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# Design, Analysis and Fabrication of Hydraulic Braking System

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**Abstract -** *This report contains a brief overview of the braking system for an (All-terrain vehicle) ATV. Brakes play a crucial role in vehicles by helping to slow down, stop, or keep them stationary. Among modern braking systems, brake discs are key, especially in automobiles. The biggest challenge with brake discs is controlling the heat generated during braking. If this heat isn't adequately dissipated it can cause the disc to heat up or cool down too quickly, leading to thermal stress and, in extreme cases, failure. In this study, we will explore the use of stainless steel material for brake discs, given its promising frictional properties and ability to conduct heat efficiently and lightweight properties. A disc brake rotor model for the all-terrain vehicle was simulated using ANSYS software for thermal analysis. We calculated heat flux, and kinetic energy and studied how pressure and frictional forces act on the brake material. The goal is to understand how these forces affect braking performance and how design changes like disc design for better heat dissipation, and a change in pedal ratio will improve driver reach. Material selection and material differentiation of material is also included in the report. The end of the report contains the calculations and iteration based on which we have designed the system.*

***Key Words*: Hydraulic braking system, All terrain vehicle, Disc (rotor), Pressure switch.**

## 1. INTRODUCTION

Braking is one of the most important aspects of vehicle safety and performance it has the ability to stop or slow down a vehicle safely which ultimately defines a vehicle's control and reliability. The braking system is not just a mechanical necessity but also a safeguard, a lifesaving feature that every vehicle depends on.

A braking system serves three fundamental purposes: To reduce vehicle speed, to bring the vehicle to a complete halt at a desired point, and most importantly, to prevent accidents by providing the driver with complete control over the motion of the vehicle. This is achieved by converting the vehicle's kinetic energy into heat energy through friction, then the heat is dissipated into the atmosphere. While this energy transformation may seem simple, it involves complex mechanical and thermal processes that must be carefully managed to ensure efficiency, consistency, and safety.

In this research, we present a design analysis and fabrication of a hydraulic braking system in an all-terrain vehicle (ATV) featuring a brake rotor of stainless steel, an independent pressure switch(one switch for the rear and one switch for front), newly designed brake pedal. The dual pressure switch with enhanced safety by introducing a fail-safe mechanism; if one switch malfunctioned the other remains functional, thereby reducing the risk of total failure.

Our approach is for both performance and reliability. The use of a hydraulic braking system will reduce pedal effort, while a disc brake will have higher heat dissipation and consistent braking force under varying conditions. This paper contains conceptualization, design methodology, component selection, material selection, and performance analysis of the braking system, to contribute safer and more efficient braking technologies in automotive engineering all-terrain vehicles.

### 1.1 LITERATURE REVIEW

Reddy S. and Venkatesh G. performed an analysis of the inboard and outboard braking systems in rear-wheel drive ATVs. The analysis has contained testing under heavy-duty trail conditions. The result showed that inboard brakes suffered slightly delayed response time due to drive train backlash.

Patel R. and Mehta S. conducted a study analyzing the performance of hydraulic disc brakes used in off-road vehicles, especially focusing on all-terrain vehicles (ATVs). Their research targeted braking force distribution across the front and rear wheels under different terrain conditions. Using simulation tools like ANSYS and SolidWorks motion, Authors analyze brake pressure, stopping distance, and dynamic load transfer. Results showed that dual hydraulic switches with pressure distribution provide better control and reduce stopping time, especially on slopes and unstable surfaces.

Khan M.A. and Patel N. did a comparative study on brake disc materials such as cast iron, stainless steel, and carbon ceramic composites used in the hydraulic braking system of ATVs. The materials were evaluated based on thermal conductivity, wear resistance, and weight. Through thermal structural FEA and lab-based wear testing, the study found that carbon ceramic composites had higher heat resistance and less weight but at a higher cost, while cast iron is cheaper but has the highest thermal deformation. Stainless steel is a balanced option with moderate weight and good corrosion resistance, making it ideal for off-road conditions.

## 2. OVERVIEW

When you press the brakes in a vehicle, you're using a system that increases the force of your foot just like using a long stick to lift something heavy. This is how hydraulic brakes work: they let you stop a fast-moving vehicle with only a small effort. Most modern vehicles use twin hydraulic circuits for safety. When two master cylinders are working together then at any condition one fails the other can still control the brakes. The system is designed in different ways: sometimes one circuit handles the front brakes and the other the rear, or both circuits may control all four wheels in a split pattern just to make sure that at least some braking is always available. During sudden or hard braking, a lot of the vehicle's weight shifts forward. This takes weight off the rear wheels, which makes them more likely to lock up and cause the vehicle to skid especially dangerous at high speeds or on slippery roads. That's why rear brakes are made slightly less powerful than the front ones, to avoid this issue. To help with this even more, many vehicles have a pressure-limiting valve. It works automatically and senses when you're braking hard. If the pressure gets too high enough to lock the rear wheels it reduces the flow of brake fluid to them, helping maintain balance and control. In advanced vehicles, you'll also find Anti-lock Braking Systems (ABS). These systems use sensors to check how fast each wheel is spinning. If any wheel starts to lock up, ABS quickly releases and reapplies the brakes many times per second so the wheels keep rotating and the vehicle stays under control.

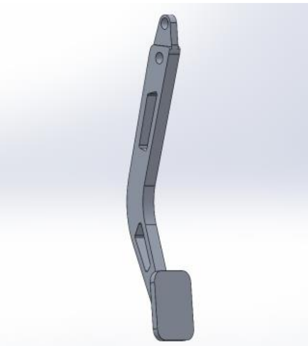

Fig no. 1 CAD of Pedal.

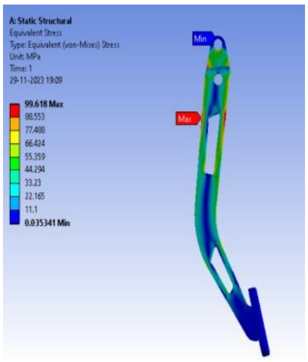


Fig no. 2 Ansys of Pedal .

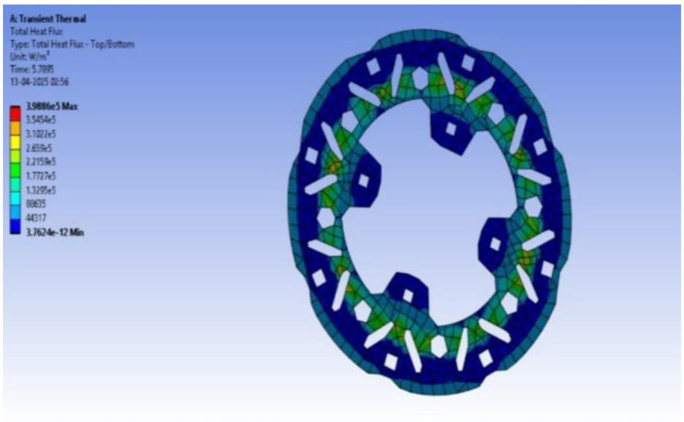


Fig no. 3 CAD Model of Brake Disc.

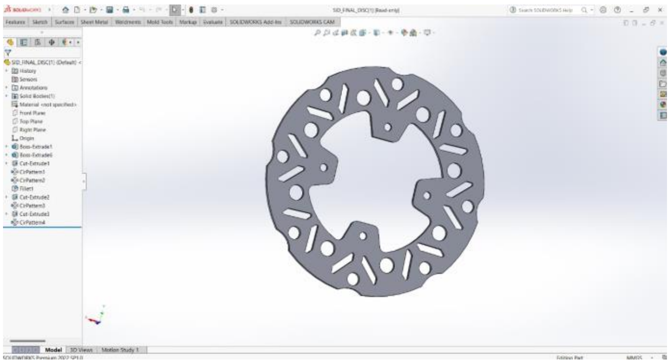

Fig no. 4 Ansys Model of Brake Disc.

## 3. METHODOLOGY

In this process all OEM (original equipment manufacturers) Products are compared concerning one another. The comparison is made on various data collected with benchmarking based on sustainability, availability, cost, and properties.

Table 1 for Rotor Material

| Properties | Stainless Steel | Cast Iron | Carbon ceramic composites | Aluminum |
|---|---|---|---|---|
| Density(g/cm^3) | 7.8 | 7.2 | 2.4-2.6 | 2.7 |
| Thermal conductivity(W/m.K) | 16-25 | 45-55 | 10-15 | 200-235 |
| Tensile Strength(MPa) | 500-800 | 200-400 | 500-700 | 90-150 |
| Operating Temp. Range(°C) | Up to 600 | Up to 500 | Up to 1200 | Up to 300 |
| Corrosion Resistance | Excellent | Poor | Excellent | Poor |
| Availability | High | High | Low | High |
| Weight(Kg) | 3-4 | 4-5 | 1.5-2 | 2-3 |

1. Stainless steel gives the best balance of performance, reliability, and cost-effectiveness.
2. Stainless steel offers higher mechanical strength than aluminum and cast iron.
3. Corrosion resistance and magnetic properties.

Table 2 for Brake Fuel

| Sr no. | Brake Fluid | Dry Bp (°C) | Wet Bp (°C) |
|---|---|---|---|
| 1 | DOT-3 | 205 | 140 |
| 2 | DOT-4 | 230 | 155 |
| 3 | DOT-5 | 260 | 180 |

1. DOT-4 performs better under heavy braking or off-road conditions.
2. DOT-4 has a balance in cost, performance, and availability.
3. DOT-4 is the ideal fluid for ATVs with moderate to high stress.

## 4. CALCULATIONS

| | |
|---|---|
| Mass | 285 kg |
| Deacceleration | 0.8g = 7.848 |
| Height of C.G. | 22inch = 0.5588m |
| Wheelbase | 58inch = 1.4732m |
| Weight ratio | 60:40 |
| Tire radii | 11.5 inch = 0.2921m |
| Reff | 0.0715 m |
| $\mu_{road\&tire}$ | 0.7 |
| $\mu_{pad\&tire}$ | 0.35 |

Step 1: Dynamic Load Transfer (DLT)

DLT = m.a.h / L=285*7.848*0.5588/1.4732 = 848.40N

Step 2: Load on Tire

Load on Front Tire = (weight * x) + DLT = (285*9.81*0.4)+ 848.40 = 1966.74N

Load on Rear Tire = (weight*x)- DLT = 9.81 (285*0.6)- 848.40 = 829.11N

Step 3: Wheel Torque on each wheel

Front = $\mu_{road\&tire}$ * load on front * tire radii *1/2= 0.7*1966.74*0.2921*1/2 = 201.06Nm

Rear = $\mu_{road\&tire}$ * load on rear * tire radii *1/2= 0.7*829.11*0.2921*1/2 = 84.764Nm

Step 4: Pressure in lines

Force on Master Cylinder = 250*7 = 1750N

Assume Master Cylinder Area = A = π/4*(0.0175) $^2$ = 0.0002405 $m^2$

P= F/A = 1750/0.0002405

= 7367824.56N/$m^2$

Step 5: Clamping Force

On Front=Pressure* π/4*($D_{caliper}$)$^2$*No.Of Piston = 7367827.56*$\frac{\pi}{4}$*(0.030)$^2$*2 =10416.02N

On Rear = Pressure* π/4*($D_{caliper}$)$^2$*No. Of Piston = 7367827.56*$\frac{\pi}{4}$*(0.030)$^2$*2 = 10416.02N

Step 6: Braking Torque

Front =Clamping Force*$\mu_{pad\&tire}$ * $R_{eff}$= 10416.02*0.35*0.0715 = 260.66 Nm

Rear =Clamping Force*$\mu_{pad\&tire}$ * $R_{eff}$= 10416.02*0.35*0.0715 = 260.66 Nm

Braking Torque > Wheel Torque, the vehicle will come to rest.

**Mount's Calculations:-**

Force on Master Cylinder's Mount = Force on Pedal x Pedal Ratio = 250*7 = 1750 N

* Kinetic energy for vehicle: - 1/2 *m*$v^2$

m = 285 kg

v = 60 km/hr =16.67 m/s

x = 0.6 = static load factor for the rear axle

K.E. = 1/2*m*$v^2$* x

= 1/2*285*16.67$^2$*0.6

= 23759.50 J

* Stopping time for vehicle: -

v = u + at

0 = 16.67+ (-0.8*9.81) * t

t = 16.67 / 7.848

= 2.12 sec

* Braking Power (Heat Flow): -

$P_b$ =K.E. / t = 23759.50 /2.12= 11207.311 W

* Heat Flux: -

Q = $P_b$ /A

A = Area swept by pads, $m^2$

$Q = 11207.311 / 0.016244$

$Q = 689935.42\ W/m^2$

Stopping distance

$S = u^2/2*a*s = 11.11^2 / 2*(0.8*9.81) = 7.86\ m$

## 5. CONCLUSIONS

Using the above calculations and knowing the advantages of stainless steel 420 series rotors compared to other materials is sustainable. The heat dissipation of the rotor is good enough to withstand all types of terrain conditions. The Numerical evaluation of the braking system confirms that effective vehicle deceleration within a safe stopping distance, system is capable of bringing the vehicle to rest efficiently. Furthermore, using DOT-4 brake oil having good performance with durability and optimal combination of both SS420 rotor and DOT-4 brake oil. Overall, the system design ensures reliable performance under real-world braking conditions.

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## BIOGRAPHIES

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