JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

# Design & Optimization of Braking System in EV

**Manasi Gawali[1], Shruti Hagawane[2], Rohit Kale[3], Vikrant Kulkarni[4], Prof. S. B. Deokar[5]**

Department of Mechanical Engineering, SKNCOE, SPPU, Pune

*Abstract-* **The braking system is the most important system in a vehicle. If the brakes fail, the results may be disastrous. Hence, an optimized braking system in a vehicle is essential for the driver's safety.**

**The objective of this project is to create a physical model of braking systems in EV. The physical model is to demonstrate the transfer of forces from mechanical domain to hydraulic domain and back to the mechanical domain. Our main aim is to provide enough braking force to completely lock the wheels at the end of specified acceleration run and also prove to be cost effective. Braking system is designed by determining parameters necessary to produce a given deceleration and comparing it to the deceleration that a known braking system would produce.**

**For the vehicle purely mechanical parking brakes would be used. When the vehicle would be in static condition the parking brake will be used to lock the rear wheels. The mechanical nature allows the driver to apply the brake even if the main hydraulic brake system fails. These types of brakes are used to ensure that a vehicle remains stationery when parked at a certain slope.**

**Firstly, a rough sketch of hydraulic brake system and mechanical parking brake will be chalked out to get an idea of how the system should look like. From then on, the design of hydraulic braking system and parking brake will be modelled in dedicated designing platform. Moving forward the system will be analyzed by using the software "Ansys Workbench" and the optimized structure will be given for manufacturing. Subsequently, the system will be tested in the actual environment and the performance criteria will be checked.**

***Keywords-*** **braking system, hydraulic brake system, Catia, Creo, Ansys Workbench, Thermal analysis, static analysis, parking brake**

## I. INTRODUCTION

Braking system plays a vital role in vehicles. Our essential point was to come up with a braking mechanism that is straightforward and has an optimized size alongside being reliable.

According to the requirements of the vehicle, the brakes are to be mounted on all the four wheels, to ensure maximum braking performance and safe driving conditions.

A brake is a device used to generate an artificial frictional force which is applied to moving member of the wheel, for stopping motion. For the execution of the braking operation, the brake pads and disc absorb the kinetic energy from the wheel. The energy absorbed by brake generates heat. The brake disc has the ability to transfer heat to the atmosphere and maintain a constant temperature to improve the performance of the disc.

In our project, for the braking system, we have used disc brakes on all the four wheels. Each of the four wheels has a caliper with self-designed brake disc to provide braking force. The vehicle has a brake pedal which actuates the master cylinder of the brake. Two hydraulic fluid lines are associated, one to the front wheels and one to the rear wheels. All the standards selected by us are predominantly give a more secure and faster reaction of brakes. We have used Tandem Caliper which has dual piston, to provide enough clamp force.

Our project is also associated with parking brakes which are also known as hand brakes. It is a model used to retain the vehicle and to assure that it remains stationary when parked on an inclined plain. This is also used in emergency conditions to stop the vehicle when the main hydraulic braking system fails. Parking brake behaves only on the rear wheel. Most of the parking brakes are connected to rear wheels, thus it reduces traction when it is parked. The apparatus which is operated can be, hand operated lever, a straight pull handle located near the steering column or foot operated pedal located with the other pedal.

## II. OBJECTIVES

- Easy way to stop a vehicle.
- To develop a physical prototype of hydraulic braking system in EV.
- To develop a physical model of parking brakes in EV.

Brakes are vital part of any vehicle especially when it comes to stopping the vehicle. Furthermore, sometimes brakes' mounting may become challenging in case of small or congested mounting space. Hence this is one of the critical research gaps that can cause inconvenience. We took this concern into consideration and came up with a solution of optimum sized caliper which would be placed on either of one side of the wheels which in turn will give high performance and effective braking in specific distance and time zone. The calipers will be down-sized as compared to other that are easily available in the market.

*A) Problem statement-*

Usually, vehicles have mirrored calipers that are mounted on either side of the wheels of a vehicle. Depending on vehicle model's size, only one type of caliper cannot be used. Hence, we have used down-sized approach for the caliper to eliminate this issue. This shrunken size of caliper can fit irrespective of vehicle's dimensions.

*B) Proposed work:*

Present work includes an optimized braking system in a vehicle which is essential for the driver's safety. The braking system is the most important system in a vehicle. If the brakes fail, the results may be disastrous.

Project work includes:

1) To study the basic braking system in thorough.
2) Designing different components of braking system according to the requirements.
3) To analyze the quality of braking components and adjust the parameters accordingly.
4) To test and check for any faults periodically.

## III. MARKET SURVEY

Market survey is an examination of the market for a specific good or service, including the study of consumer demands and preferences. Here market survey is divided into two parts namely: Material Selection (for components) and Brake Oil Selection.

*A) Material*

Material selection stages:

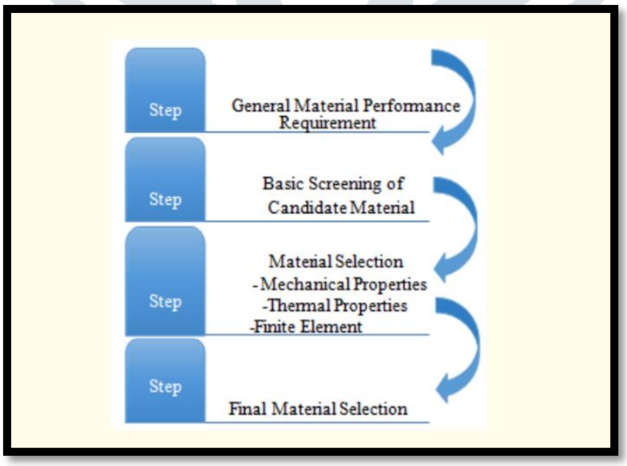


Fig.1: Stages in material selection

Material selection depends upon various factors such as:

1) Strength to weight ratio
2) Cost
3) Physical and Mechanical properties
4) Availability

Components:

- **Brake Disc**

Materials available –

- Grey cast Iron
- Titanium Grade 5 (Ti-6Al-4V, 3.7165, R56400)
- Stainless Steel 420
- Aluminum 7075 T6

Table I.: Material Properties comparison (for Disc)

| Materials | Ultimate Tensile (Mpa) | Tensile Yield (Mpa) | Density ($g/m^3$) | Specific Heat capacity (J/kgK) | Thermal conductivity (W/mK) |
|---|---|---|---|---|---|
| Grey Cast Iron | 260 | 180 | 7.5 | 490 | 46 |
| Titanium grade 5 | 1000 | 910 | 4.4 | 560 | 6.8 |
| Stainless Steel 420 | 640 | 380 | 7.7 | 480 | 27 |
| Aluminium 7075 T6 | 560 | 480 | 3.0 | 870 | 130 |

Table II.: Results and Cost Comparison (for Disc)

| Materials | Factor of Safety | Deformation (mm) | Cost (INR per kg) |
|---|---|---|---|
| Grey Cast Iron | 1.7956 | 0.03016 | 68 |
| Titanium grade 5 | 7.266 | 0.03031 | 3000 |
| Stainless Steel 420 | 3.034 | 0.0319 | 113 |
| Aluminium 7075 T6 | 4.788 | 0.03037 | 600 |

After considering all the factors mentioned in above table, we selected Stainless Steel 420 for our brake disc.

- **Pedal**

Materials available –

- Aluminium 7075 T6
- Aluminium 6061
- AISI 1018

Table III.: Material Properties comparison (for Pedal)

| Material | Ultimate Tensile (Mpa) | Tensile Yield (Mpa) | Density ($g/m^3$) | Weldability |
|---|---|---|---|---|
| Aluminium 7075 T6 | 560 | 480 | 3.0 | Not weldable |
| Aluminium 6061 | 310 | 276 | 2.7 | Weldable |
| AISI 1018 | 756 | 510 | 7.8 | Weldable |

After considering all the factors mentioned in above table we selected Aluminium 6061 for the pedal.

- **Brake Hose**

  - Metal Hose

Materials available –

- Stainless Steel
- Aluminium

Table IV.: Material Properties comparison (for Metal hose)

| Material | Ultimate Tensile (Mpa) | Tensile Yield (Mpa) | Density ($g/m^3$) | Machinability |
|---|---|---|---|---|
| Stainless Steel 420 | 640 | 380 | 7.7 | Good |
| Aluminium Alloy | 560 | 480 | 3.0 | Fair |

After considering all the factors mentioned in above table we selected Aluminium Alloy for the brake hose.

- **Brake Pads**

Materials Available-

- Organic
- Ceramicmatrix composite
- Metallic

Table V.: Comparison for brake pad material

| Parameters | Organic | Ceramic | Metallic |
|---|---|---|---|
| Price | $ | $$$ | $$ |
| Performance | Low | Medium | High |
| Noise | Low | Very low | High |
| Wear & Tear on brake system | Low | Very low | Medium |

After considering all the factors mentioned in above table we selected ceramic material for brake pads

- **Caliper**

Table VI.: Caliper Comparison

Materials available:

- Stainless Steel
- Aluminium Alloy

| Parameters | Caliper 1 | Caliper 2 |
|---|---|---|
| Company name | Wilwood | Logan |
| Cost | 2700 /- each | 1019.5 /- each |
| Weight | 480 gm | 320 gm |
| Size | 97mm × 63mm | 19 mm |

After considering all the factors mentioned in above table we selected Caliper 2 for braking system.

*B) Brake Fluid*

| Brake Fluid | Dry Boiling Point | Wet Boiling Point |
|---|---|---|
| DOT 3 | 205 °c | 140 °c |
| DOT 4 | 230 °c | 155 °c |
| DOT 5 | 260 °c | 180 °c |
| DOT 5.1 | 270 °c | 190 °c |

Fig.2: Brake Fluid comparison

After considering all the factors mentioned in above table according to our requirements DOT 4 brake fluid was selected.

## IV. DESIGN & CALCULATIONS

**Braking system**

The purpose of the braking system is to slow down or stop the vehicle as per driver's requirement. In order to achieve better performance, the brakes are designed to lock all the wheels.

*A) Design:*

We use two types of braking systems which serve two different purposes.

*1) Dynamic Braking system of the vehicle:*

We chose hydraulic braking system which clamps on disc. This system is mounted on all four wheels for best possible performance. Disc brakes are used because of its high heat dissipation capabilities, torque transmitting capacity, good efficiency in wet weather conditions. The reason why brake discs remain dry in wet weather conditions is because it flings the water of its surface using centrifugal force.

*2) Parking Brake system of the vehicle:*

We chose mechanical braking system which clamps on disc. This system is mounted on two of the wheels(rear) for sufficient generation of braking torque. We chose mechanical braking system in this requirement as parking brakes are used for constant long actuation time. In constant long actuation type condition hydraulic brakes can tend to lose its pressure resulting in disengagement of brakes. As mechanical brakes work on steel wire's tension, which cannot be changed, hence fulfilling the purpose excellently.

Table VII.: Parameters and Values

| Parameters | Values |
|---|---|
| Muscular Force | 100N |
| Lever Ratio Brake Pedal | 3:1 |
| Mean Effective Radius of Disc | 0.09 m |
| Rolling Radius of Wheel | 0.26 m |
| Diameter of piston in Master Cylinder | 19.05 mm |
| Diameter of piston in Caliper | 15 mm |
| Co-eff of friction (μ) | 0.8 |
| Height of the CG (h) | 21 inches |
| Wheel Base (WB) | 45 inches |

*B) Brake Calculations*

Stopping distance:

Initial speed (u) = 30 kmph = 8.33 mph

Stopping distance (S) = $u^2 / 2*\mu*g$ = 4.42 m

Deceleration needed

$V^2 - U^2 = 2*A*S$

A = 7.84 $m/s^2$

*1) For Dynamic Braking system of vehicle.*

Muscular Force = 100 N (considered)

Pedal Ratio = 3:1

Pedal Force = Muscular Force * Pedal Ratio = 300 N

Fluid Pressure = Force / Area

Area of Piston = pi * $d^2 / 4$ = 285.02 $mm^2$

:. Fluid pressure = Force / Area = 1.052 pa.

Caliper Force = Fluid pressure * Area

Area of Caliper piston = pi * $d^2 / 4$ = 176.714 $mm^2$.

:. Caliper force = Fluid Pressure * Area = 185.903 N

Total Caliper Force = Caliper Force * 2 (2 pistons) = 371.806 N

Braking Force = Clamping Force * μ (μ = Coefficient of friction of Disc = 0.8) = 297.444 N

Braking Torque by one caliper = Braking Force * Radius of Disc = 26.769 Nm.

Braking Torque offered by 4 calipers. = Braking Torque * 4 = 107.079 Nm.

Applied Torque = 107.079 Nm.

Required Torque = 77.72 Nm.

Applied Torque >> Required Torque

Calculations Justified.

Brake Force on Wheel = Braking Torque / Radius of Wheel = 411.84 N.

According to the weight distribution of vehicle 60:40 the static weight of the vehicle on the rear and front are calculated.

Static weight on front=0.40*total weight of vehicle. = 80 kg
Static weight on rear=0.60*total weight of vehicle = 120 kg

Further we calculated weight transfer by using formula

Weight Transfer (WT) = mass*deceleration*height of CG / g * WB = 53.116 kg
The dynamic weight transfer can be calculated as,
Dynamic weight on Front= Static weight + WT = 133.116 kg
Dynamic weight on rear= Static weight – WT = 66.884 kg
Dynamic weight on one front tyre is
Weight on one front tyre = (Dynamic weight on front axle) / 2 = 66.558 kg
Dynamic weight on one front tyre is
Weight on one rear tyre = (Dynamic weight on rear axle) / 2 = 33.442 kg

Frictional forces on the tyres

Force on front tyre= Weight on one tyre (Front) * μ * g = 533.34 N
Force on rear tyre= Weight on both tyres (Rear) * μtyre * g = 262.45 N

Torque on the tyres = (Force on tire) / Rolling radius
For front = 138.66 Nm
For rear = 68.237 Nm

Braking force = (Torque on tire) / MER of disc
For front = 1540.66 N
For rear = 758.188 N

Clamping Force = Braking force / μpad
For front = 1925.825 N
For rear = 947.735 N

2) *For static braking system of the vehicle.*

Considering gradient test of 10º we resolve the forces in 2 directions.
Horizontal force when calculated = sin10º * Mass. (Mass = 200 N) = 34.72 N.
Required braking torque.
BT = BF * ($R^2$/r)
R = Radius of Tyre.
R = Mean effective radius of disc.
BT = 26.72 Nm. (required)

In order to park we need to generate Braking Torque > or equal to 27 Nm.

Applied entities
Muscular force = 100 N.
Pedal ratio = 4:1
Force applied on caliper = 400 N
Load on pad (Clamping force) = 400 N.

Braking Force = Force * μ (μ = coefficient of friction) = 320 N.

BT = BF * ($R^2$/r) = 240.32 Nm. (applied)
Applied >> Required.

3) *Heat Flux*

Area of Disc (A) = 0.029$m^2$

Time taken to stop the vehicle (sec) = 5 sec

Temperature difference (ΔT) = 15ºc.

Weight of Disc (m) = 320g.

Specific Heat Capacity of Stainless steel (Cp)= 420 J/kgºc.

Heat Generated (Q) = m x Cp x ΔT Joules = 2016 Joules.

Heat Flux (q) = Q / Sec / A = 13903.44 W/$m^2$ = 13.903 KW/$m^2$.

**<u>Components used in our braking system: (CAD Models)</u>**

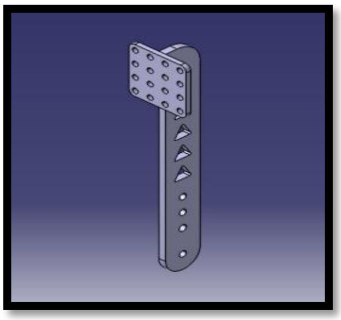

Fig.3: Brake Pedal

Fig.4: Master Cylinder

Fig.5: Brake Hose

Fig.6: T-Joint

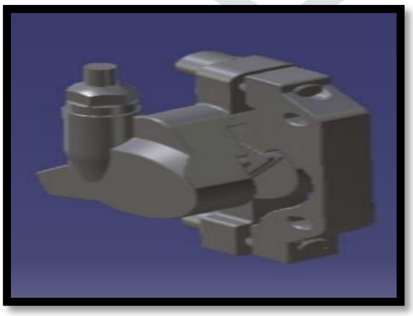

Fig.7: Hydraulic Caliper

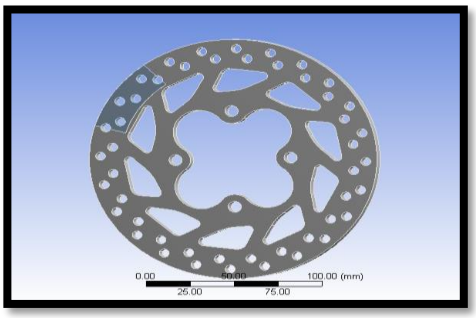


Fig.8: Brake Disc

*C) CAD MODEL*

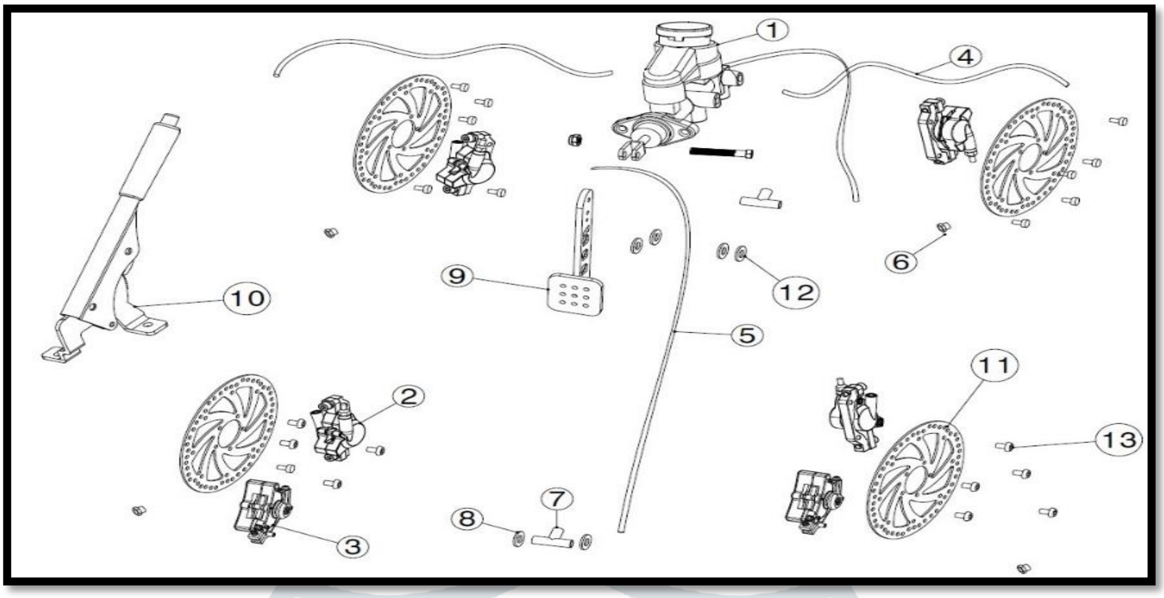


Fig.9: Exploded View

Table VIII.: Brake Parts

| Sr. No | Part Name | Sr. No | Part Name |
|---|---|---|---|
| 1. | Tandem Master Cylinder | 8. | Brass Washer |
| 2. | Hydraulic Caliper | 9. | Brake Pedal |
| 3. | Mechanical Caliper | 10. | Brake Lever |
| 4. | Flexible Brake Hose | 11. | Brake Disc |
| 5. | Metal Hose | 12. | Metal Washer |
| 6. | M10-M8 Converter | 13. | Brake Disc Bolts |
| 7. | T-Joint | | |

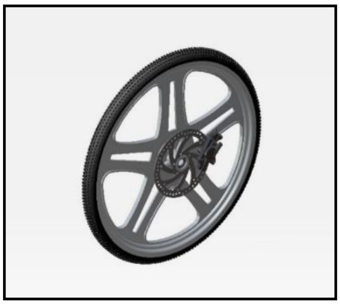

Fig.10: Front Left Brake

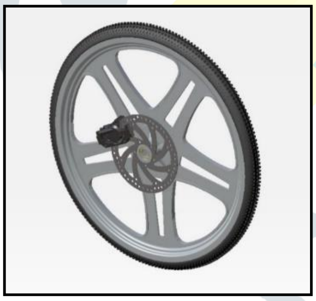

Fig.11: Front Right Brake

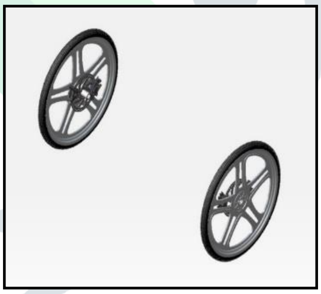

Fig.12: Rear Brake Assembly

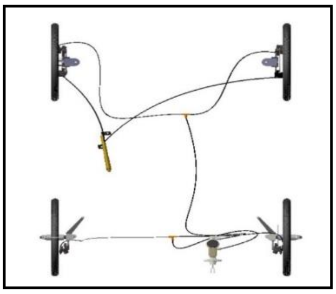

Fig.13: Brake Connections

## V. ANALYSIS

*A) BRAKE DISC*

**a) Assumption & considerations**

*1) Thermal Analysis*

**Introduction:** Heat flux that is calculated analytically by the Brakes Department. Brake is applied on the contact surface of the brake pads and as forced convection occurs while the vehicle is moving the convection coefficient is taken as 200 $W/m^2$ and applied on the whole body. The disc is solved for temperature and the temperature load imported in Static Structural and bolting position are fixed and Stresses are calculated.

**Objectives:** The Maximum Temperature of the Disc after applying the Brakes should not exceed above 250 Degree Celsius and the FOS of the ThermalStresses induced in the Disc should be within 1.5 to 2.

**Boundary conditions applied for shaft are as follows:**

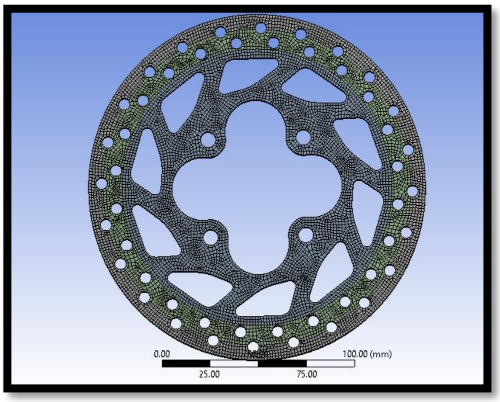

Fig.14: Meshing on Brake Disc

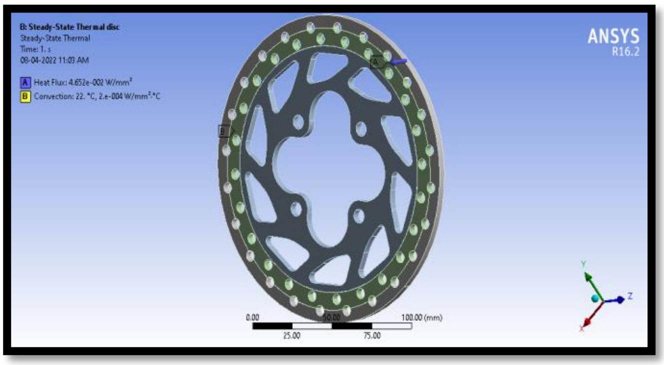

Fig.15: Boundary conditions on Brake Disc

## b) Analysis Results:

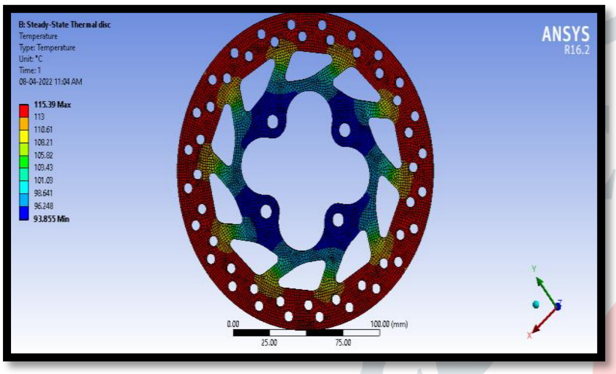

Fig.16: Temperature

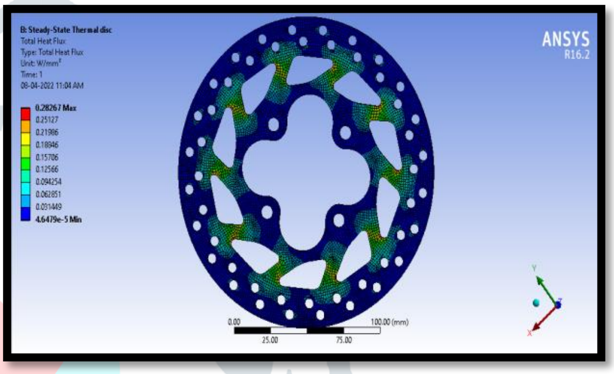

Fig.17: Heat Flux

*2) Static structural Analysis of brake disc.*

**Boundary conditions applied for shaft are as follows:**

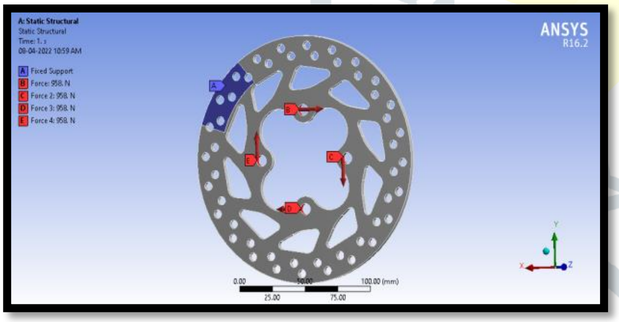

Fig.18: Boundary Conditions on Brake Disc

**Analysis Results:**

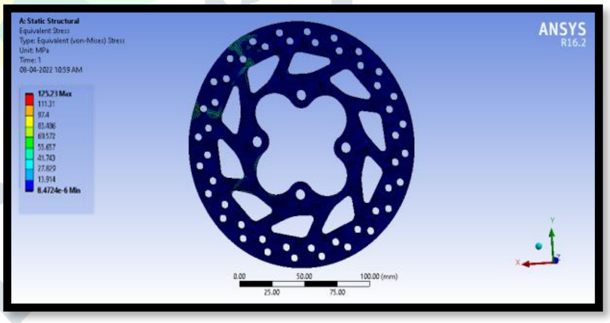

Fig.19: Stress in Brake Disc

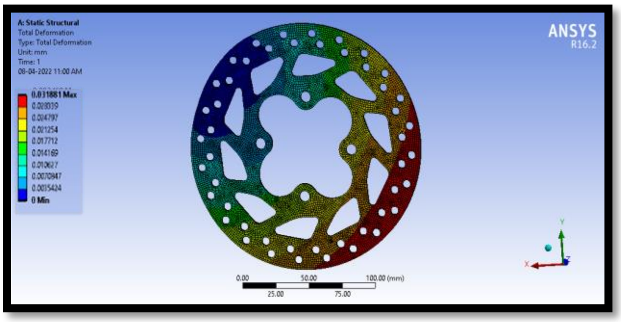

Fig.20: Deformation of Brake Disc

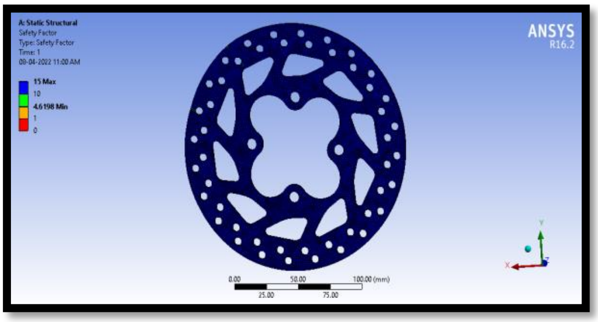

Fig.21: Factor of Safety

*B) PEDALS*

**a) Assumption & considerations**

**Introduction**: As the material used is aluminum to be on the safer side, the Static analysis of the pedals is done. The maximum force that the driver can apply on the brake pedals is calculated by placing a weighing at the position of the brake pedal in the Kart.

**Objectives**: the pedals should not bend when the driver applies the brake in a condition when he brakes very heavily while driving on circuit.

**Boundary conditions applied for Pedal are as follows:**

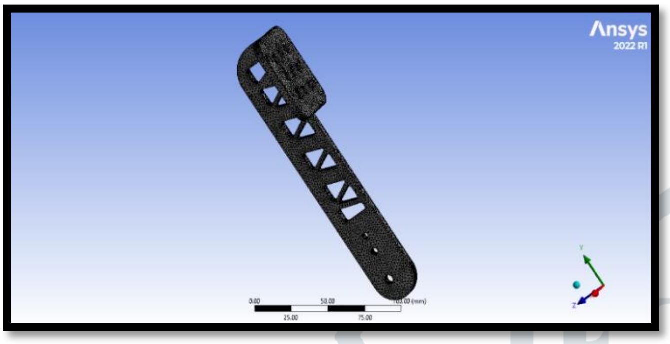


Fig.22: Meshing on Pedal

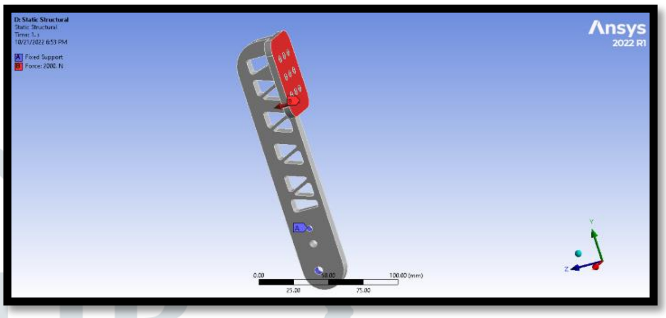


Fig.23: Boundary Conditions on Pedal

**b) Analysis Results:**

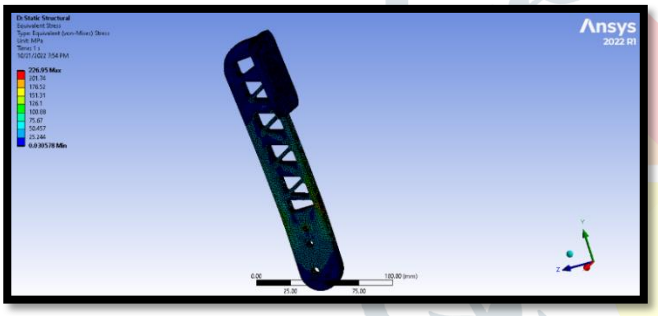


Fig.24: Stress in Pedal

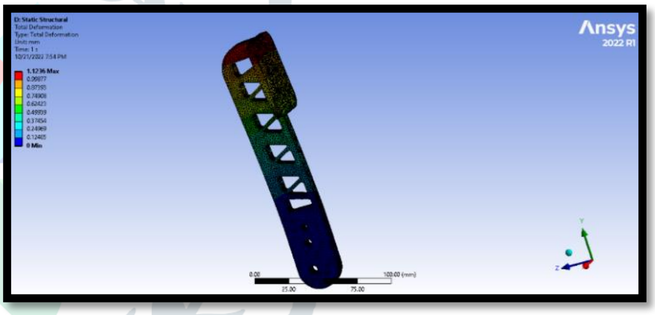


Fig.25: Deformation of Pedal

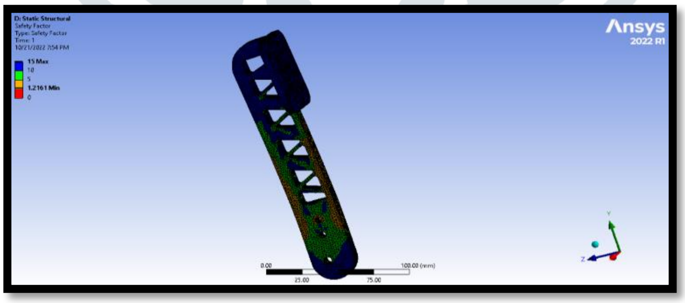


Fig.26: Factor of Safety

## VI. MANUFACTURING

Manufacturing concentrates on developing and running integrated systems for the creation of high-caliber, price-competitive products. Computer networks, robotics, machinery, and material-handling instruments are a few examples of these systems.

Few of the processes that we used in manufacturing are:

1. Laser Cut
2. Welding
3. Cutting
4. Drilling

1. Laser Cut: Brake Disc

For brake disc laser cut operation was performed to get desired shape as per the design.

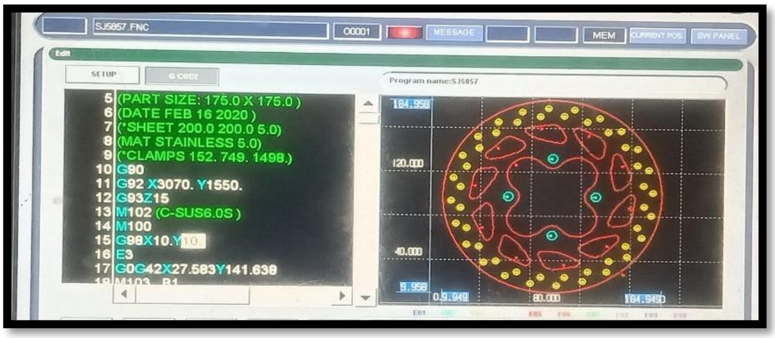


Fig.27: Laser Cut (for Disc)

2. Cutting, Drilling & Welding:

These processes were performed to manufacture mountings namely- Pedal, master cylinder, brake lever.

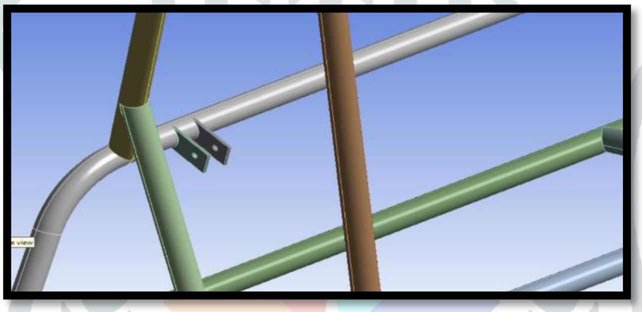

Fig.28: Brake Pedal Mounting

*A) Manufactured and Procured Components:*

Fig.29: Pedal

Fig.30: Reservoir

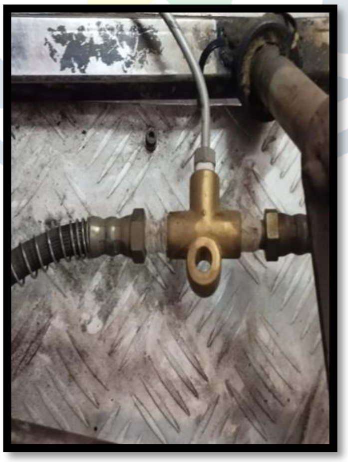

Fig.31: T-Joint

Fig.32: Caliper

Fig.33: Knuckle

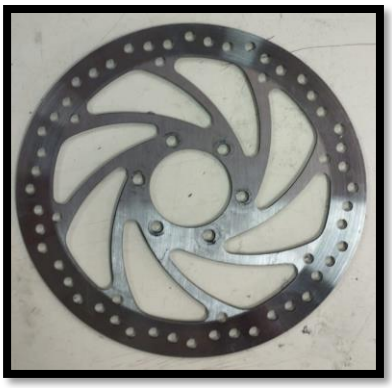

Fig.34: Brake Disc

Fig.35: Metal Hose

Fig.36: Brake Lever

Fig.37: Master Cylinder

Fig.38: Brake Pads

## VII. ASSEMBLY

Fig.39: Master Cylinder with Reservoir & Pedal

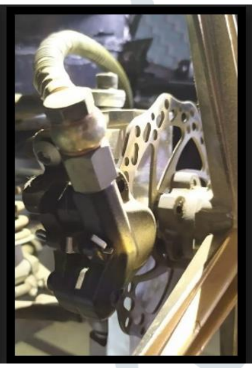

Fig.40: Front Left

Fig.41: Front Right

Fig.42.: Rear Left

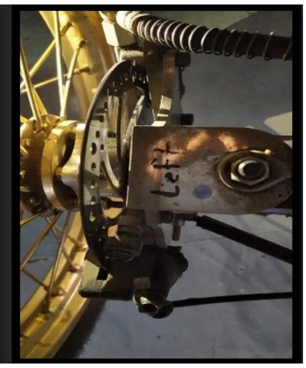

Fig.43: Rear Right

## VIII. RESULTS

Table IX.: Market Survey Outcome

| **Part Name** | **Selected** |
|---|---|
| Brake Disc | Stainless Steel 420 |
| Pedal | Aluminium 6061 |
| Brake Pads | Ceramic matrix composite |
| Metal Hose | Aluminium Alloy |
| Caliper | Company : Logan |
| Brake Fluid | Dot 4 |

Table X.: Mesh Details

| Mesh Details | Components | |
|---|---|---|
| | Brake Disc | Pedal |
| Element Size (mm) | 1 | 1 |
| Min mesh size (mm) | 0.1 | 0.17 |
| Max mesh size (mm) | 1.0 | 0.99 |
| No.of Nodes | 163003 | 73775 |
| No.of Elements | 27706 | 40443 |
| Types of Elements | Quadrilateral | Tetrahedron |
| Mesh Quality (Jacobian ratio) | 0.77 | 0.976 |

Table XI.: Result Table

| Parameters | Components | |
|---|---|---|
| | Brake Disc | Pedal |
| Deformation (mm) | 0.0934 | 1.124 |
| Stress (MPa) | 409.11 | 226.95 |
| Factor of Safety | 3.034 | 1.216 |

## IX. CONCLUSION

The hydraulic braking system with optimized caliper size, cost-effective self-designed brake disc and brake lining is an effective solution for ensuring improved in terms of performance and cost-effectiveness. The optimized caliper design ensures that the brake pads are in close proximity to the brake disc, providing better stopping power and reducing the risk of brake fade. The use of ceramic brake pads can provide superior stopping power and longer lifespan compared to traditional metallic brake pads. By optimizing the size of components, the system is more compact and requires less space, which makes it easier to install and maintain. Additionally, the smaller components are less expensive, which reduces the overall cost of the system.

We examined the braking system on the basis of braking efficiency. This efficiency was evaluated on many trials that we performed during testing phase. One of the tests that was conducted had a track where the vehicle would accelerate for a certain distance and when braking would occur it should stop the vehicle within a range of 5 meters. Many difficulties were faced but we were able to overcome those by bleeding the hydraulic braking system, checking and improving the brake connections and so on. In this way we implemented an effective and optimized braking system

## X. FUTURE SCOPE

Brake systems are becoming increasingly innovative so they can meet the future needs. Future brake system mainly hinges on safety and sustainability of the vehicle. Every car will still require wheel brakes, regardless of the architecture of the brake system of the future. Wheel brakes are essential for slowing down, stopping suddenly, stabilizing, managing standstills, and fail-safe operation. Brakes, however, further need to help reduce $CO_2$ and dust emissions. The optimized hydraulic braking system can be applied to various types of vehicles, including electric vehicles and mopeds, as they also require efficient and reliable braking systems. By implementing this optimized hydraulic braking system, these vehicles can experience improved braking performance, better durability, and potentially reduced costs. To ensure the effectiveness and safety of the optimized hydraulic braking system, it is important to conduct thorough testing on the system when installed on a vehicle. This can include testing the system's performance under various driving conditions and analyzing any potential issues that may arise.

## ACKNOWLEDGEMENT

I take this opportunity to thank all those who have contributed in successful completion of this Project work. I would like to express my sincere thanks to my guide Prof. S.B. Deokar who have encouraged me to work on this topic and provided valuable guidance wherever required. I also extend my gratitude to Prof. T. S. Sargar (H.O.D Mechanical Department) who has provided facilities to explore the subject with more enthusiasm.

I express my immense pleasure and thankfulness to all the teachers and staff of the Department of Mechanical Engineering of Smt. Kashibai Navale College of Engineering for their co-operation and support.

## REFERENCES

[1] Hydraulic Brake Model A Major Qualifying Project Report Submitted to the Faculty Of the WORCESTER POLYTECHNIC INSTITUTE In partial fulfilment of the requirements for the Degree of Bachelor of Science By Ryan Moseley, Mikhail Tan

[2] A H Rozainia, M R Ishak, A R Abu Bakar and M Z Mohd Zain Faculty of Mechanical Engineering, University Technology Malaysia, 81310, Johor, Malaysia

[3] Liang Chen1, a, Hua Chi1, b, Yue Feng1, c, ChuanMin Zhang1, d 1 SORL Auto Parts, Inc., Wenzhou 325200, China a sorl_cl@163.com, b chihua706608@163.com, c feng993032@163.com

[4] Pier Giuseppe Anselma*, Giovanni Belingardi Department of Mechanical and Aerospace Engineering (DIMEAS), Center for Automotive Research and Sustainable Mobility (CARS), Politecnico di Torino, Torino, Italy

[5] Aarish Afsar1, Arbab Karim2, Fardeen Nayeem3, Rounaque Noor4, Shiraz Sajid Hashmi5 1,2,3,4,5Student, Department of Mechanical Engineering, Faculty of Engineering & Technology, Jamia Millia Islamia, New Delhi, India

[6] Somesh Kumar, Vikash Kumar Patel, Shubham Chopra, Devnandan Kumar, Shivam Sudarshan Verma,Student of Mechanical Engineering, Lovely Professional University, Phagwara Punjab, India.

[7] Parikshit Pandey1, Narendra Pogul2, Shreekar Rahate3, Pankaj Sahu4, Prof. Pravin Alone51, 2, 3, 4Student, 5Assistant Professor, Department of Mechanical Engineering, New Horizon Institute of Technology and Management, Thane, Maharashtra, India.