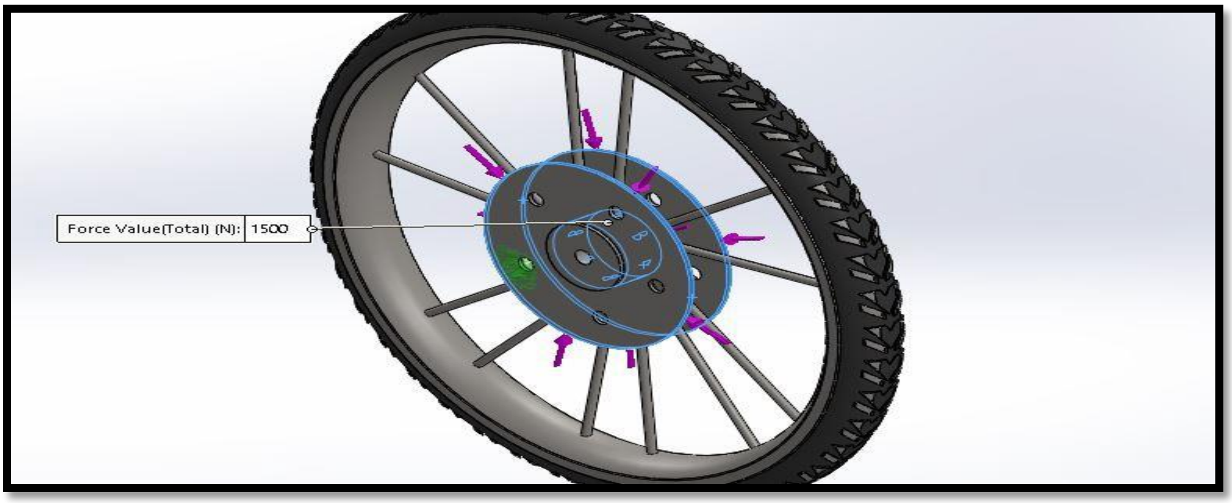
Now test the wheel for load conditions of 1500 N in solidworks software .

Material Properties

<table>
<tr><th>Model Reference</th><th colspan="2">Properties</th></tr>
<tr><td rowspan="9"></td><td>Name:</td><td>Plain Carbon Steel</td></tr>
<tr><td>Model type:</td><td>Linear Elastic Isotropic</td></tr>
<tr><td>Default failure criterion:</td><td>Unknown</td></tr>
<tr><td>Yield strength:</td><td>2.20594e+008 N/mm^2</td></tr>
<tr><td>Tensile strength:</td><td>3.99826e+008 N/mm^2</td></tr>
<tr><td>Elastic modulus:</td><td>2.1e+011 N/mm^2</td></tr>
<tr><td>Poisson's ratio:</td><td>0.28</td></tr>
<tr><td>Mass density:</td><td>7800 kg/mm^3</td></tr>
<tr><td>Shear modulus:</td><td>7.9e+010 N/mm^2</td></tr>
</table>

LOADING

Load of 1500 Newton act on wheel .The load act of the periphery of hub of wheel .Load is divided on both side of hub of wheel .

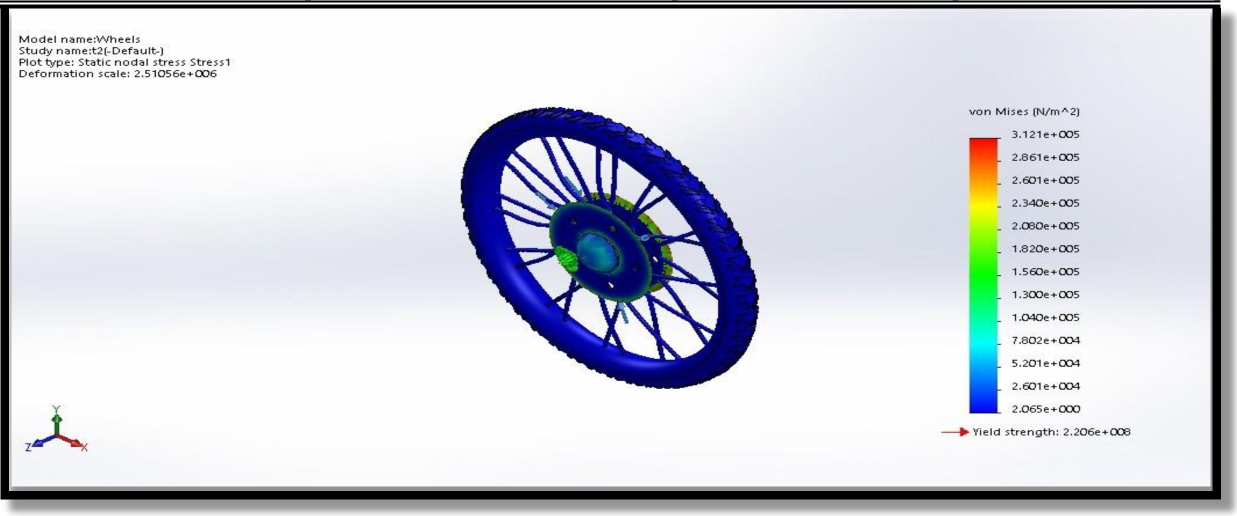


REACTION FORCES

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-1.56122	2.76754	-0.000281976	3.17752

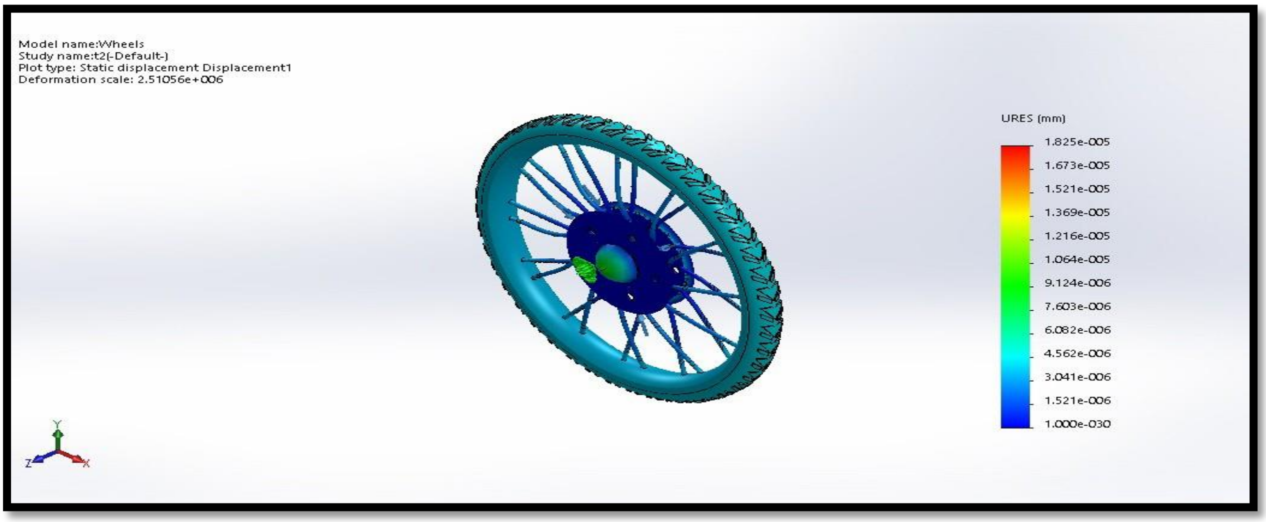
Study Results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	2.06 N/m^2 Node: 78221	312 kN/m^2 Node: 102461



The above study shows that maximum stress generated is less than von mises stress .So our design is safe .

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 139	1.825e-005 mm Node: 5902



The above study shows that maximum deflection value is 0.000018 which is very less so our design is safe .

BATTERY MOUNTING DESIGN

- Size of battery is 185 x150x 175 mm so battery frame design accordingly .
- Weight of battery is 11 Kg or 110 Newton so that frame should be sufficiently strong to bear its load
- Battery should be fixed in mounting frame and should not be moved while acceleration and deceleration .

DESIGN PROCESS

A rough sketch is produced as per input requirements, the designing process takes place considering the sketch as per battery dimensions.

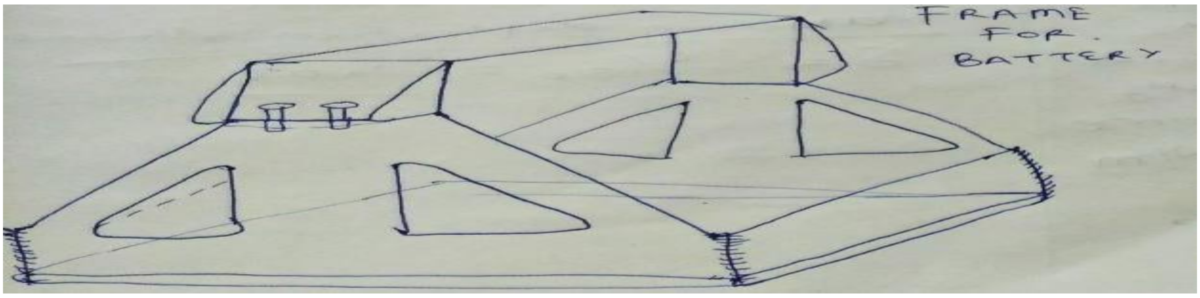
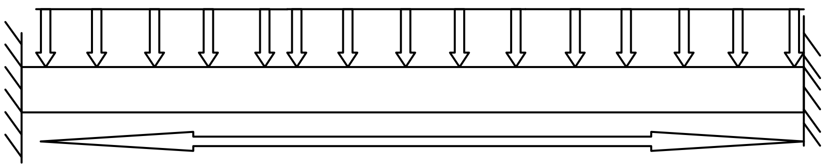


Figure :-2.1 (Mounting frame sketch)

- Consider the weight of battery is 11 Kg or 110 N. So this 110 N load act on the the base of frame. Angles are used at the corners of frame to support the load act on the frame .
- The total load act of the frame is uniformly distributed on the angle face .Suppose if 4 angle are used then total load will be divided among 4 angles .The load act on 1 angle is 27.5 Newton .This assume 1/4th total load on each side .
- Considering the factor of safety of 2 ,The angle is tested at load of 55 Newton .
- Consider the case of fixed support angle where the load is acted uniformly distributed .
- For the worst case , design will be done from the width of frame . As the width of battery is 150 mm , consider the length of angle used is 160 mm .



343.75 N/m

160 mm

According to structural engineering [10]

Minimum depth of angle used = L /20 = 160 /20 = 8 mm

So d = 8 mm

Maximum deflection allowed for this angle according to IS707 an IS700

y = L /150 = 160 /150 = 1.06 mm

Shear force and bending moment diagram

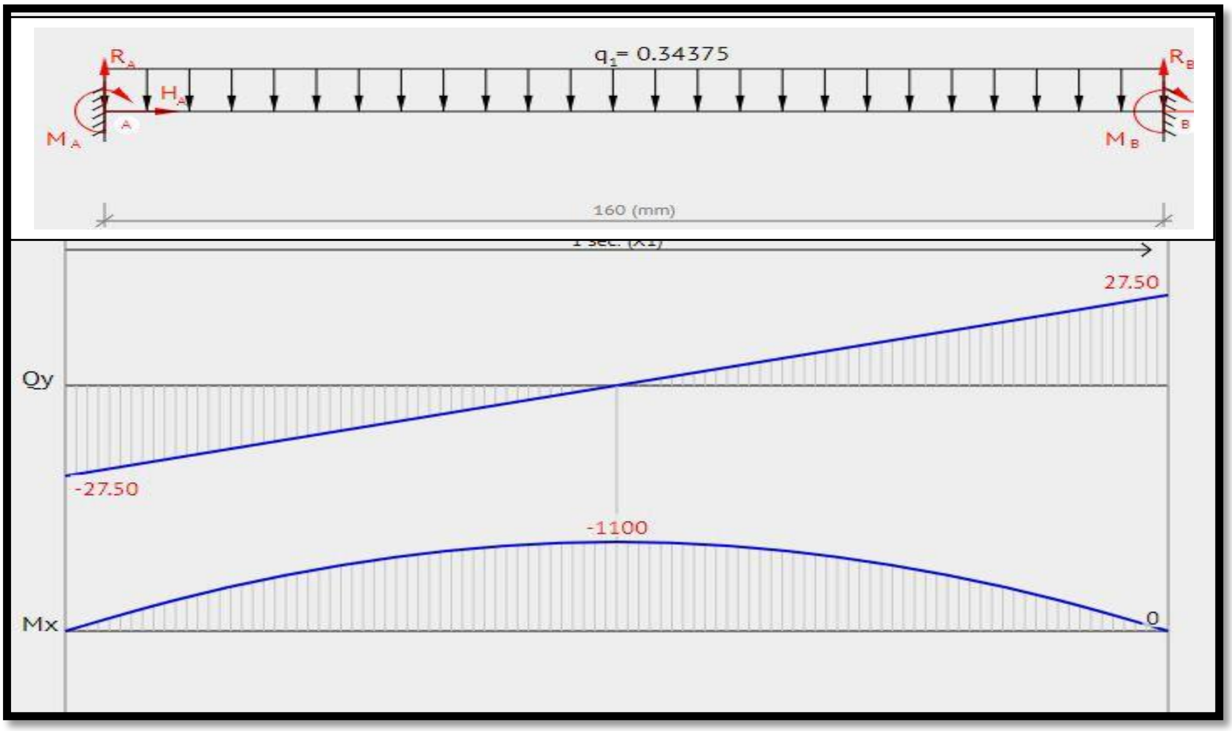


Figure :-2.2 (Shear force & Bending moment diagram)

Calculate the reactions at the supports of a beam

1. A beam is in equilibrium when it is stationary relative to an inertial reference frame. The following conditions are satisfied when a beam, acted upon by a system of forces and moments, is in equilibrium:

$\Sigma F_x = 0$: $H_A = 0$

$\Sigma M_A = 0$: The sum of the moments about a point A is zero:

$q_1*160*(160/2) + R_B*160 = 0$

$\Sigma M_B = 0$: The sum of the moments about a point B is zero:

$- R_A*160 - q_1*160*(160 - 160/2) = 0$

2. Solve this system of equations:

$H_A = 0$ (N)

Calculate reaction of roller support about point B:

$R_B = \mathbf{(} - q_1*160*(160/2)\mathbf{)} \mathbf{/ 160} = \mathbf{(} - 0.34375*160*(160/2)\mathbf{)} \mathbf{/ 160} = -27.50$ (N)

Calculate reaction of pin support about point A:

$R_A = \mathbf{(} - q_1*160*(160 - 160/2)\mathbf{)} \mathbf{/ 160} = \mathbf{(} - 0.34375*160*(160 - 160/2)\mathbf{)} \mathbf{/ 160} = -27.50$ (N)

3. The sum of the forces is zero: **$\Sigma F_y = 0$:** $- R_A + q_1*160 - R_B = - 27.50 + 0.34375*160 - 27.50 = 0$

First span of the beam: $0 \le x_1 < 160$

Determine the equations for the shear force (Q):

$Q(x_1) = - R_A + q_1*(x_1 - 0)$

$Q_1(0) = - 27.50 + 0.34*(0 - 0) = -27.50$ (N)

$Q_1(160) = - 27.50 + 0.34*(160 - 0) = 27.50$ (N)

The value of Q on this span that crosses the horizontal axis. Intersection point:

x = 80

Determine the equations for the bending moment (M):

$M(x_1) = - R_A*(x_1) + q_1*(x_1)^2/2$

$M_1(0) = - 27.50*(0) + 0.34*(0 - 0)^2/2 = 0$ (N*mm)

$M_1(160) = - 27.50*(160) + 0.34*(160 - 0)^2/2 = 0$ (N*mm)

Local extremum at the point x = 80:

$M_1(80) = - 27.50*(80) + 0.34*(80 - 0)^2/2 = -1100$ (N*mm)

Maximum deflection will be at centre

$$ee = \frac{WW * ll^4}{384\ EE * II}$$

From the maximum deflection allowed y =1.06 mm

$$\frac{106}{1000} = \frac{55 * 0.16^4}{384\ EE * II}$$

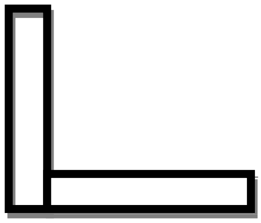
Ex I = 0.588 N mm^2

Material selection

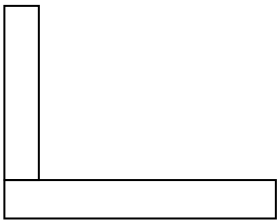
As For Aluminium E = 69 GPa

For Steel E = 210 GPa

- If the Aluminium material is considered for frame and angles , then to satisfy E * I value , the size of the angle need to be increased .
- As young modulus for steel is high as compared to aluminium , so small size of angle can be used to get the required strength .
- To maintain the flexural rigidity value with steel , angle of 20x20x4 is used [9].
- From the above two design of angles , design b will be preferred because moment of inertia along x axis will be greater for design b.High moment of inertial means less deflection .



Design a



Design b

WELDING DESIGN & PLATE SELECTION

- According to welding theory , Welding thickness should be maintained similar to the thickness of the plate used , here the angle having thickness of 4 mm .
- So to make the design save , minimum welding of 4 mm must be done between two joining end of angles and plate .
- To maintain the uniformity in design , 4 mm base plate is used with 20x20x4 angle .

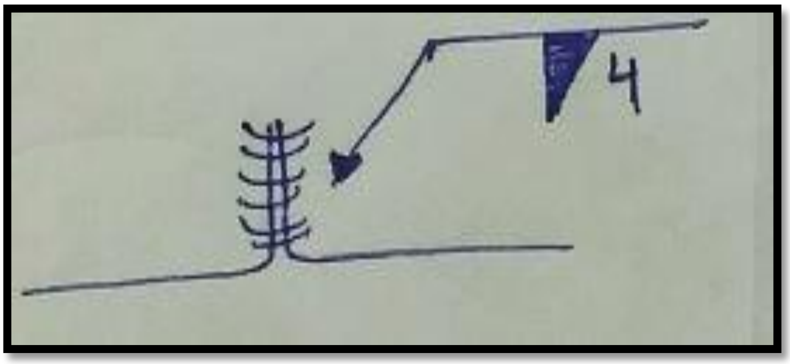


Figure :-2.3 (Welding design)

STRAIN ENERGY

- It is the energy absorbed by the angle/ plate when the load applied on it .Here when the battery is placed on the frame , then some amount of energy absorbed by frame depending upon the weight of battery .
- If the strain energy within elastic limit , then it is called resilience .When the load is removed then the energy is released .
- But when the strain energy value exceed the resilience limit , then permanent deformation of angle/plate takes place , it is called as toughness .

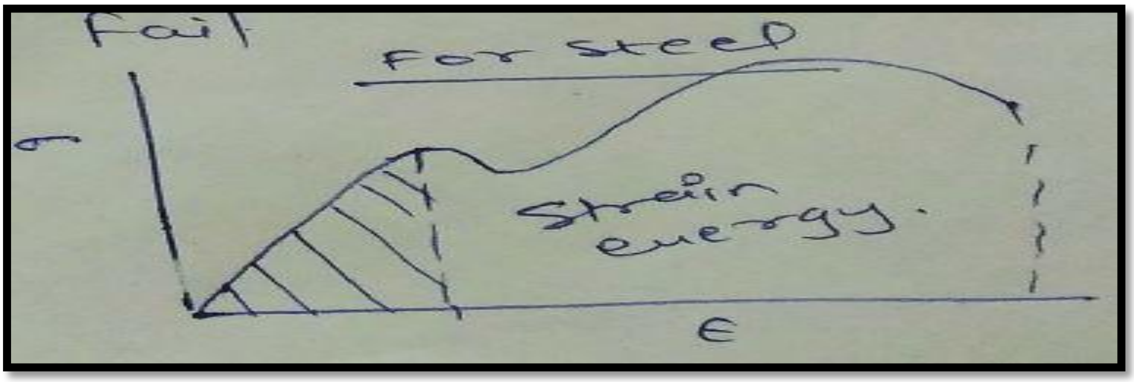


Figure :-2.4 (Strain energy)

Strain energy in this case ,

S.E = ½ * load * deflection

S.E = ½* 55* 1.06/1000

Strain energy = 27.5 Nmm

DESIGNING USING SOFTWARE

Designing of battery frame is done using solidworks .The details of battery frame is provided below:-

1) BATTERY/MOTOR MOUNTING FRAME

The designed frame has the capability to bear the load of battery in given conditions .

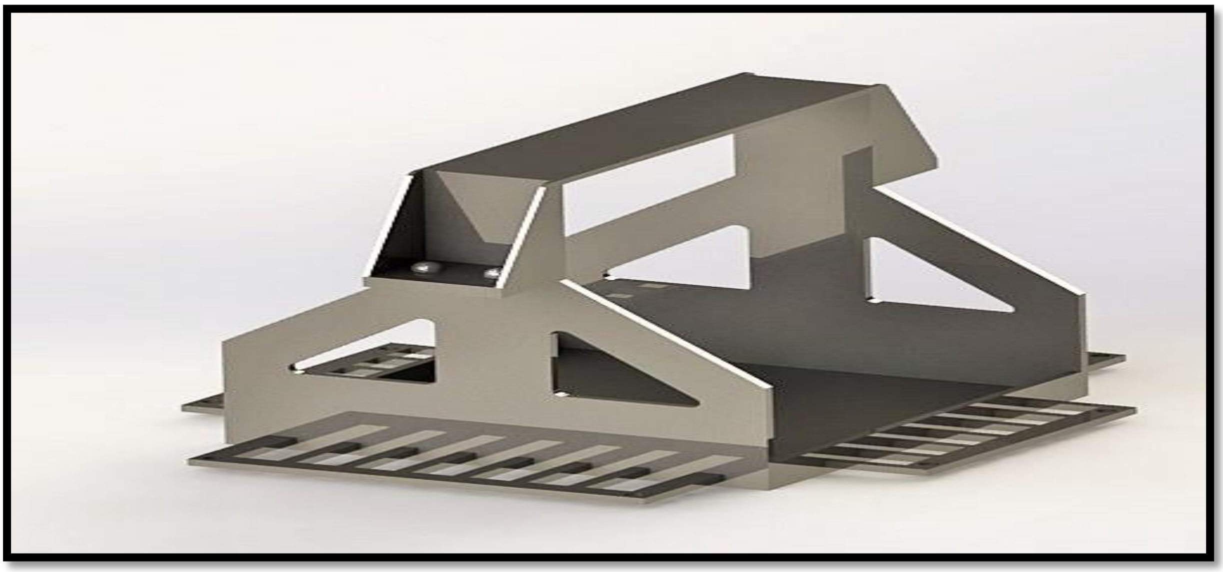


Figure :-2.5 (Mounting frame design using solidworks)

Manufacturing process :-

The mounting frame is manufacture by sheet metal process .Angles is welded around the corner of frame and rest part is prepared by welding of 4 mm plate all around [11] .

Assembly

The base frame consist of three parts :-

1. upper frame part
2. lower frame part
3. bolts

Material used :- Plain carbon steel

By comparing the different material for base frame , flexural rigidity (E*I) value is high in steel as compared to aluminium .So plain carbon steel is used for mounting frame material .

Major properties of plain carbon steel is shown below

Elastic Modulus	210	GPa
Poisson's Ratio	0.28	N A
Shear Modulus	7.9	GPa
Mass Density	7800	kg / m^3
Tensile Strength	400	MPa
Yield Strength	220	MPa
Thermal Conductivity	43	W / (m · K)

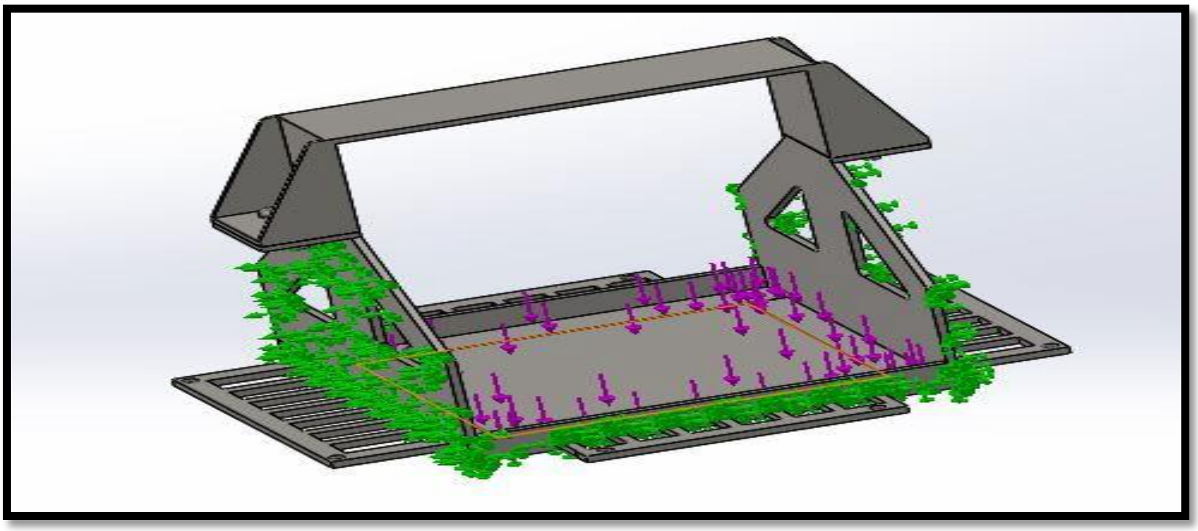
Table :-2.1 (Plain carbon steel material properties)

STATIC SIMULATION OF MOUNTING FRAME FOR WEIGHT OF BATTERY

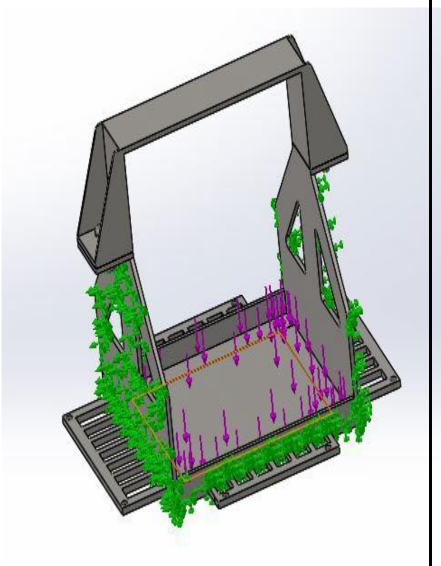
As the total weight of battery acted upon the mounting frame is considered to be =11 kg or 110 Newton

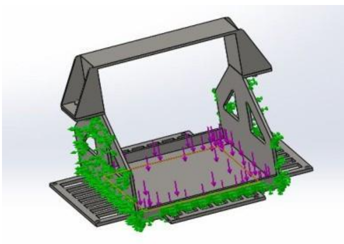
Now consider the factor of safety of 2 , Weight acted on frame = 110 x 2 = 220 N

Now test the wheel for load conditions of 220 N in solidworks software .



Material Properties

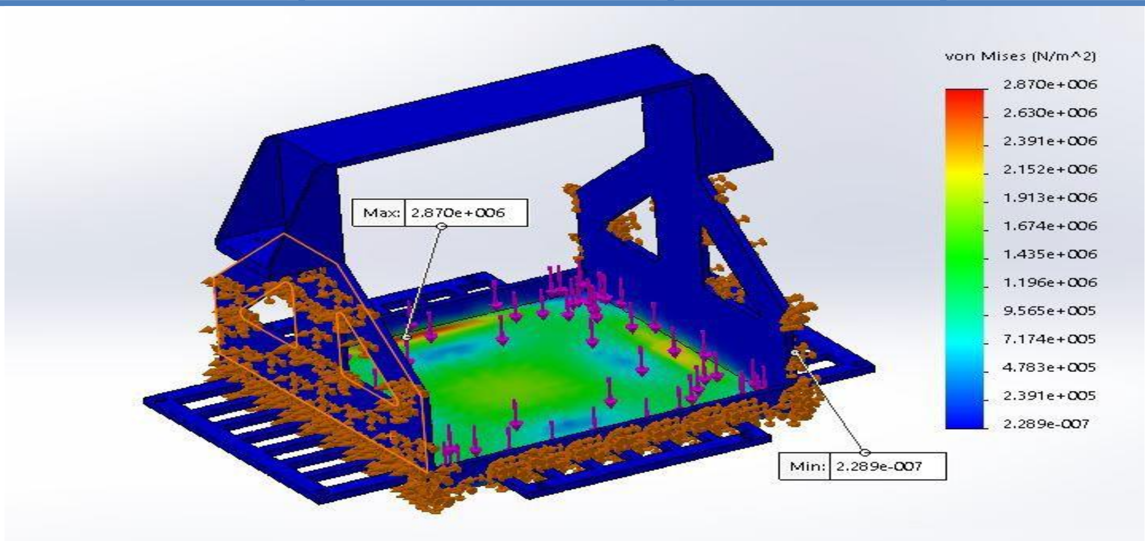
Model Reference	Properties
	Name: **Plain Carbon Steel** Model type: **Linear Elastic Isotropic** Yield strength: **2.20594e+008 N/m^2** Tensile strength: **3.99826e+008 N/m^2** Elastic modulus: **2.1e+011 N/m^2** Poisson's ratio: **0.28** Mass density: **7800 kg/m^3** Shear modulus: **7.9e+010 N/m^2** Thermal expansion coefficient: **1.3e-005 /Kelvin**

Load name	Load Image	Load Details
Force-1		**Entities: 2 face(s)** **Type: Apply normal force** **Value: 220 N**

Study Results

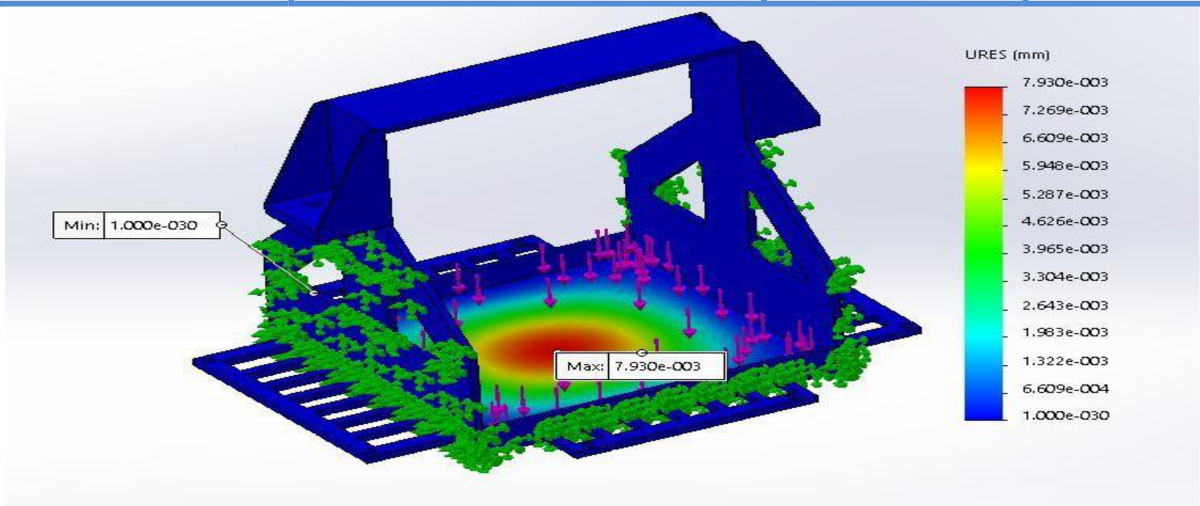
Name	**Type**	**Min**	**Max**
Stress1	VON: von Mises Stress	0 N/m^2 Node: 3399	8.041 MPa Node: 7780

Name	Type	Min	Max



Assembly-frame-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 5	7.9e-003 mm Node: 7981



Assembly-frame-Displacement-Displacement1

From the above results , it is concluded that deflection in the mounting frame is very less .So the design is safe .

SEAT BELT DESIGN

Seat belt is a safety part of vehicle which is used to hook the driver with the seat while driving. As seat belt directly links with human being so its material should be soft enough on the other sides it should have capabilities to have load carrying capacity .A general design of seat belt is proposed below .

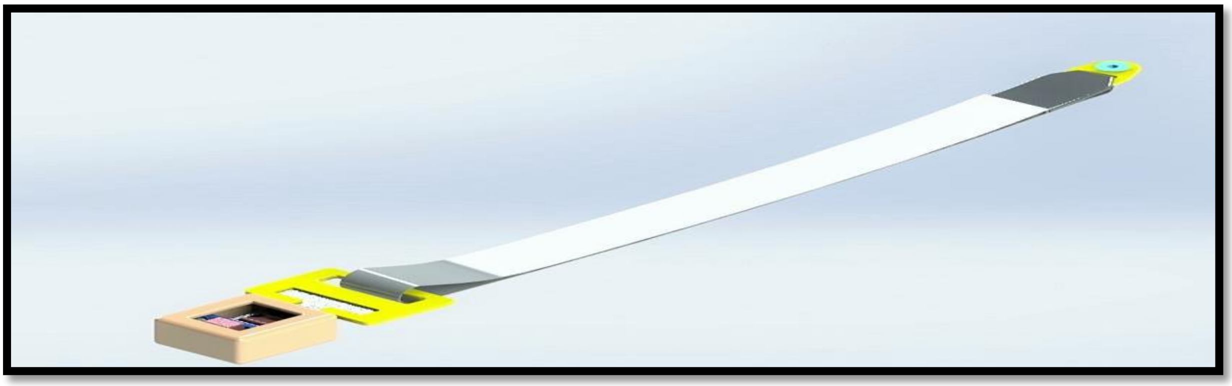


Figure :-3.1 (Seat belt assembly)

The main components of seat belt is shown below :-

1) Locking assembly

   The locking assembly is used to lock the belt with the vehicle frame and it is located at one end of belt .The parts of locking assembly is shown below .

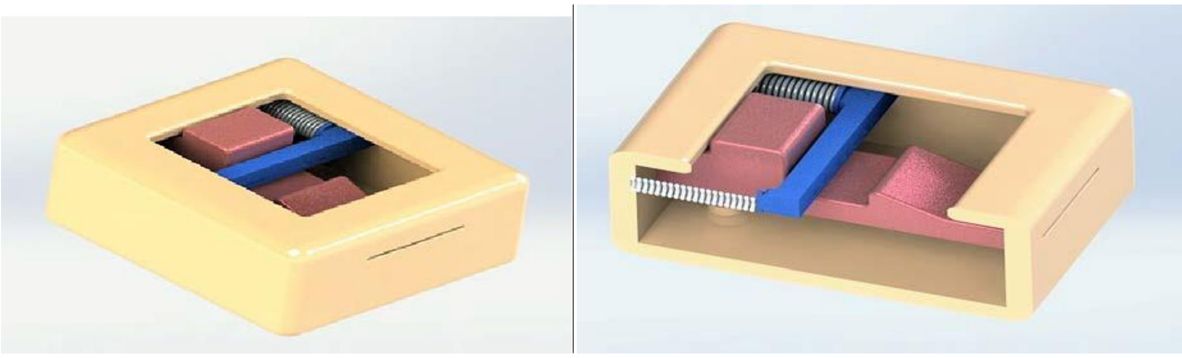


Figure :-3.2 a,b (Locking assembly)

2) Belt

   Belt is the main part of seat belt as load act on belt surface. Belt material should be highly flexible and elastic to absorb and release energy without failure. The main belt length is 2000 mm to cover the seat .The mini belt is join the belt with hook 3 .

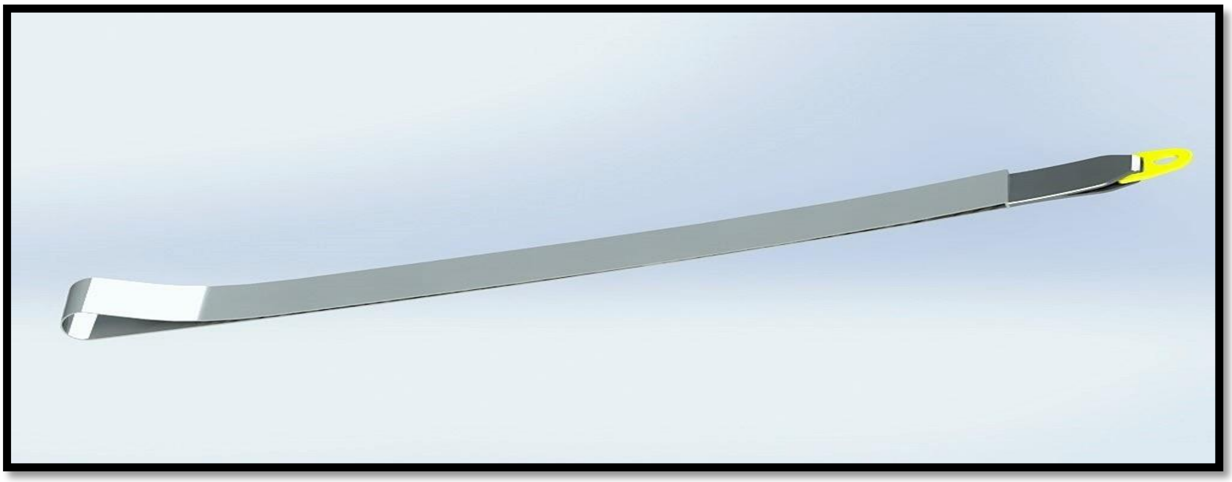


Figure :-3.3 (Belt assembly)

Material used :- Nylon

Nylon is selected as belt material for its high tensile strength .

Major properties of Nylon is shown below

Property	Value	Units
Elastic Modulus	1	GPa
Poisson's Ratio	0.3	Not applicable
Mass Density	1150	Kg $/mm^3$
Tensile Strength	79.2	MPa
Yield Strength	60	Mpa
Thermal Expansion Coefficient	1e-006	/ K
Thermal Conductivity	0.53	W / (m·K)
Specific Heat	1500	J / (kg·K)

Table :-3.1 (Nylon material properties)

3) Hook

Hook is used to tie the belt with the locking assembly. The hook is provided with the sufficient space to hook the belt on one side and locking arrangement on other side .

Figure :-3.4 (Hook)

Theoretical Calculation

The material select for belt is nylon because it have high tendency to store elastic energy when load is applied and release the energy when load is released.

Load on the belt act when the brakes applied by the driver .Suppose the driver suddenly apply brakes from the speed of 50Km/hr .

Speed of vehicle = 50Km/hr or 13.8 m/s

Mass of driver = 70 Kgs (assume)

Kinetic energy of driver = ½* m * v^2

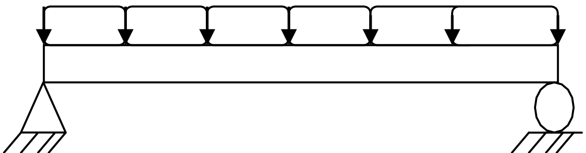
Kinetic energy of driver = ½* 70 * 13.8^2

= 6708.3 J

For the belt design should be safe , this kinetic energy will be act on belt and becomes belt strain energy .

So strain energy of belt =6708.3 J

Load acting on belt according to the case of uniform distributed load .



Maximum deflection will be at centre

$$ee = \frac{5W * l^4}{384\, E * I}$$

Load =40 kg or 400 N

L = 2 m

E =1 Gpa

Put all values we get

X = 60 mm

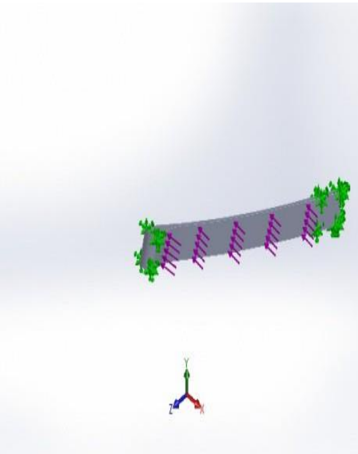
So maximum defection allowed on belt is 60 mm.

Design using software

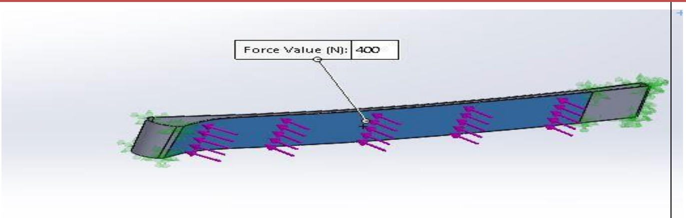
Simulation

In simulation, ends of belt are kept fixed and load applied on belt is 400 Newton in horizontal direction.

Material Properties

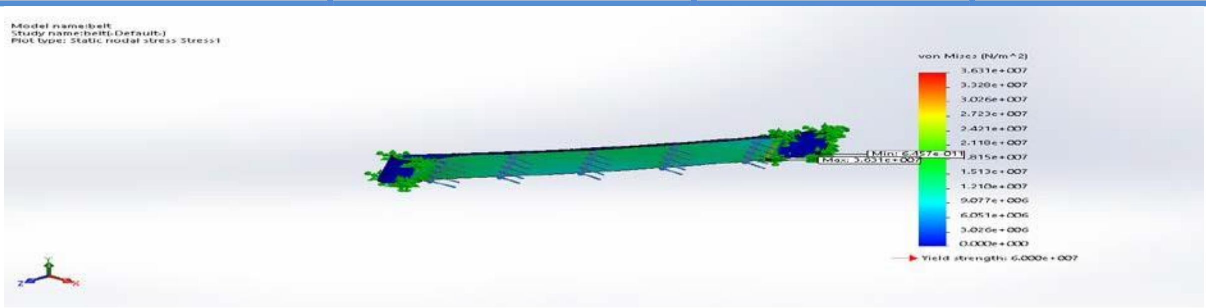
Model Reference	Properties
	Name: Nylon 101 Model type: Linear Elastic Isotropic Default failure criterion: Max von Mises Stress Yield strength: 6e+007 N/m^2 Tensile strength: 7.92897e+007 N/m^2 Elastic modulus: 1e+009 N/m^2 Poisson's ratio: 0.3 Mass density: 1150 kg/m^3 Thermal expansion coefficient: 1e-006 /Kelvin

Force

Load name	Load Image	Load Details
Force-1		**Entities: 1 face(s)** **Type: Apply normal force** **Value: 400 N**

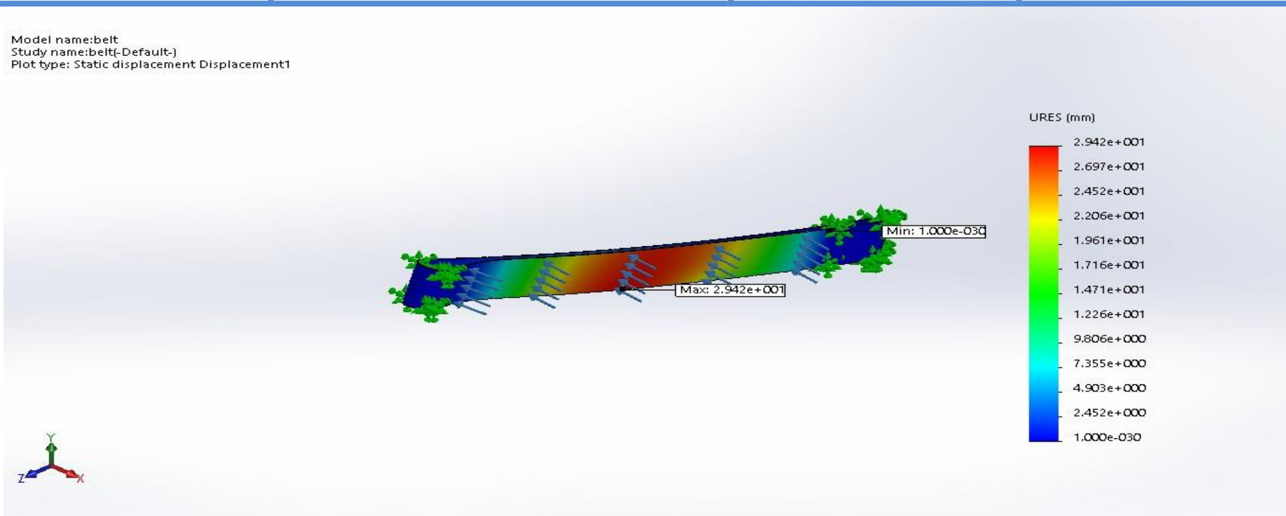
Study Results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	0 N/m^2 Node: 1	36.3 Mpa Node: 21849



belt-belt-Stress-Stress1

Name	Type	Min	Max
Displacement	URES: Resultant Displacement	0 mm Node: 1	29.4185 mm Node: 1726



belt-belt-Displacement-Displacement1

As maximum allowable displacement is 60 mm , in above picture maximum displacement is 29.415 mm , so it is concluded that the design is safe .

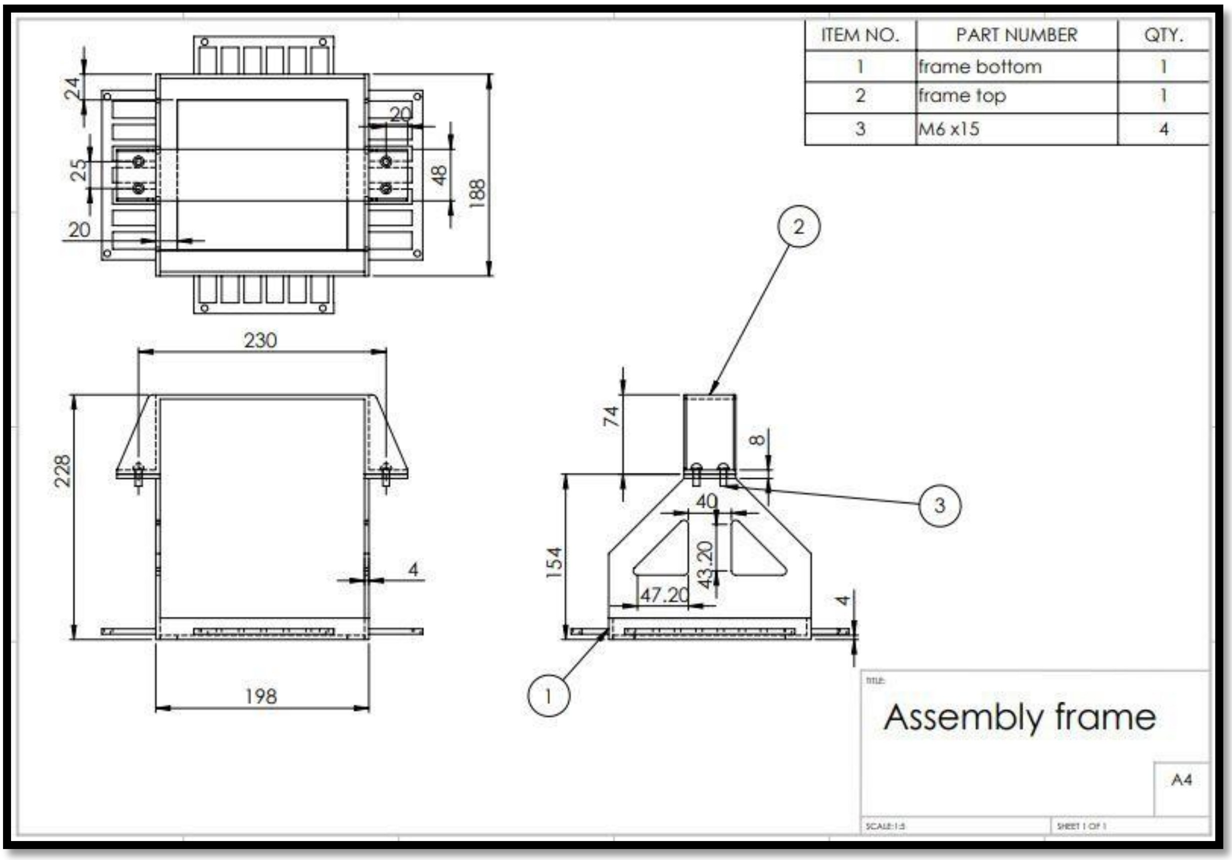
CONCLUSION

The braking system , battery frame and seat belt is design using optimum condition and result obtained is in the form of maximum stress acted upon the part . The theory used of stress analysis is von mises theory (maximum distortion energy theory) .For all three parts , maximum stress value is way less than its von mises stress . So it is concluded that the design is safe .

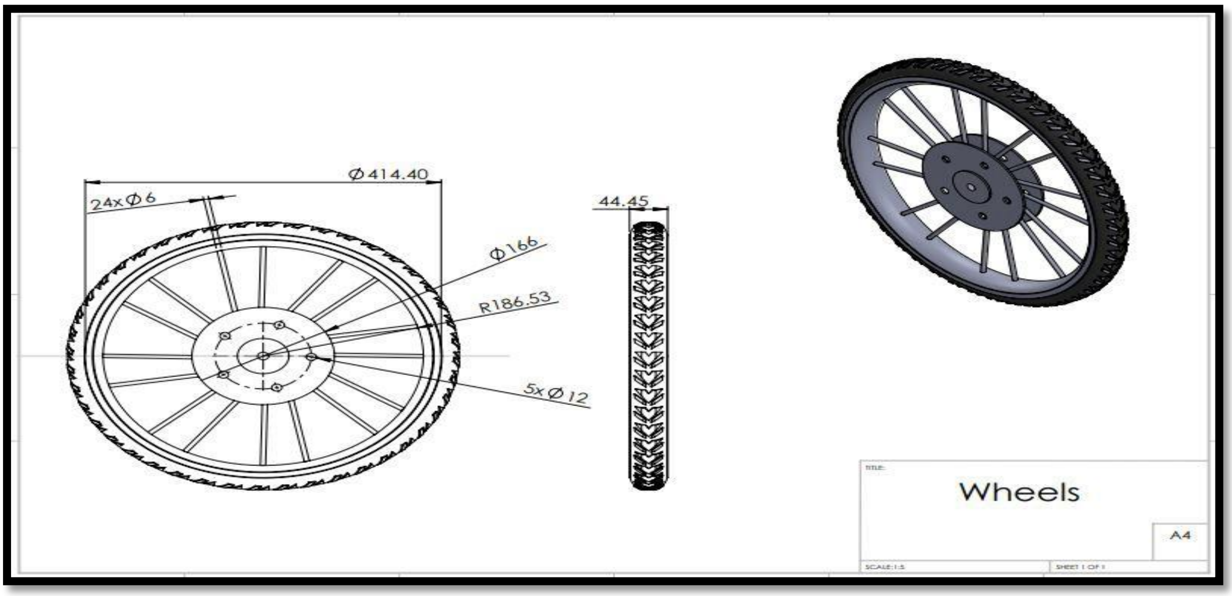
APPENDIX

Detailed drawings

- Frame

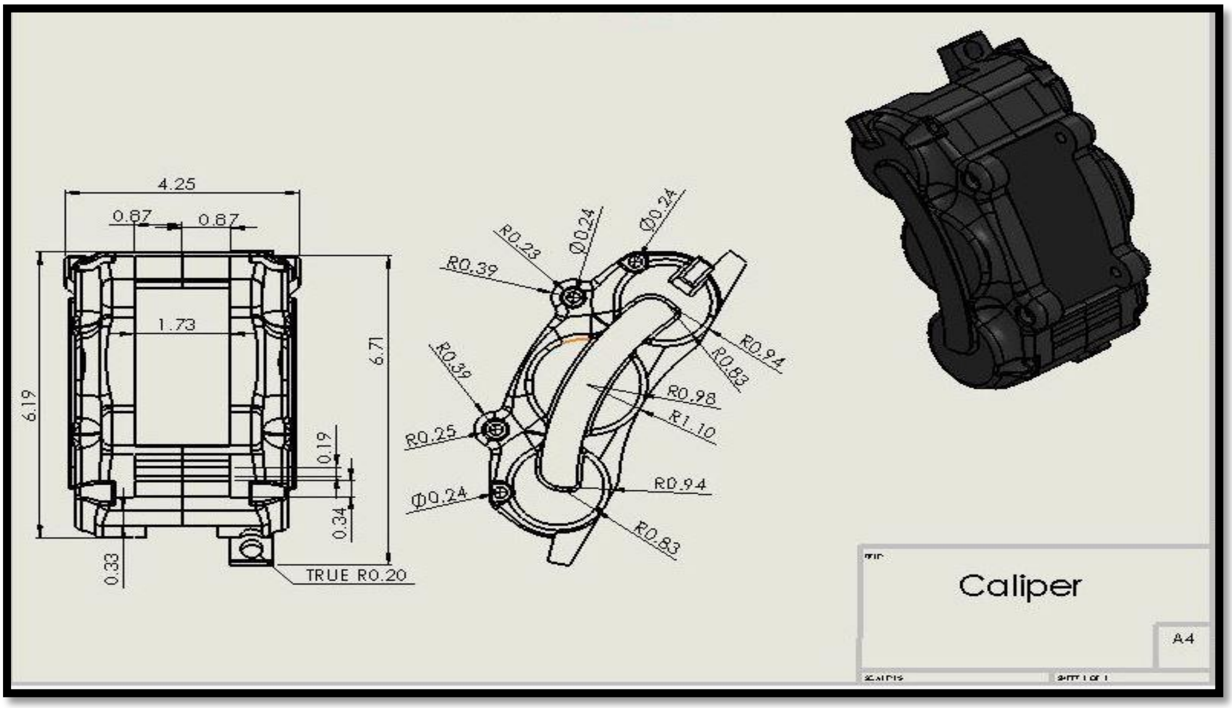


- Brake Wheel

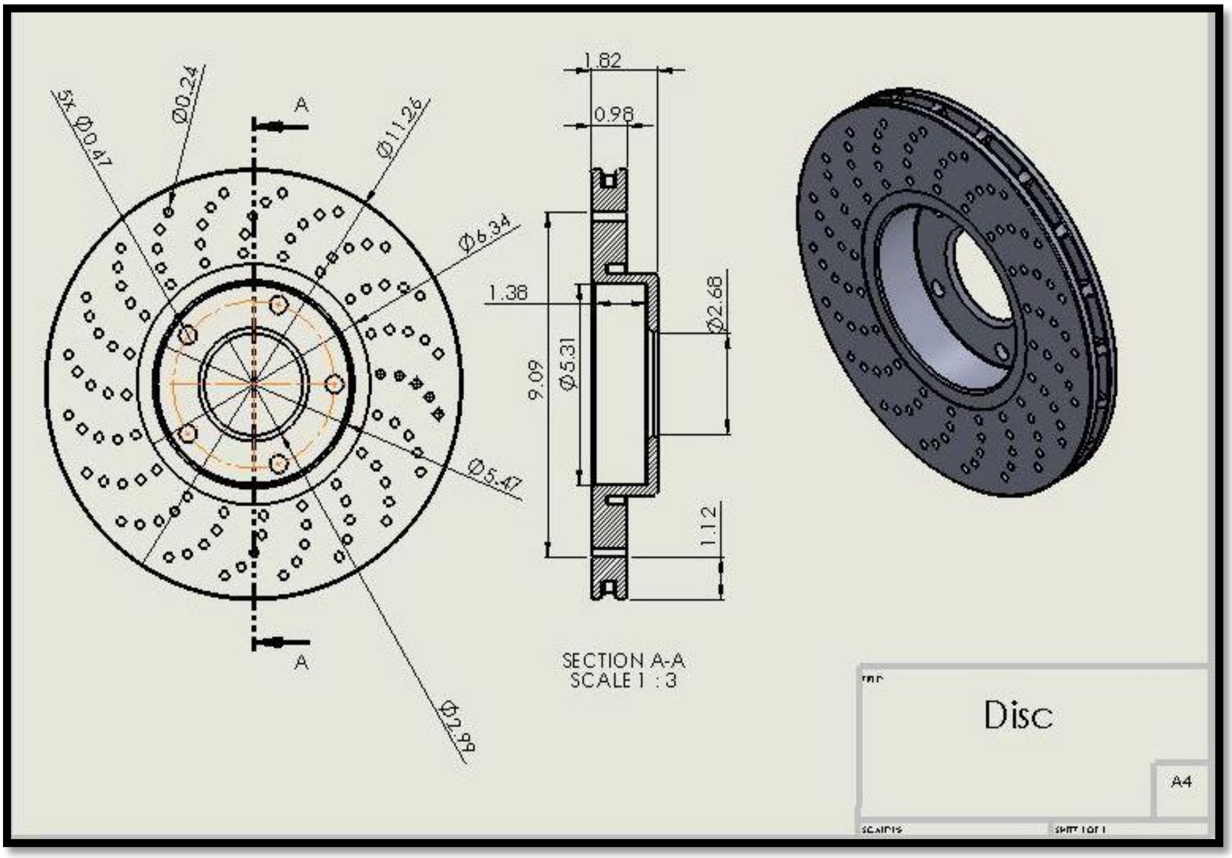


ENGINEERING DESIGN REPORT

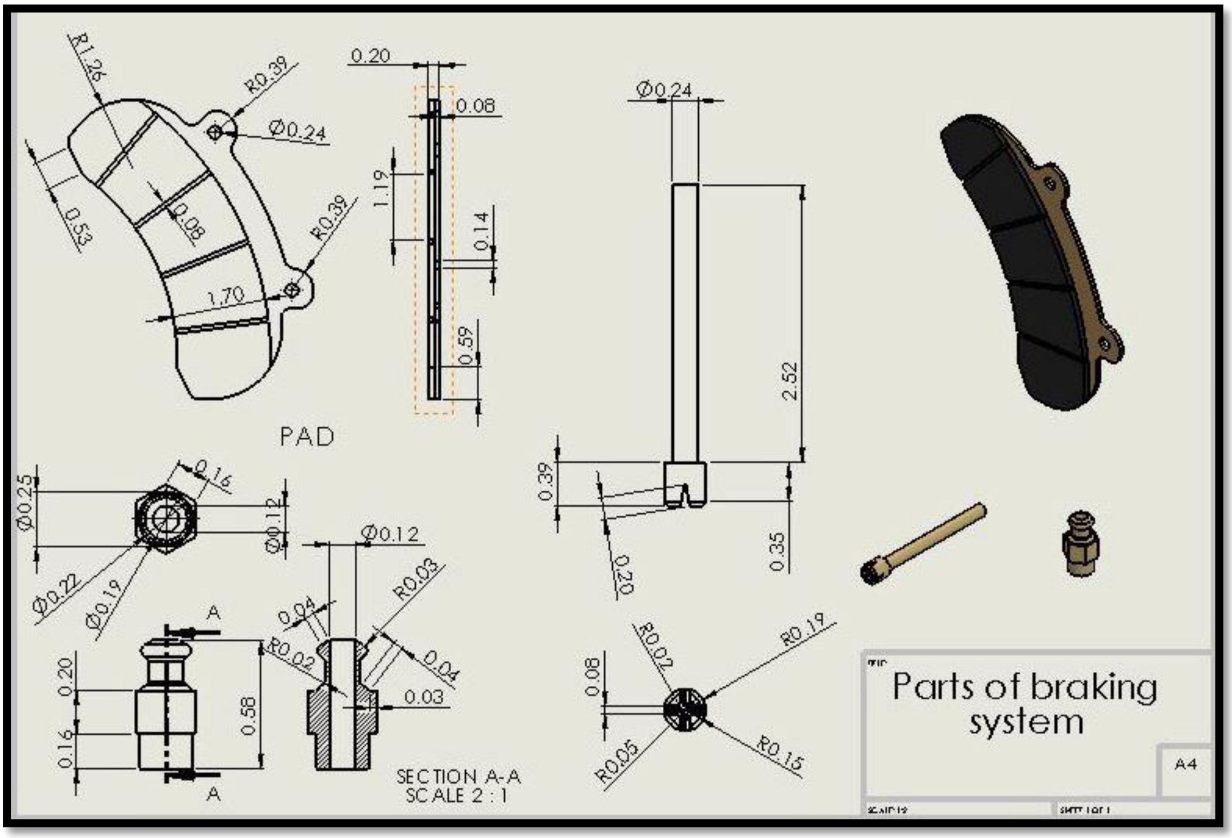
❖ Calliper



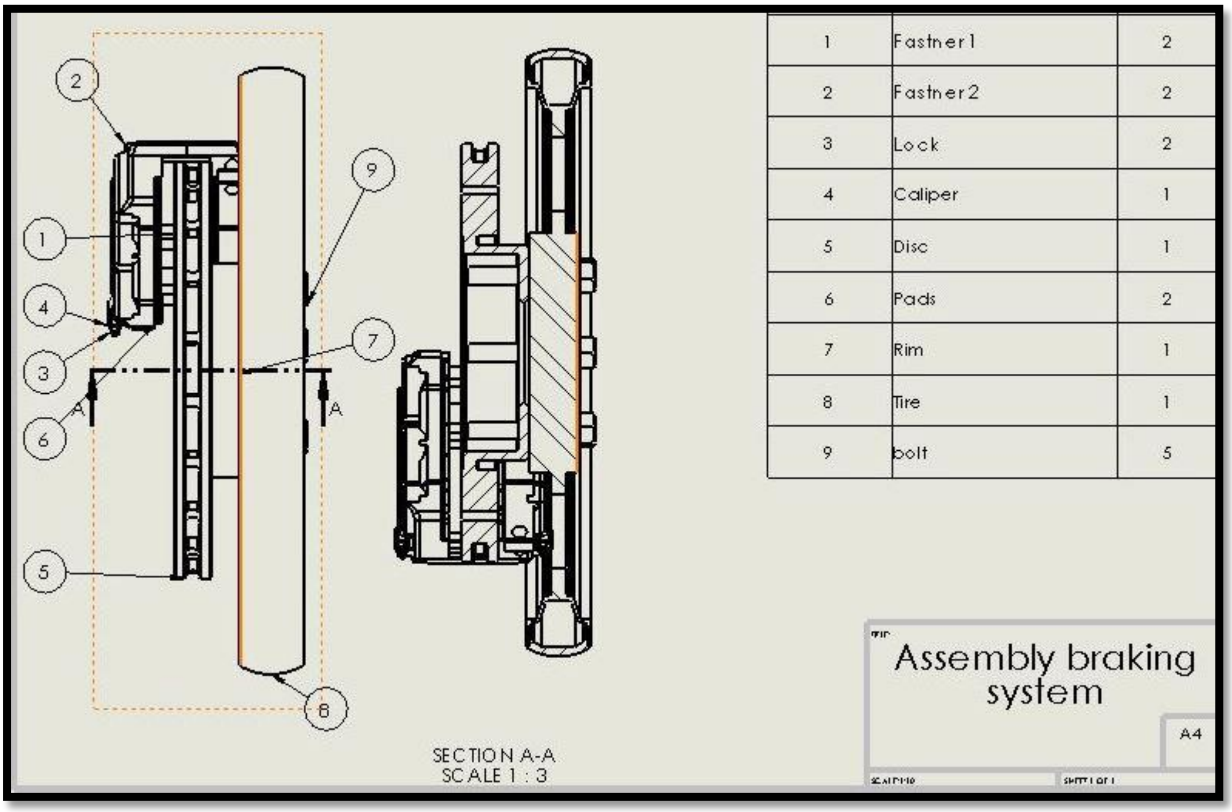
❖ Rotor/Disc



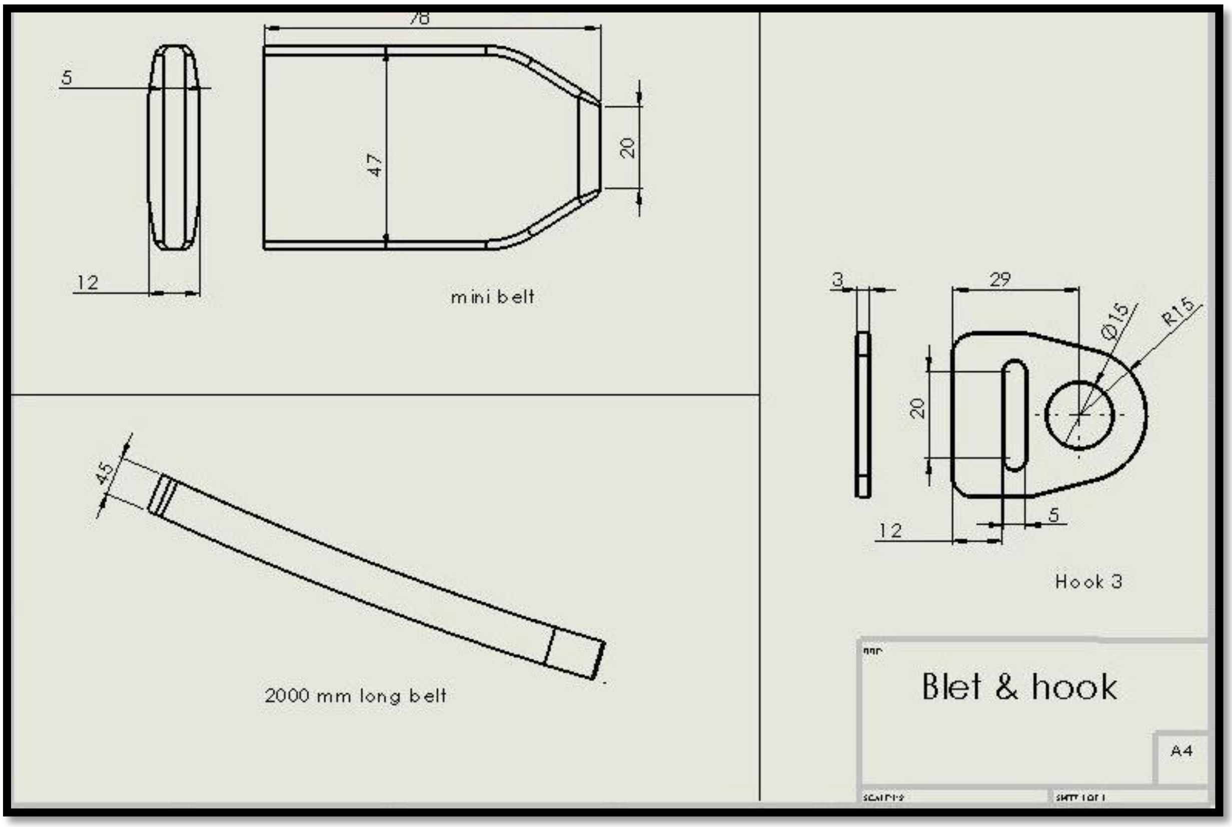
- Pad



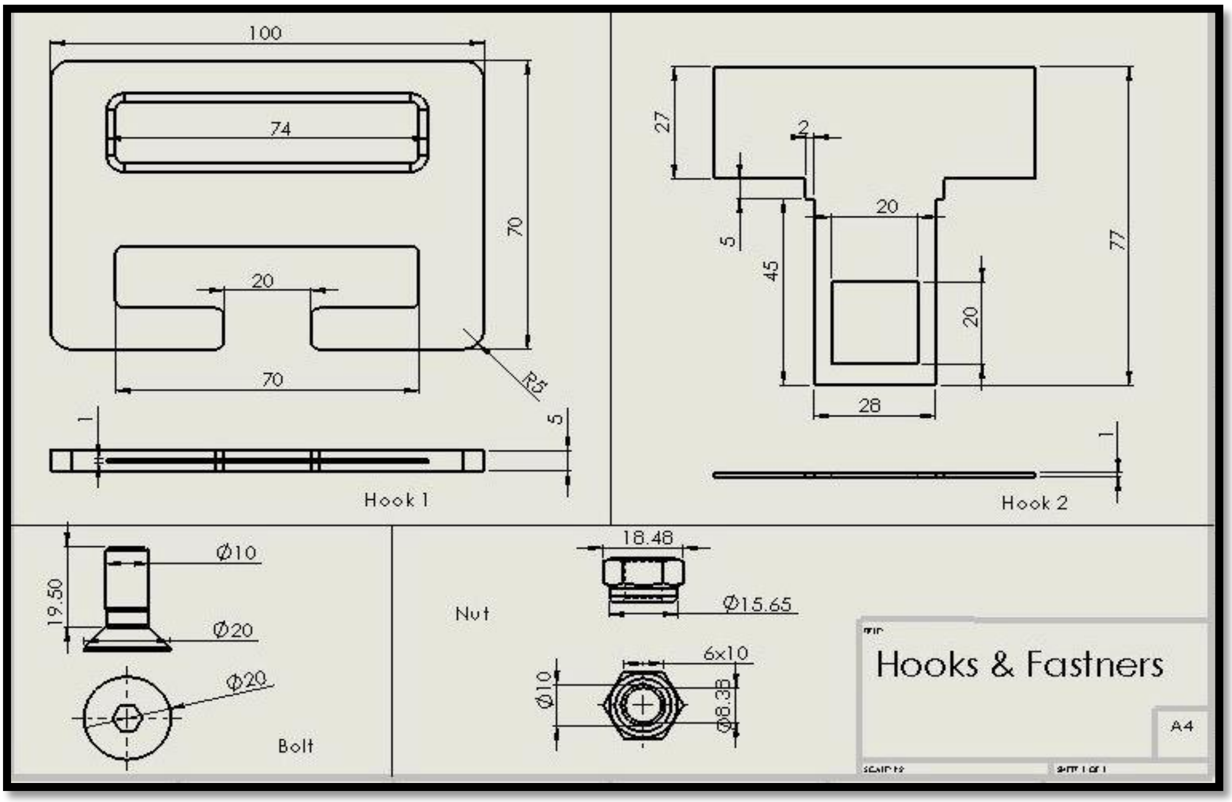
- Brake assembly



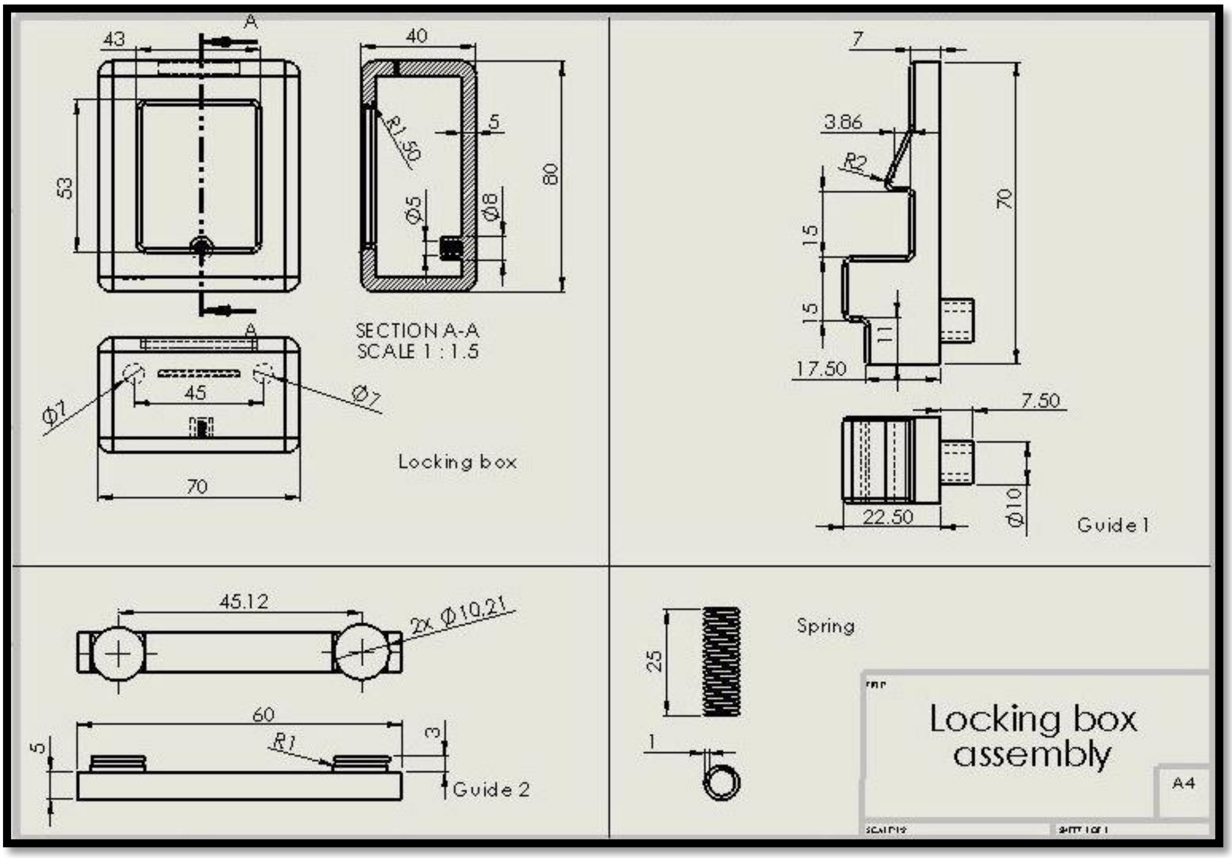
- Belt hook



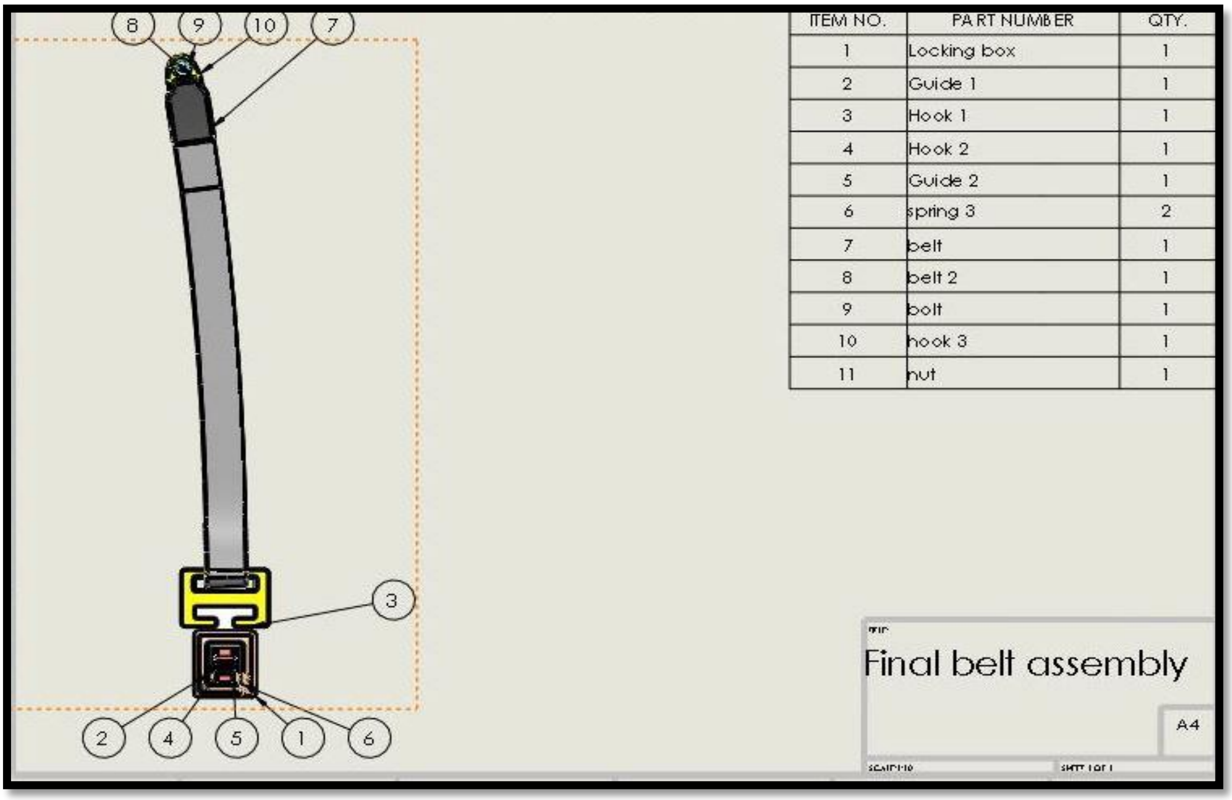
- Hook fastener



- Locking assembly



- Belt Assembly



ITEM NO.	PART NUMBER	QTY.
1	Locking box	1
2	Guide 1	1
3	Hook 1	1
4	Hook 2	1
5	Guide 2	1
6	spring 3	2
7	belt	1
8	belt 2	1
9	bolt	1
10	hook 3	1
11	nut	1

Mesh information for brake design

Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Jacobian points	4 Points
Element Size	0.236382 in
Tolerance	0.0118191 in
Mesh Quality	High

Total Nodes	104941
Total Elements	60892
Maximum Aspect Ratio	13.812
% of elements with Aspect Ratio < 3	89
% of elements with Aspect Ratio > 10	0.0197

Mesh information for frame design

Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Jacobian points	4 Points
Element Size	9.90144 mm
Tolerance	0.495072 mm

Total Nodes	18286
Total Elements	8390
Maximum Aspect Ratio	17.809
% of elements with Aspect Ratio < 3	64.1
% of elements with Aspect Ratio > 10	0.0834

Mesh information for belt design

Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Jacobian points	4 Points
Element Size	6.42006 mm
Tolerance	0.321003 mm
Mesh Quality	High

Mesh information - Details

Total Nodes	23432
Total Elements	12998
Maximum Aspect Ratio	65.525
% of elements with Aspect Ratio < 3	0.354
% of elements with Aspect Ratio > 10	45.7

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