

**Shivaramu H T<sup>1</sup>**  
**Aveen K P**  
**Raeid**

Research paper  
DOI – 10.24874/QF.25.108



## **DESIGN, ANALYSIS AND FABRICATION OF BRAKE SYSTEM FOR ALL TERRAIN VEHICLE**

**Abstract:** *All Terrain Vehicles (ATV) is a vehicle that can move on almost all types of terrain and travels on low-pressure tires. As the safety of the driver is paramount and depends on breaking there is a need to design and fabricate a safe and reliable braking system. This work aims to use various braking components in the system and design an effective braking system considering various scenarios of the environment and CAE analysis of the brake disc rotor. This study made recommendations for the development of ATV after analyzing developed disc brake rotors. For each design, structural analysis and steady-state thermal analysis are included in the brake rotor study. The designed braking system is effective, reliable, and has minimum weight without any compromise in its safety standards and performance. Moreover, by analyzing the brake rotor it was established that the maximum temperature obtained at the brake pad contact surface is 78.408 °C which is concluded as very much safe..*

**Keywords:** *All-Terrain Vehicle (ATV), Brake system, Disc rotor Condition*

### **1. Introduction**

The evolution of braking systems for vehicles has been a critical factor in advancing safety and performance in the automotive industry. From the early mechanical brakes that relied on manual force to modern systems with advanced electronic controls, braking technology has undergone significant improvements. Hydraulic brakes, first introduced by Frederick William Lanchester in 1902 and later refined by Malcolm Loughead in 1918, revolutionized the field, offering more reliable and effective braking than mechanical systems. Over the decades, innovations such as disc brakes, anti-lock braking systems (ABS), and electronic stability control (ESC) have made vehicles

safer and more efficient.

Fundamentals of Vehicle Dynamics, is an overall guide to designing an automobile used for a better understanding of the braking system, its performance improvements, and for braking calculation. It covers the very basic coordinating system, acceleration performance system, braking performance, road loads, ride, suspension, and tires (Gillespie, 1992).

Brake Design and Safety, is a pure guide to brake fundamentals, braking systems, automatic brake control, analysis design and analysis of friction brakes helps us to revise our concepts and correct our mistakes. Calculation of the braking system was done based on the data available (Limpert, 1963).

<sup>1</sup> Corresponding author: Shivaramu H T  
Email: [shivaramu@mite.ac.in](mailto:shivaramu@mite.ac.in)

As mentioned a disc rotor developed fully from the zero-basis using the product development steps, disc was tested as a part of the BAJA ATV- All-terrain vehicle braking system under critical limits and achieved the target constraints. Rulebook, a set of every minute data being used to design the whole vehicle and guides thoroughly (BAJA SAEINDIA, 2022).

The problems that occur in brake system during braking like Squealing, scarring, excessive rusting, and cracking. It helps to understand the whole of braking calculation with the proper assembly of the braking system and assumed data makes a calculation of forces generated torque at pads, net heat flux, and other parameters. The use of ANSYS was also done to mesh the disc and thermal analysis was performed to get the real-time view of the disc under circumstances (Abhang & Bhaskar, 2014).

An overview of how technology changing the world today and brief disc brake rotor system assembly and describes material selection for disc brake rotor in comparison to steel, aluminium, and alloy like magnesium, and titanium. It guides us to choose the best suitable material under the current scenario considering our object of work. An assumed data was used to calculate working force, stress, and the torque generated, brake distance, and its calculation. The use of wide-ranging calculations was done to understand the braking phenomenon and for comparison (Mishra et al., 2016).

Research on material selection through an exhaustive method, and the comparative analysis starts with steps of material selection choosing six materials into consideration and provides using Digital Logic Method (DLM) assigns numbers using product-process matrix (Maleque et al., 2014).

In the context of all-terrain vehicles (ATVs), the design, analysis, and fabrication of a robust brake system is essential for ensuring safety and performance across diverse off-

road conditions. ATVs, known for their rugged use, require braking systems that can handle extreme terrains and demanding operating conditions. This research paper presents the development of a reliable brake system tailored for an ATV, focusing on key phases including design, analysis, and fabrication.

The design phase involves selecting suitable components such as master cylinders, calipers, rotors, pads, and hydraulic lines, with attention to factors like material selection and heat dissipation. Computer-aided engineering tools such as Finite Element Analysis (FEA) and Computational Fluid Dynamics (CFD) are used to evaluate the system's structural integrity and optimize hydraulic flow. Once fabricated, the brake system undergoes thorough testing to validate its performance under real-world conditions, ensuring that the system meets the safety and control requirements for off-road use.

This paper highlights the importance of integrating modern technologies and rigorous testing to create an efficient and reliable brake system for ATVs, contributing to improved safety and driving confidence in challenging terrains.

## **2. Methodology**

### **2.1 Requirement Analysis**

The requirements include the maximum speed of the ATV, the maximum weight it can carry, the terrain on which it will be used, and the stopping distance required. The first step in designing a brake system for an ATV is to determine the type of brake system required. There are two main types of brake systems, disc brakes, and drum brakes. Disc brakes are more efficient and reliable than drum brakes, making them the preferred choice for ATVs. The brakes are further classified into inboard and outboard braking systems. Onboard and outboard braking refers to the location of the braking

components in a vehicle. Inboard brakes are located on the inside of the vehicle's wheels and are often found in high-performance vehicles, particularly racing cars. In these systems, the braking components are located within the wheel hub, which allows for better weight distribution and reduced unsprung weight. Inboard brakes are typically more expensive and complex to design and manufacture than outboard brakes, but they can provide better performance. Outboard brakes, on the other hand, are located on the outside of the wheels and are more commonly found in regular passenger vehicles. In these systems, the braking components are mounted to the vehicle's suspension system. Outboard brakes are simpler and less expensive to design and manufacture than inboard brakes, but they can also be less effective in terms of braking performance. In the current work, outboard brakes for the front and inboard brakes for the rear were used.

## 2.2 Component Selection

The brake system consists of several components, including the master cylinder, brake-pads, brake calipers, brake lines, and brake rotors. Determining the size and specifications of each component based on the requirements was crucial. The brake pedal that is utilized in the buggy is made up of mild steel (1018) because it can withstand the load applied by the driver on it and also the force it exerts on the push-rod of the master cylinder without undergoing any deformation. The pedal ratio is about 7:1 which shows that the force exerted by the pedal on the master cylinder is 7 times more than the force applied by the driver on it. A Bosch tandem master cylinder of bore diameter 19.05mm is used because it has two outlet ports out of which one outlet port can be connected to the rear and the other port can be connected to the front brake lines with a splitter for effective braking and it is a dual piston master cylinder due to which it can produce enough pressure even in case of

failure of one piston. A steel-braided brake hose is used in the ATV because it is quite flexible and can transfer pressure to the brake calipers without any distortion. A fixed type of caliper is used in the braking system as it has more clamping force than the floating type.

## 2.3. Material Selection

Initially, stainless steel, grey cast iron and aluminum are considered to be analyzed so that one of them can be adopted as the material of the rotor. Moreover, the density of the aluminum is the lowest in comparison to the other two so it would be lightweight which is preferable. Aluminum has better thermal conductivity than the other two materials which could lead to better dissipation of heat throughout the rotor, but the co-efficient of thermal expansion is double of the other materials, which means that the rotor material will expand on heating which is indeed a disadvantage. When the melting-point of the three materials is compared, it is observed that aluminum has the lowest melting point as compared to the other two.

**Table1.** Physical properties of SS410

Density	0.276 lb./in <sup>3</sup>
Specific gravity	7.65
Melting range	1482-1532°C
Modulus of elasticity	200GPa

Stainless steel (SS) of grade 410 has a low density and specific gravity which can be observed in Table 1. So stainless steel has lightweight which helps in gaining better performance as well as reduces the unsprung mass of the buggy. In addition to the density and specific gravity, the melting range of SS410 is also high, so it can withstand exposure to extreme temperatures. Moreover, SS410 is corrosion-resistant. So, it is concluded that the SS410 is best to be used as the rotor material.

## 2.4. CAD modeling

Once the brake system design is finalized, created a 3D model of the system using computer-aided design (CAD) software. Fig. 1 visualizes the brake rotor.



Figure 1. Brake rotor

## 2.5. Testing

Test the brake system prototype under different conditions to validate its performance. This includes testing the brake system on different terrains, at different speeds, and with different loads.

## 2.6. Optimization and final production

Based on the testing results, optimize the brake system design to improve its performance. This could involve modifying the size or specifications of certain components or adjusting the brake system's overall configuration. Once the brake system design is optimized, produce the final brake system components and assemble them into the ATV.

## 3. Design and calculations

The following calculations lay the foundation for selecting the rightful caliper for a BAJA vehicle to achieve precise braking and perfect handling of the vehicle. Some of the input parameters include track width, wheelbase, total weight (including Driver's weight), a total height of C.G (including driver's mass), the diameter of the tire (same for front and rear), effective brake rotor diameter (Front and Rear), the distance of the center of gravity (from front tire's center and rear tire's center), diameter and

pedal ratio.

## 3.1 Brake Design

The dynamic load transfer on the axles serves as the starting point for the design calculation of the braking system. Because it provides the value of the necessary braking torque on the wheels, this load transfer needs to be computed.

### A. Dynamic Load transfer

It involves the computation of the reaction forces brought about by the inboard system's self-weight on the front and rear axles. Both of the rear wheels were locked using a single rotor and calliper. Calculating the reaction forces on the front and rear axles as a result of the vehicle's own weight transfer as it slows down to stop is known as self-weight transfer.

$\psi$  = Static C Transfer

Mfdyn = Mass on Front- axle = 149.66Kg

M = Mass of Vehicle = 207.26Kg

X=Relative C.G =h = 0.4353

a= Deceleration in g units = 0.68 g

$1-\psi = 144.66 - (0.4353 \times 0.68)$

$1-\psi = 0.4336$

$\psi = 0.5664$

$$Rf = \frac{W(x + \mu h) \cos\theta}{b}$$

$$Rr = \frac{W(x - \mu h) \cos\theta}{b}$$

Where,

Rf=Load on front axle,

Rr=Load on the rear axle,

x=Distance of centre of gravity from rear axle = 21.683in = 0.5507m b=Wheel base = 1.27 m

h=Height of centre of gravity from Ground = 0.5529 m

$\mu$ =Co-efficient of friction between tire and road = 0.68 (it is the value for the gravel road)

$$W = \text{Weight of Vehicle} = 207 \times 9.81 = 2060.63 \text{ N}$$

Now,

$$R_f = 1477.455 \text{ N}$$

$$R_r = 584.78 \text{ N}$$

$$W \sin \theta + \frac{W}{g} \alpha = \mu (R_f + R_r)$$

$$2060.63(0) + 2060.63$$

$$\alpha = 0.68(1477.4 + 584.78) / 9.81$$

$$\alpha = 6.6 \text{ m/s}^2 \text{ (deceleration)}$$

$$[(1-\psi) + (X.a)] M = M_{fdyn}$$

Where, Now

$$M_r = \psi M = 110.419 \text{ Kg}$$

The load transfer resulted is in dynamic conditions

$$\text{Load on Front-Side} = 72.96 \%$$

$$\text{Load on Rear-Side} = 27.03 \% \text{ in static condition,}$$

$$\text{Load on Front-Side} = 43.36 \%$$

$$\text{Load on Rear-Side} = 56.64 \%$$

Now compute the necessary braking force and braking torque once we have the values of the dynamic load transfer on the axel.

### B. Necessary Braking Forces and Torque:

$$FB = M \cdot a \cdot g$$

Where,

$$M = \text{Mass of the vehicle} = 207.26 \text{ Kg}$$

$$a = \text{Deceleration in (g) units} = 0.68 \text{ g}$$

$$g = \text{Accelerations due to the gravity} = 9.81$$

$$FB = 207.26 \times 0.68 \times 9.81 = 1322.15 \text{ N}$$

Now,

In dynamic condition, for front-side,

$$F_{BF} = \mu \times R_f = 965.01 \text{ N}$$

$$z = F_{BF} \times R_{Wheel}$$

$$(R_{Wheel} = 11.5 \text{ in} = 0.2921 \text{ m})$$

$$= 281.87 \text{ N-m}$$

$$\text{Torque on the single wheel, } z = 281.87 / 2 = 140.93 \text{ N-m}$$

$$\text{For Rear Side, } F_{BF} = \mu \times R_r = 357.53 \text{ N}$$

$$z = F_{BF} \times R_{Wheel}$$

$$(R_{Wheel} = 11.5 \text{ in} = 0.2921 \text{ m})$$

$$= 104.43 \text{ N.m}$$

### C. Design of the systems

Now the values needed to stop the car is available. Therefore, must build the brake system to produce these necessary values.

To calculate pressure in Tandem master cylinder

$$\text{Pedal-force} = 300 \text{ N}$$

$$\text{Bore-diameter of Tandem master cylinder} = 19.05 \text{ mm}$$

$$\text{Force act on Tandem master cylinder (FTMC)} = 7 \text{ times of Pedal Force} = 2100 \text{ N}$$

$$\text{Area of TMC, ATMC} = \frac{\pi D^2}{4}$$

$$= 285.9 \times 10^{-6} \text{ m}^2$$

$$\text{Pressure in Tandem master cylinder (PTMC)} = \frac{FTMC}{ATMC}$$

$$= 7.3245 \times 10^6 \text{ N/m}^2$$

$$= 73.245 \text{ Bar}$$

Now,

$$\text{Diameter of piston of front - calipers} = 34 \text{ mm}$$

$$\text{Diameter of piston of rear - Calipers} = 32 \text{ mm}$$

$$\text{Area of cross-section of front-caliper piston} = \frac{\pi D^2}{4} = 9.0792 \times 10^{-4} \text{ m}^2$$

$$\text{Area of cross-section of rear-caliper piston} = 8.042 \times 10^{-4} \text{ m}^2$$

Force acting on a caliper,

Clamping force generated by front-caliper,

$$F_{CP} = \mu \times PTMC \times \text{Area of Caliper} = 0.34 \times 73.24 \times 9.0792 \times 10 = 2267.038 \text{ N}$$

Generated Torque on the single-wheel,

$$z = 0.065 \times 2267.038$$

(0.065 m is the radius of the front disc rotors)

$$= 147.35 \text{ N-m}$$

Clamping Force generated by rear Caliper,

$$F_{CP} = 2 \mu \times PTMC \times \text{Area of Caliper} = 2 \times 0.34 \times 73.24 \times 8.042 \times 10 = 4016.34 \text{ N}$$

Torque on Single Wheel,

$$z = 2008.17 \times 0.070$$

(0.070 m is the radius of the rear-disc rotors)

$$= 140.5719 \text{ N-m}$$

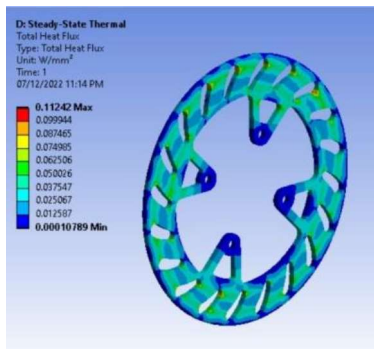
The calculated parameters are listed in the Table 2.

**Table 2.** Calculated parameters

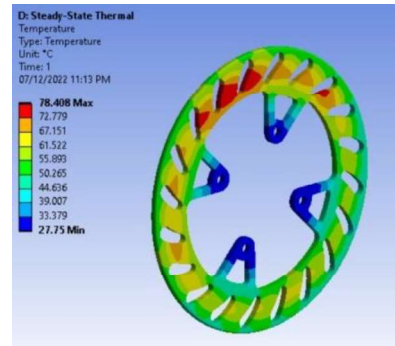
Parameter	Remarks
Weight transfer at 40 to 0 kmph	1331.4 N
Static rolling radius of the tyre	0.292
Co-efficient friction for tyre and rod	0.7
Force required by the caliper	4481.42
Brake torque required	660.05 N-m
Balance between two braking circuit	Designed for simultaneous locking
Brake force distribution	Equally distributed on front and rear

#### 4. Brake rotor analysis

After the CAD modeling of the brake rotors, heat flux and thermal analysis of disc rotor was conducted using ANSYS software. The heat flux and thermal analysis are shown correspondingly in the Fig. 2 and 3. For heat flux analysis at a maximum heat flux value of 0.11242 W/mm<sup>2</sup> and in thermal analysis at a maximum temperature of 78.408 °C was attained.



**Figure 2.** Brake Disc Heat Flux Analysis



**Figure 3.** Brake Disc Thermal Analysis

The purpose of analysis is to examine the capabilities and limitations of the Brake Rotor during sudden braking and load transfer actions. The given conditions were compared to the main intense values that can be observed, and thus analysis is performed. ANSYS was used to calculate and simulate load transfer under such conditions. These components are prone to high temperatures due to the friction generated among the brake disc and brake pads (Sarkar et al., 2014).

A well-designed, properly analyzed, and carefully fabricated brake system can significantly improve the safety and performance of an ATV. A high-quality brake system can reduce the stopping distance of the vehicle, improve control and handling, and prevent accidents caused by brake failure. By ensuring that the brake system is designed and fabricated to the highest standards, with this can guarantee that ATV is safe and reliable, even in the most challenging terrain and conditions.

#### 5. Fabrication

Once the brake system design is finalized and tested using FEA, developed a physical prototype of the brake system. The Fig. 4, 5 and 6 depicts the fabricated front brake, rear brake and brake pedal respectively. Used FEA software to simulate the brake system and test its performance under different conditions. FEA can help identify any potential weaknesses or areas that need

improvement in the brake system design. This involves fabricating each component of the brake system and assembling them.



**Figure 4.** Front brake setup



**Figure 5.** Rear brake setup



**Figure 6.** Brake pedal

## 6. Conclusions

The designed braking system is effective, reliable and has minimum weight without any compromise in its safety standards and performance. Two floating callipers with a 34 mm bore diameter are used in conjunction with steel disc rotors that are 170 mm in diameter as part of this actuation system. Additionally, the rear inboard actuation system has a single fix type calliper with a 160 mm steel disc rotor and a 32 mm bore diameter. Moreover, by analyzing the brake rotor it was found that the maximum temperature obtained at the brake pad contact surface is 78.408 °C which is concluded as very much safe.

## References:

- Abhang, S. R., & Bhaskar, D. P. (2014). Design and analysis of disc brake. *International Journal of Engineering Trends and Technology*, 8(4), 165-167.
- BAJA SAEINDIA. (2022). *BAJA SAEINDIA 2023 Rulebook* (Rev 00). Retrieved from [https://bajasaecindia.org/upload/Resource/BAJA%20SAEINDIA%20RULEBOOK%202023\\_Rev0\\_1660412649.pdf](https://bajasaecindia.org/upload/Resource/BAJA%20SAEINDIA%20RULEBOOK%202023_Rev0_1660412649.pdf)BAJA SAEINDIA+2
- Gillespie, T. D. (1992). *Fundamentals of vehicle dynamics* (pp. 45–76). Society of Automotive Engineers, Inc.
- Limpert, R. (1963). *Brake design and safety* (3rd ed., pp. 22–122). Society of Automotive Engineers.
- Maleque, M. A., Dyuti, S., & Rahman, M. M. (2010). Material selection method in design of automotive brake disc. In *Proceedings of the World Congress on Engineering* (Vol. 3).
- Mishra, Y. H., Deulgaonkar, V. R., & Makasre, P. A. (2016). Design and optimisation of disc brake rotor (for two wheeler). *International Engineering Research Journal*, 2, 288–300.
- Sarkar, S., Rathod, P. P., & Modi, A. J. (2014). Research paper on modeling and simulation of disc brake to analyse temperature distribution using FEA. *International Journal for Scientific Research & Development*, 2(3), 2321–0613.

---

**Shivaramu H T**

Department of Mechanical  
Engineering, Mangalore Institute  
of Technology & Engineering,  
Autonomous Institute,  
Moodbidri, D.K - 574225,  
Karnataka, India  
[shivaramu@mite.ac.in](mailto:shivaramu@mite.ac.in)  
ORCID 0000-0002-4979-3035

**Aveen K P**

Department of Mechanical  
Engineering, Mangalore  
Institute of Technology &  
Engineering, Autonomous  
Institute, Moodbidri, D.K -  
574225, Karnataka, India  
[aveen@mite.ac.in](mailto:aveen@mite.ac.in)  
ORCID 0000-0002-2682-8442

**Raeid**

Autoliv India pvt. ltd., Bande  
Kodigehalli, Singahalli,  
Bangalore, Karnataka 562149,  
India  
[raeidrst007@gmail.com](mailto:raeidrst007@gmail.com)  
ORCID 0009-0006-8561-8003

---