# DESIGN, ANALYSIS AND FABRICATION OF OUTBOARD BRAKING SYSTEM FOR AN ATV

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**Abstract -** *This study presents the design, analysis, and fabrication process of an outboard braking system for an All-Terrain Vehicle (ATV). The outboard braking system offers several advantages, including improved cooling efficiency and reduced unsprung weight compared to traditional inboard braking systems. The design phase involves conceptualization, component selection, and CAD modeling to meet performance and safety requirements. Finite Element Analysis (FEA) is employed to assess the structural integrity and thermal performance of the braking components under various operating conditions. Fabrication techniques such as machining, welding, and assembly are utilized to construct the prototype system. The experimental evaluation includes performance testing on a test rig and on-field trials to validate the functionality, reliability, and durability of the outboard braking system. Results demonstrate the effectiveness of the proposed design in enhancing braking performance and overall vehicle dynamics, thus contributing to the advancement of ATV technology.*

***Key Words*: All-Terrain Vehicle, Outboard Braking, CAD modelling, Fabrication, Braking performance.**

## 1.INTRODUCTION

The Indian automotive industry is one of the largest in the world. ATV (All-Terrain Vehicle) is one of the fastest growing segments in the automobile industry. ATVs can handle a variety of terrains and are used in diverse activities such as agriculture, off-road racing or leisure. The use of ATVs for racing is becoming increasingly popular.

One key concern with the ever increasing speeds of these vehicles is safety. This is not only a concern for the riders but also for track side personnel and spectators. With the average mass of an ATV being in the region of 250 kg and capable of reaching speeds in excess of 100 kmph, it becomes clear that stopping these vehicles safely and quickly is no simple task. A system capable of doing so reliably under harsh and varied conditions is required.

The primary form of braking used in ATVs is currently the Outboard braking system. This system is efficient when used as an in-board system in dry conditions. However, its effectiveness is reduced during off-road activities such as racing, where the likelihood of encountering water and mud is high. This can cause the disc to become wet and covered in debris, reducing the braking effectiveness significantly. A solution to this problem is to use an outboard system, which can be sealed and isolated from the atmosphere, enabling it to work in a clean and dry environment.

This is a proven system in the motorcycle industry and could be an effective method of braking for ATVs. However, as of now there is no specific literature or documented information on the design and analysis of an outboard brake system for an ATV. This paper aims to provide information to future designers on the ways to do this effectively.

## 2.PROBLEM STATEMENT

The following are issues that arise when an ATV installs an inboard braking system.

**1. Disc Performance Affected by Oil leaking:** The inboard braking system has difficulties as a result of gearbox oil leaking, which makes the disc greasy. This problem not only impairs braking effectiveness but also prompts questions about dependability and safety.

**2. Subsystem Mounting Issues:** The design and integration of the inboard braking system are significantly hampered by subsystem mounting issues, such as engine mounting. Complex engineering challenges are involved in ensuring appropriate alignment and stability while accommodating multiple components within the restricted available space.

**3. Excessive Cost of Brake Hub:** The inboard braking system faces financial difficulties because of the brake hub's exorbitant cost. Exorbitant production expenses.

These issues collectively impede the efficiency, reliability, and cost-effectiveness of the inboard braking system, demanding innovative solutions and careful consideration in design and implementation processes.

## 3. OUTBOARD BRAKING

The mechanics of outboard brakes are simpler. Because the caliper and disc are easily accessible, repairs and maintenance may be completed more quickly and easily. This results in reduced maintenance expenses and reduced repair downtime. The benefits of outboard braking are as follows:

1. Due to their less complicated design, outboard braking systems are also less expensive to construct than inboard systems.

2. The packaging of outboard brakes within the vehicle's chassis is more flexible. They may be adjusted for best performance without affecting other vital parts because they are separate from the axle and differential assemblies. This is particularly beneficial for cars with complex drive-trains or suspension system.

3. The inherent cooling efficiency of outboard brakes is a significant benefit. The brake disc's open location permits direct Brake fade is avoided by this airflow's effective removal of heat produced by friction during braking. An important problem where too much heat diminishes the efficiency of the braking system is brake fade.

4. With outboard brakes, inspecting the brake discs and pads visually is quick and simple. This makes it possible to identify wear and tear early on, which facilitates prompt maintenance and averts possible breakdowns.

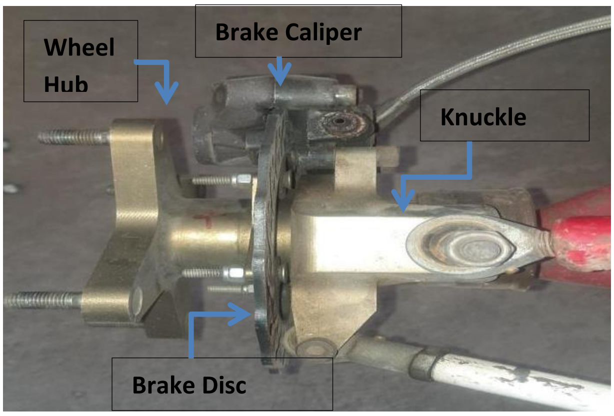


**Fig -1**: Outboard Braking System

## 4. SCOPE AND OBJECTIVE

The scope of an outboard braking system for an ATV includes enhanced braking performance[3], improved heat dissipation, increased durability, and potentially better weight distribution for improved handling. Additionally, such a system could offer easier maintenance access and potentially reduce the risk of brake fade during prolonged or intense use. However, implementation would need to consider factors such as cost, complexity, and compatibility with existing ATV designs and regulations.

The outboard braking system for an ATV has several objectives, with one of the primary aims being to increase control and stability of the vehicle

The outboard braking system, which places the brakes outside of the wheel hub, reduce unsprung weight and improve handling and control.

In all-terrain conditions, active braking and all-wheel locking may be required at an instant time. The outboard braking system can provide more even braking and better distribution of braking force, allowing for quicker and more precise stops.

The outboard braking system can enhance safety for the rider and others by improving control and braking performance, riders can avoid accidents and collisions, reducing the risk of injury or damage to the vehicle.

## 5. CONSTRUCTION

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

1. Brake Calipers:
In Outboard Braking System, the brake calipers are mounted on each wheel outside the ATV chassis. The caliper contain the brake pads and are responsible for squeezing the against the rotor to slow or stop the vehicle.

2. Brake Master cylinder:
The Brake master cylinder is responsible for generating the hydraulic pressure, necessary to activate the brake system. It is mounted on the ATV chassis using the brake master cylinder mounts.

3. Brake lines:
Brake lines connect the brake caliper to the brake master cylinder, transferring the pressure necessary to activate the brake system through the brake fluid.

4. Brake Rotors:
The Brake disc is designed according to its mounting position on wheel hub. Also to maximize the heat flow through the pad actuating area and to remove any debris stuck between brake disc and pad , Proper slotting are made on disc. Even the padding area is increased to improve efficiency of braking.

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

6. Brake Fluid Reservoir:
The brake fluid reservoirs stores the brake fluid used to generate the hydraulic pressure necessary to activate the brake system.

## 7. WORKING

The working of an outboard braking system is similar to that of a conventional braking system, with the primary difference being the brake components. Here are the general steps involved in the working of an outboard 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 on each wheel hub outside the chassis.
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 outboard 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 outboard 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 = 285 kg

Deceleration = 0.8g =0.8 X 9.8 = 7.84

Height of centre of gravity of vehicle= 22inch =0.5588 m

Wheel base = 58 inch = 1.4732 m

Weight ratio = x = 0.4 (40 : 60)

Tyre Radius = 11.5 inch = 0.2921 m

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

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

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

$R_i$ = inner radii of disc

$R_o$= outer radii of disc

$R_{efficiency}$ = 0.0715

Pedal Ratio = 7 : 1

**Dynamic Load Transfer (DLT)**

$$DLT = \frac{\text{Mass X Deceleration X HC.G}}{\text{Wheel Base}}$$

$$= \frac{285 \text{ X } 7.848 \text{ X } 0.5588}{1.4732}$$

= 848.40N

**Load on Front Axle :**

= (weight of vehicle X x) + DLT

= (mg X x ) + DLT

= (285 X 9.81 X 0.4) + 848.40

= 1966.74 N

**Load on Rear Axle :**

= (weight of vehicle X (1-x)) - DLT

= (285 X 9.81 X 0.6 ) - 848.40

= 829.11 N

**Wheel Torque on each wheel**

1. **Front :**

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

$= 0.7 \text{ x } 1966.74 \text{ x } 0.2921 \text{ x } \frac{1}{2}$

= 201.06 Nm

2. **Rear :**

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

$= 0.7 \text{ x } 829.11 \text{ x } 0.2921 \text{ x } \frac{1}{2}$

= 84.764 Nm

**Calculation for pressure generated by Master Cylinder**

1. **Pressure in lines** $= \frac{\text{Pedal Force}}{\text{Bore Area (Master Cylinder)}}$

$$= \frac{\text{Pedal Force}}{\pi/4 * (Dmc)^2}$$

$$= \frac{300 \times 7}{\pi/4 \times (0.01905)^2}$$

$$= 7367824.56 N/m^2$$

**2. Clamping Force**

$$= \text{Pressure x } \frac{\pi}{4} \text{ x } (D_{caliper})^2 \text{ x No.Of Piston}$$

$$= 7367827.56 \text{ x } \frac{\pi}{4} \text{ x } (0.030)^2 \text{ x } 2$$

$$= 10416.02 N$$

**Calculation for braking torque**

$$= \text{Clamping Force x } \mu_{pad \;\&\; rotor} \text{ x } R_{efficiency}$$

$$= 10416.02 \text{ x } 0.35 \text{ x } 0.0715$$

$$= 260.66 \text{ Nm}$$

**Braking torque > Wheel torque**

**260.66 Nm > 201.06 Nm**

Therefore vehicle will come at rest.

**Thermal Calculation :**

**Kinetic Energy for Vehicle:**

$$= \frac{1}{2} \text{ x m x } v^2$$

m= 285 , v = 60 km/hr, x =0.6(Static Factor)

$$K.E. = \frac{1}{2} \text{ x m x } v^2 \times x$$

$$= \frac{1}{2} \text{ x } 285 \text{ x } 16.67^2 \text{ x } 0.6$$

$$= 23760 \text{ J}$$

**Stopping Time for Vehicle**

$$v = u + at$$

$$0 = 16.67 + (-0.8 \times 9.81) \times t$$

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

$$t = 2.125$$

**Braking Power:**

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

$$= \frac{23760}{2.125}$$

$$= 11181.17 \text{ W}$$

**Heat Flux :**

$$Q = \frac{Pb}{A}$$ A= Area swept by pads

$$Q = \frac{11181.17}{0.016244}$$

$$= 688326.15 \text{ W / } m^2$$

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

## 9. ANALYSIS

**Master Cylinder Mount Analysis**

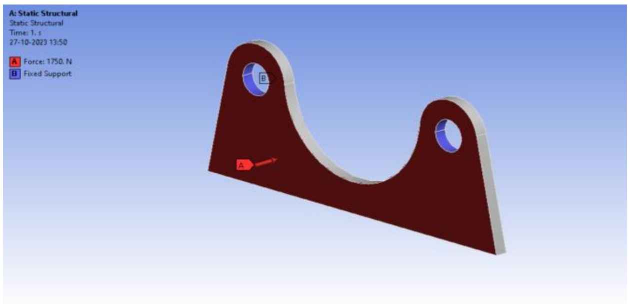

**Fig -2**: Boundary Condition

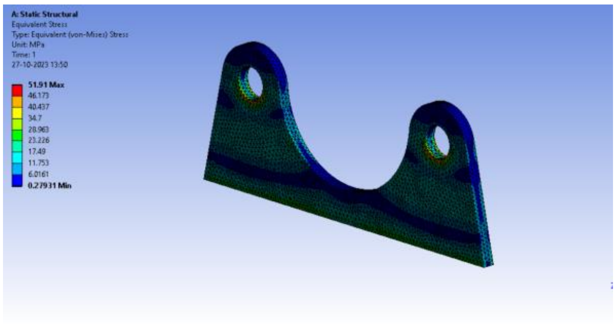

**Fig -3**: Equivalent Stress

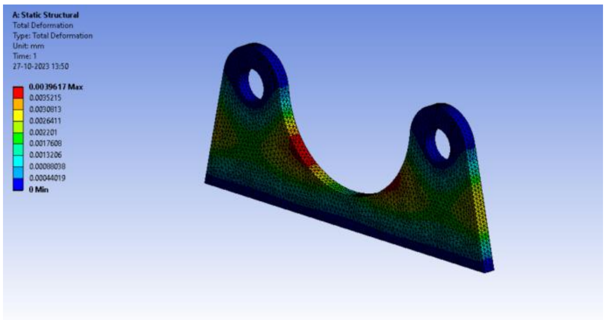

**Fig -4**: Total Deformation

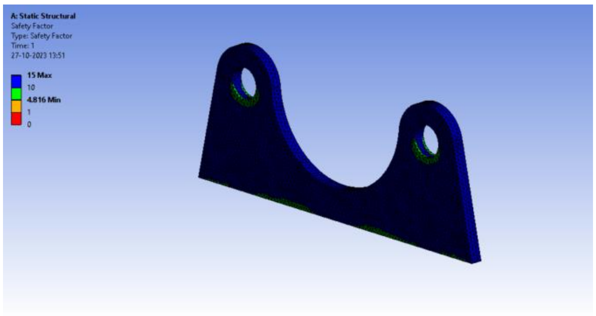

**Fig -5**: Factor of safety

### Brake Rotor Analysis

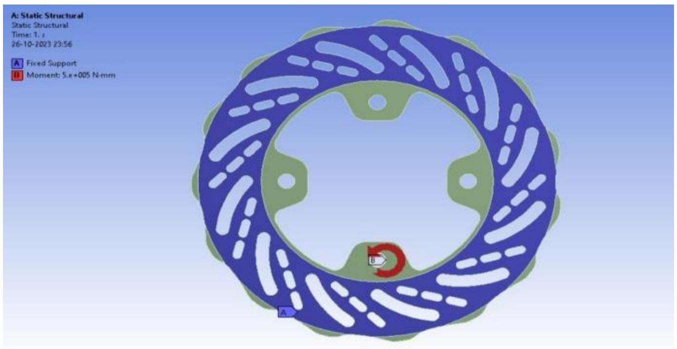

**Fig -6**: Static Structural

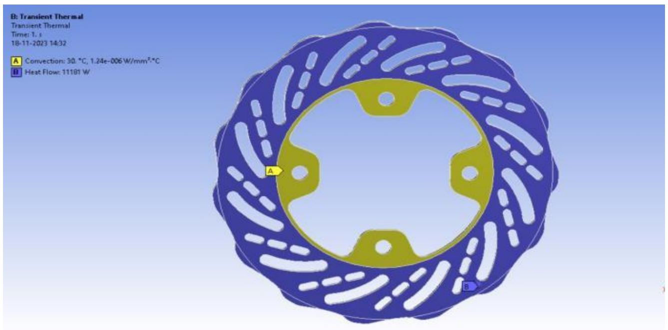

**Fig -7**:Transient Thermal

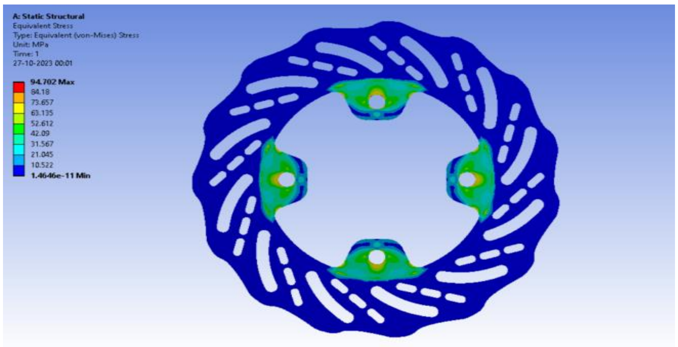

**Fig -8**: Equivalent Stress

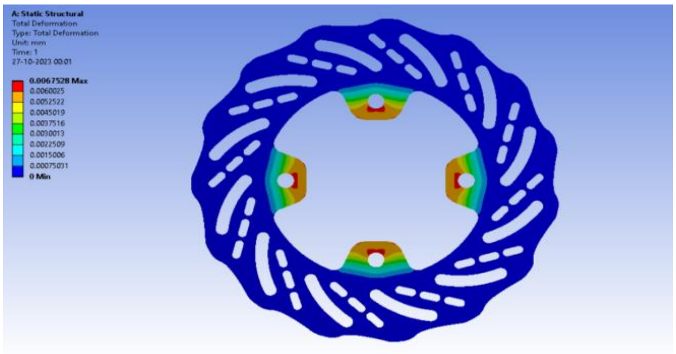

**Fig -9**: Total Deformation

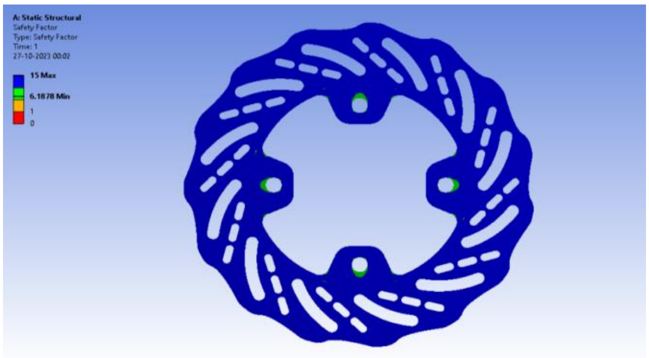

**Fig -10**:Factor of safety

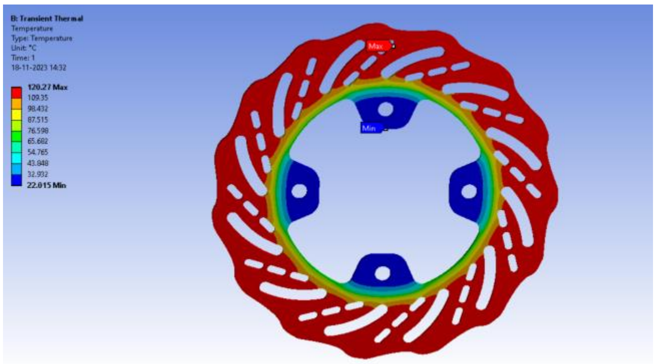

**Fig -11**: Temperature

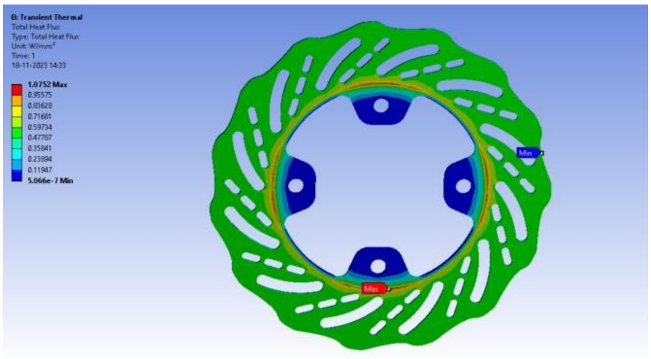

**Fig -12**: Total Heat Flux

## Pedal Analysis

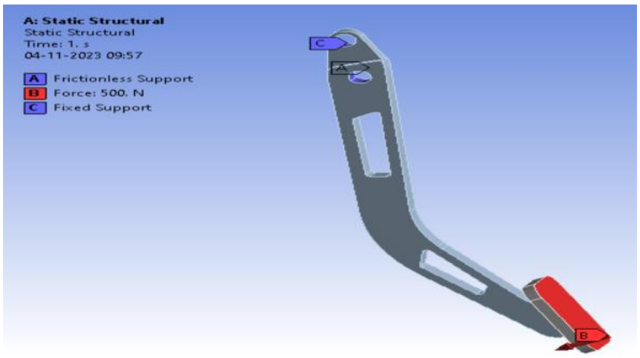


**Fig -13**: Boundary Conditions

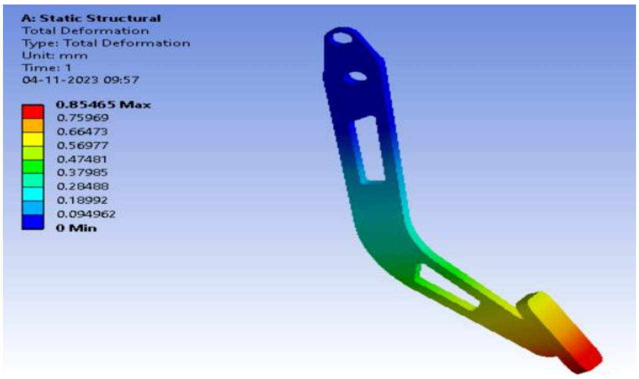


**Fig -14**: Total Deformation

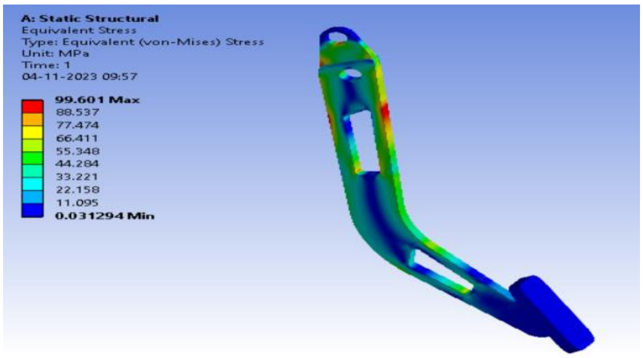


**Fig -15**: Equivalent stress

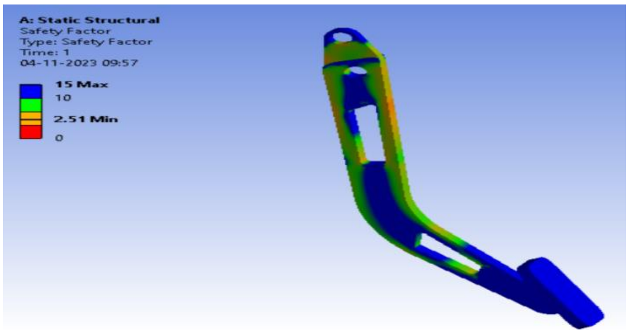


**Fig -16**: Factor of safety

## Table of Material

**Table - 1 :** Material Table

| Components | Specification |
|---|---|
| Dual Master Cylinder | 19.05 mm Bore Diameter |
| Brake Disc Dimension and Material | 176 mm x 3.5 mm Stainless Steel 420 |
| Brake Pedal Ratio | 7:1 |
| Brake Fluid | DOT 4 |
| Caliper Piston Area | 1017.87 mm2 |
| Fluid Lines | 4 mm Teflon ID (Steel Braided) |

## 10. CONCLUSIONS

To sum up, all terrain vehicles (ATVs) benefit greatly from the outboard braking system, which improves performance, safety, and maneuverability. We have demonstrated via our study how well it distributes braking forces, lowers the possibility of rollovers, and improves control on difficult terrain. Its modular design also makes maintenance and modification simple, which appeals to ATV fans even more. The outboard braking system surely offers a potential way to improve ATV capabilities in a variety of off-road situations, even though more research may be required to examine its long-term durability and cost-effectiveness.

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