Design and Analysis of Inboard Braking System for Vehicle

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Abstract - *An inboard braking system is a type of braking system where the brake discs are located inside the vehicle's drivetrain, rather than on the wheels themselves. This type of braking system offers several advantages over traditional outboard systems, including improved weight distribution, reduced unsprung weight, and increased packaging flexibility. This abstract provides a brief overview of the inboard braking system, its components, and its benefits. It also discusses some of the challenges associated with designing and implementing such a system, including cooling and packaging considerations and the need for sophisticated control systems to ensure safe and effective braking performance.*

Key Words: Inboard Braking, rotor, caliper, rotor hub.

1. INTRODUCTION

An inboard braking system is a type of braking system used in automobiles where the brakes are located inside the vehicle's drivetrain rather than on the wheels themselves. In this system, the brake discs and calipers are mounted on the axle or differential housing, rather than on the wheels.

Inboard braking systems are commonly used in high-performance sports cars and race cars because they provide better weight distribution, improved handling, and more consistent braking performance. By keeping the weight of the brakes closer to the centre of the car, inboard braking systems help to reduce the car's unsprung weight and improve its handling and responsiveness.

Another advantage of inboard braking systems is that they are better protected from the elements, such as rain, dust, and debris, which can cause damage to the braking components. They are also easier to cool, which helps to prevent brake fade during prolonged or high-intensity use.

However, inboard braking systems can be more complex and expensive to design and manufacture compared to traditional outboard braking systems. They also require more maintenance and are more difficult to service when compared to conventional brake systems.

Overall, inboard braking systems offer several advantages over outboard braking systems in terms of performance and handling, but they also require more complex design and engineering, which can make them more expensive to produce and maintain.

2.PROBLEM STATEMENT

Inboard braking systems are located inside the chassis, which reduces the unsprung weight of the wheels. This can improve the handling and stability of the vehicle, making it more responsive to driver inputs. Inboard brakes are protected from the elements, which can help improve heat dissipation and reduce the risk of brake fade. This is particularly important in high-performance applications where braking is a critical factor. By locating the brakes inside the chassis, inboard braking systems free up space on the outside of the wheels. This can allow for the use of larger tires, suspension components, and other systems that can further improve the performance of the vehicle. Inboard braking systems can be designed to improve the aerodynamics of the vehicle by reducing drag and turbulence. This can improve fuel efficiency and reduce wind noise. Inboard brakes can be more visually appealing than outboard brakes, as they can reduce clutter and visual distractions on the outside of the wheels.

Fig -1: Inboard Braking System

3. SCOPE AND OBJECTIVE

- Improved Heat Dissipation: Inboard braking systems can be designed to dissipate heat more efficiently, reducing the risk of brake fade and ensuring consistent performance.
- Reduced Unsprung Weight: By locating the brakes inside the chassis, inboard braking systems can reduce the unsprung weight of the wheels, improving handling and stability.
- Improved Aerodynamics: Inboard brakes can be designed to reduce drag and turbulence, improving the overall aerodynamics of the vehicle.

4.INBOARD BRAKING

"Inboard braking" as in to a type of braking system where the brakes are fitted inside the vehicle's chassis, typically near the differential. In contrast, "outboard braking" refers to a braking system where the brakes are located on the outside of the vehicle's wheels.

Inboard braking systems offer several advantages over outboard braking systems, including reduced unsprung weight, improved heat dissipation, increased space for other components, improved aerodynamics, and improved aesthetic appeal. However, inboard braking systems also present certain challenges, such as increased complexity and maintenance requirements, which may limit their application in some situations.

Inboard braking systems are primarily used in high-performance vehicles and heavy-duty commercial vehicles, where these advantages are most beneficial. They can provide improved handling, stability, and safety while also enhancing the overall performance of the vehicle.

5. GEOMETRY

The geometry of inboard braking systems can vary depending on the specific design and application. In general, inboard braking systems are designed to locate the brakes inside the vehicle's chassis, typically near the differential. This can involve the use of special brackets or mounts to secure the brake calipers to the chassis.

The geometry of the brake components themselves, such as the rotors and calipers, may also be modified to optimize their performance within the inboard location. For example, the rotors may be larger in diameter to improve heat dissipation, or the calipers may be designed to fit more tightly around the rotor to increase braking force.

6. CONSTRUCTION

The main components of the inboard braking system are as follows:

1. *Brake Calipers:*

   Inboard braking systems use special brake calipers that are mounted inside the vehicle's chassis. The calipers contain the brake pads and are responsible for squeezing them against the rotor to slow or stop the vehicle.

2. *Brake Rotors:*

   Inboard braking systems use brake rotors that are mounted on the vehicle's differential or transmission output shaft. The rotors are typically larger in diameter than those used in outboard braking systems to provide improved heat dissipation.

3. *Brake Lines:*

   Brake lines connect the brake calipers to the brake master cylinder or hydraulic control unit, providing the hydraulic pressure necessary to activate the brake system.

4. *Rotor hub:*

   Special mounting brackets or mounts are used to secure the brake calipers to the vehicle's chassis in the inboard location.

5. *Brake Master Cylinder or Hydraulic Control Unit:*

   The brake master cylinder or hydraulic control unit is responsible for generating the hydraulic pressure necessary to activate the brake system. In some inboard braking systems, this component may be located outside the chassis.

6. *Brake Pedal:*

   The brake pedal is used to actuate the brake system and generate the hydraulic pressure necessary to activate the brake calipers.

7. *Brake Fluid Reservoir:*

   The brake fluid reservoir stores the brake fluid used to generate the hydraulic pressure necessary to activate the brake system

Overall, the components of an inboard braking system work together to provide effective and efficient braking performance, while minimizing the weight and complexity of the braking system.The specific components and design of an inboard braking system can vary depending on the application, the type of vehicle, and other factors.

7. WORKING

The working of an inboard braking system is similar to that of a conventional braking system, with the primary difference being the location of the brake components. Here are the general steps involved in the working of an inboard braking system:

1. When the driver presses the brake pedal, it activates the brake master cylinder, which creates pressure in the brake lines.

2. The brake fluid flows through the brake lines to the brake calipers, which are located inside the vehicle's chassis near the differential.

3. The brake calipers hold the brake pads and use the pressure from the brake fluid to clamp the pads onto the brake rotors, creating friction and slowing or stopping the vehicle.

4. As the brake pads create friction against the rotor, heat is generated. In some inboard braking systems, cooling ducts or other features may be used to dissipate the heat and prevent brake fade.

5. Once the brake pedal is released, the pressure in the brake lines is released, and the brake calipers release the brake pads from the rotor, allowing the vehicle to move freely again.

Overall, the working of an inboard braking system is designed to provide reliable and effective braking performance, while also minimizing the weight and complexity of the braking system

8. CALCULATION

Calculation for braking torque

Mass = 270 kg

Deceleration = 0.8g = 0.8 X 9.8 = 7.84

Height of centre of gravity of vehicle = 21 inch = 0.533 m

Wheel Base = 56 inch = 1.4224 m

Weight Ratio = x = 0.4 (40 : 60)

Tyre Radius = 0.2667 m

$\mu_{\text{road \& tyre}} = 0.7$

$\mu_{\text{pads \& rotor}} = 0.3$

$R_{\text{efficiency}} = \frac{1}{2}(R_i + R_o)$ ($R_{\text{efficiency}}$ = mean radii of pads)

R_i = inner radi of disc

R_o = outer radii of disc

$R_{\text{efficiency}} = 0.0715\text{m}$

Pedal Ratio = 7 : 1

Dynamic Load Transfer (DLT)

$$= \frac{\text{Mass} : \text{Deacceleration} : \text{Height of CG}}{\text{Wheel Base}}$$

$$= \frac{270 \times 0.8 \times 9.81 \times 0.533}{1.4224}$$

= 794.01 N

Load on Front Axle:

=(Weight of vehicle X x) + DLT

= (mg X x) + DLT

= (270 X9.81 X0.4) +794.01

= 1853.49 N

Load on Rear Axle :

=(Weight of vehicle X (1-x)0 - DLT

= (mg X (1-0.4)) – DLT

= (270 X9.81 X0.6) -794.01

= 795.21 N

Wheel Torque on each wheel

1. Front:

$\mu_{\text{road \& tyre}} \times \text{Load on Front Axle} \times \text{Tyre Radii} \times \frac{1}{2}$

= 0.7 X 1853.49 X 0.2667 X 0.5
= 173.01 Nm

2. Rear:

$\mu_{\text{road \& tyre}} \times \text{Load on Rear Axle} \times \text{Tyre Radii} \times \frac{1}{2}$

= 0.7 X 795.21 X 0.2667 X 0.5
= 74.22 Nm

Calculation for Pressure generated by Master Cylinder

1. Pressure in brake line = $\frac{\text{Force}}{\text{Area (m.c.bore dia)}}$

$= \frac{\text{Pedal Force} \times \text{Pedal ratio}}{\frac{\pi}{4} \times d^2 mc}$

$= \frac{300 \times 7}{\frac{\pi}{4} \times 0.01905}$

= 7367827.56 N/m

=7.36 MPa

2. Pressure X ($\frac{\pi}{4} \times d^2_{\text{caliper}} \times$) X (no. of piston)

= 7367827.56 X ($\frac{\pi}{4} \times 0.030^2$) X 2

= 10416.02 N

Calculation for braking torque

Clamping force X $\mu_{\text{pads \& rotor}} \times R_{\text{efficiency}}$

= 10416.02 X 0.3 X 0.0715

= 223.42 Nm

Braking torque > Wheel Torque

223.42 Nm> 173.01 Nm

Therefore vehicle will come at rest.

Thermal Calculation:
Kinetic Energy for Vehicle:

$$= \frac{1}{2} mv^2$$

m= Mass of Vehicle

v= velocity in m/s

m = 270, v = 60 km/hr, x = 0.6 (Static Factor)

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

$$= \frac{1}{2} 270 \times 16.67^2 \times 0.6$$

=22509 J

Stopping Time for Vehicle:

v=u+at

v = final velocity, u = initial velocity, a = acceleration, t = time

0=16.67+ (-0.8X9.81) X t

$$T= \frac{16.67}{7.848}$$

T= 2.125

Braking Power:

$$P_b = \frac{K.E}{t}$$

$$= \frac{22509}{2012}$$

$$P_b = 10617.45 \text{ W}$$

Heat Flux:

$$Q = \frac{P_b}{A}$$

A = Area swept by pads

$$Q = \frac{10617.45}{0.016244}$$

Q = 653623.05 W/m^2

Calculated heat flux is approximately equal to the derived heat flux from Ansys workbench (Transient Thermal)

9. ANALYSIS

Rotor Hub Analysis

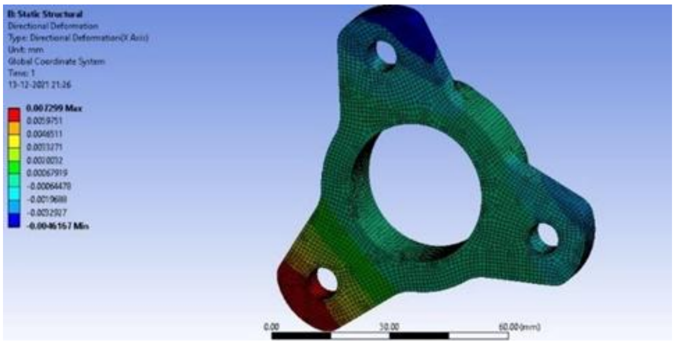

Fig -2: Directional Deformation

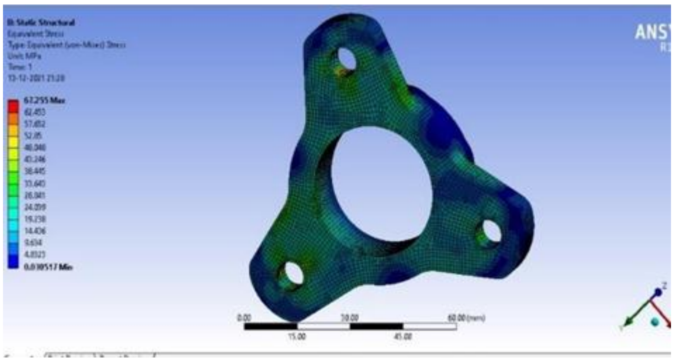

Fig -3: Equivalent Stress

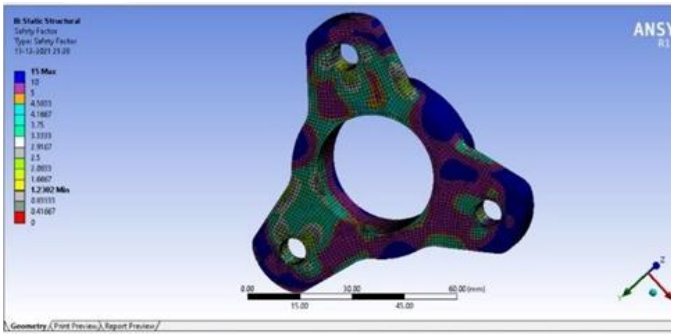

Fig -4: Safety Factor

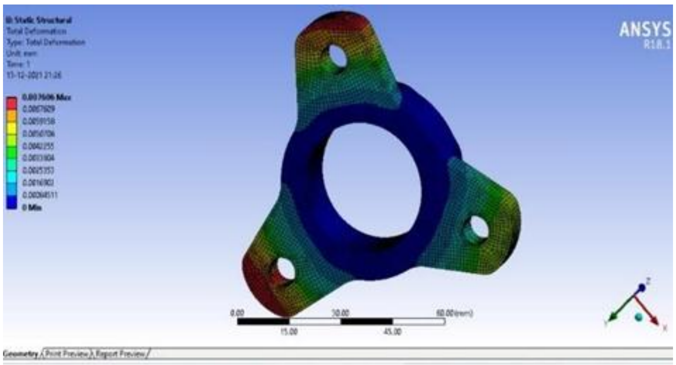

Fig -5: Total Deformation

Brake Rotor Analysis

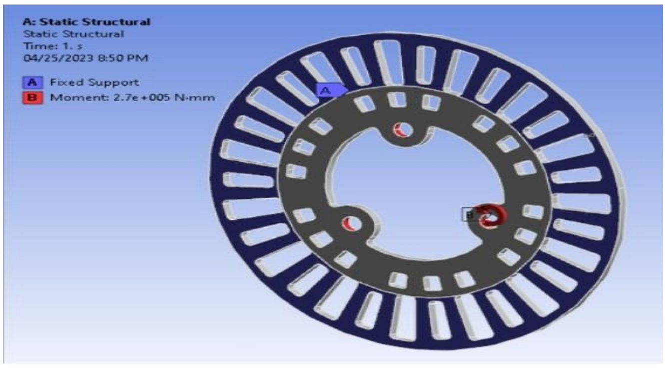

Fig -6: Static Structural

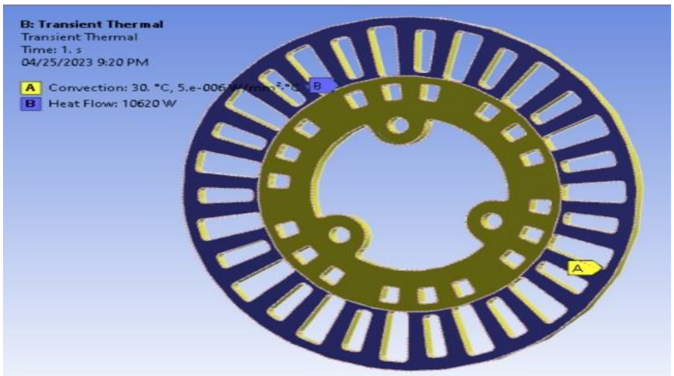

Fig -7: Transient Thermal

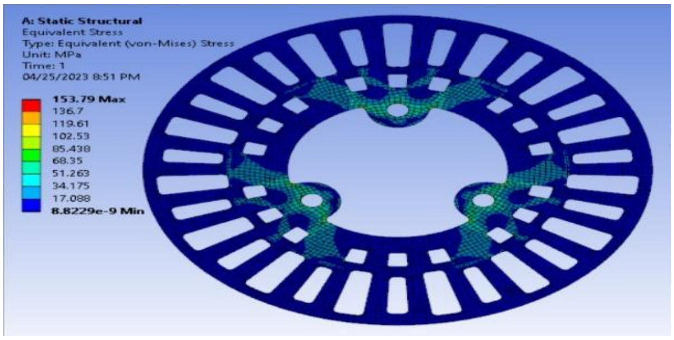

Fig -8: Equivalent Stress

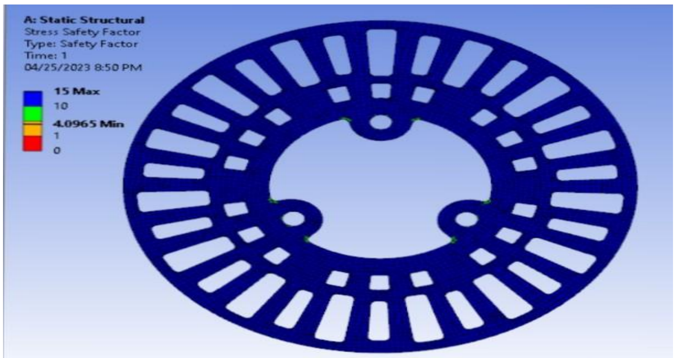

Fig -9: Stress Safety Factor

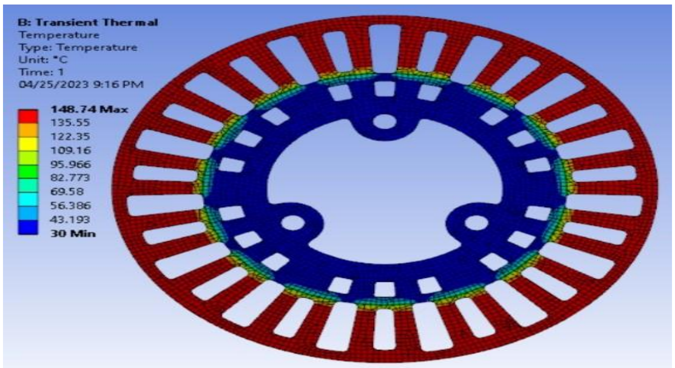

Fig -10: Temperature

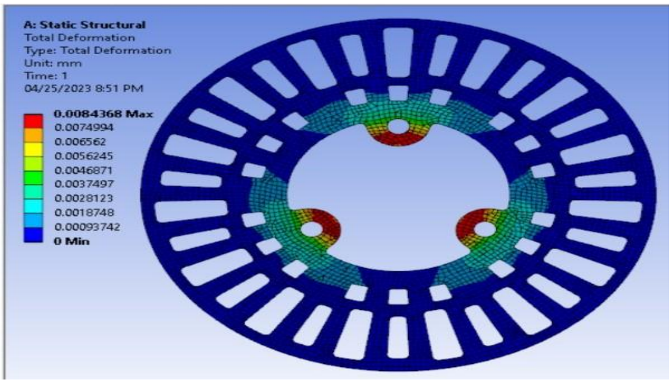

Fig -11: Total Deformation

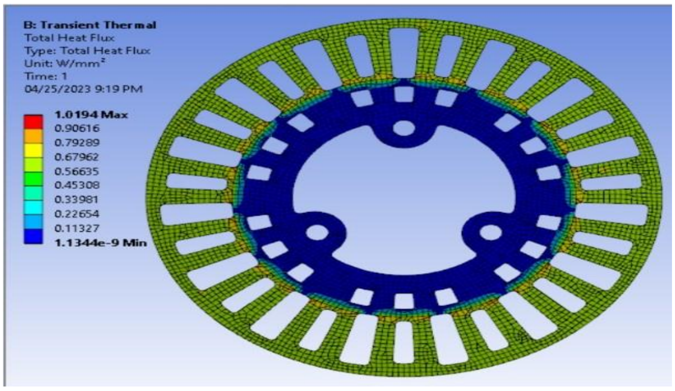

Fig -12: Total Heat Flux

Pedal Analysis

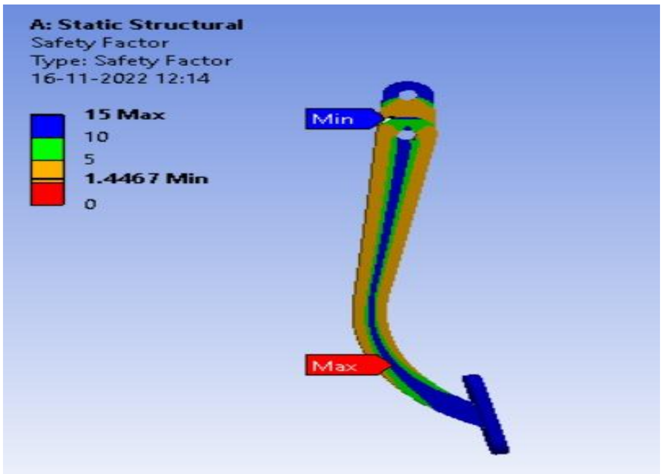

Fig -13: Safety Factor

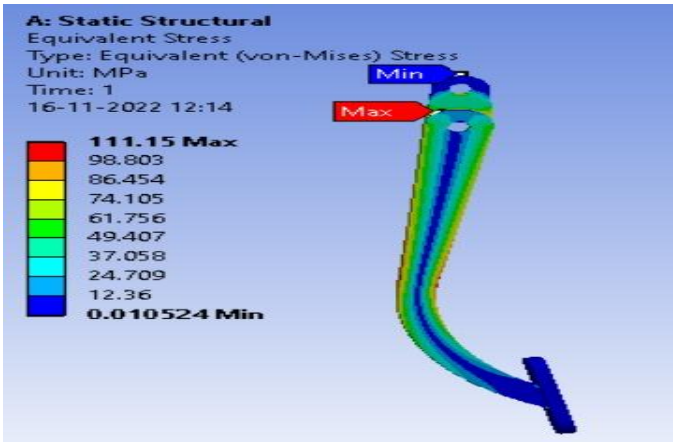

Fig -14: Equivalent Stress

10. TABLE OF MATERIAL

Table-1: Material Table

COMPONENTS	SPECIFICATIONS	
BOSCH Tandem Master Cylinder	19.05 mm Bore Diameter	
Disc Rotors	Front	Rear
	160 mm	180 mm
	Stainless Steel 420	
Caliper Piston Area (mm^2)	Front	706.85
	Rear	706.85
Brake Pedal	Ratio 7:1 (Top Mount, Class 1 Lever) Aluminium 6061 T6	
Brake Fluid	DOT 4	
Fluid Lines	4 mm Teflon ID (Steel Braided)	

11. CONCLUSION

An inboard braking system is a braking system that is located inside the vehicle's wheel hub. It is a popular choice for high-performance vehicles due to its ability to provide better balance and weight distribution. In addition, the inboard braking system is more aerodynamically efficient, resulting in improved fuel economy and reduced emissions.

The inboard braking system has several advantages over traditional braking systems. One of the most significant advantages is that it provides better stability and control over the vehicle, especially during high-speed driving or sudden stops. It also provides a more consistent and reliable braking performance, which is critical in racing and other high-performance applications.

In conclusion, the inboard braking system is a suitable option for high-performance vehicles or racing cars, where the benefits of improved handling and braking outweigh the added costs and complexity. For everyday vehicles, a more traditional outboard braking system may be a more practical and cost-effective choice. Ultimately, the choice of braking system depends on the specific needs and requirements of the vehicle and its intended use.

12. REFERENCES

Here are a few references on the inboard braking system that you may find helpful:

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These resources provide insights into the technology behind inboard braking systems, their advantages and disadvantages, as well as their applications in various industries, particularly in motorsports.

13.BIOGRAPHIES

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