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# Finite Element Analysis of Rotor Used in Vehicles Braking System using Ansys

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**Abstract -** *During regular braking, disc (rotor) brakes are subjected to substantial heat loads, and during severe braking, they are subjected to significant thermal stresses. The project's goal is to create and model a discs. SolidWorks is a modelling application. Three materials will be used to study the structural and thermal characteristics of disc brakes: stainless steel, cast iron, and carbon carbon composite. To guarantee the disc brake's strength, a structural study is done, as well as a thermal analysis to determine its thermal characteristics. Deformation, stresses, temperature, and other properties of the three materials may be compared to determine which is the best. Solidworks is a popular 3D modelling programme used in the design process. ANSYS is a finite element analysis (FEA) software programme that may be used for a variety of tasks. Finite Element Analysis (FEA) is a technique for breaking down a complicated system into smaller (user-defined) components called elements. The primary goal of this research is to look into the thermal analysis of cast iron and stainless-steel materials. The low thermal gradient material is chosen in a comparison of the two materials for the Thermal values and material characteristics acquired from the Thermal study. The best design, low thermal gradient material cast iron is utilised for the Disc Brakes for a better outcome.*

***Key Words***: ANSYS, Disc brake, Braking System, FEM, Thermal analysis.

## 1.INTRODUCTION

It is referred to as a brake disc rotor when it is the rotating component of a disc braking system that is typically placed on the front axle. A rubbing surface, a cap, and a neck region are all included. The rubber's surface is responsible for the tangential friction force that produces the braking force in the tyre-ground flat, which is responsible for the vehicle's retardation between the rotor and the conventional pad. The upper part of the wheel is connected to the hub via a nut and bolt assembly. In the neck, which is connected to the cap, rubbing is experienced. For the most part, passenger car manufacturers choose brake discs as the primary front-wheel foundation brake since they are the most common. Upon depressing the brake pedal, a drum brake is activated, which is an internal expanding brake that makes use of a mechanism to expand two shoes against a rotative drum. When hydraulic pressure is supplied to the calliper piston, the disc is squeezed between two friction surfaces as a result of the force given to it by the hydraulic pressure. For this reason, disc brakes are less powerful than drum brakes since they do not benefit from friction between the lining and the rotor to enhance braking strength. Because the majority of the disc brake is exposed to the environment, the heat dissipation rate is the greatest. This phenomenon is critical in preventing brake fade from occurring. It also facilitates self-cleaning by eliminating dust and water from the surface and decreasing friction. When a machine component moves, a brake is a device that creates artificial resistance to the movement of the component in order to prevent it from moving. Modern engines are equipped with disc brakes on the front wheels, while the rear wheels are equipped with a developing path. As a matter of fact, braking is an exercise in electrical stability, and braking equipment is designed to transfer the vehicle's mechanical energy into another form while simultaneously reducing its forward speed. Once distributed throughout the environment, the cinematic energies undergo dry friction conversion, which results in the production of thermal energy. Two brake pads are shown in Figure 1.

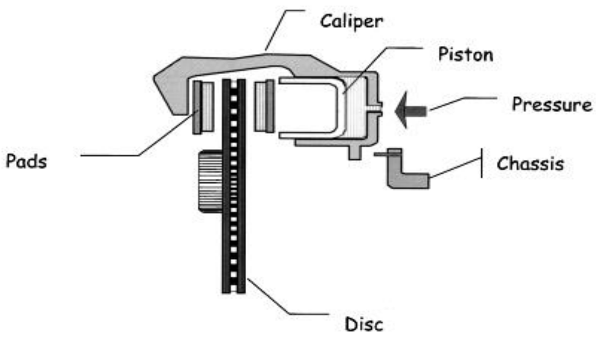


**Figure 1: Disc brake assembly [4]**

### 1.1 Disc Brake

The brake disc rotor, brake pads, and calliper are all part of a disc braking system. Because of the arrangement of these components, the moving wheel may enjoy strong braking over a short distance. The brake disc features a circular hole in the centre that is placed at the wheel hub. It is encircled by some of the holes for the wheel bolts. At the side of the wheel, the brake disc spins. The normal force generated when the brake is applied results in in-plane friction pressure at the disc-pad contact. As a result, a braking torque is generated at the wheel's centre of rotation. The brake torque response is evident in the braking force between the tyre and the ground, slowing the vehicle.

Disc brakes function by applying pressure to two brake pads on opposite sides of a rotating rotor attached to the wheel hub. A calliper lies above the spinning disc and holds the disc brake pad. All disc brake friction additives are exposed to the air, which helps to cool the brake components and improve braking efficiency at some point after repeated hard stops from higher speeds. To provide the same braking energy as a comparable drum brake, a disc brake requires more hydraulic strain and pressure. Disc brakes are often used to reduce speed by applying friction by pressing a brake pad against a brake disc using callipers. The brake disc is usually composed of cast iron, although it may also be built of composites in certain instances. Warmth flux, which is typical of the time and space variables, corresponds to the contacts conditions between the disc and pads. Convection, radiation, and the recognised temperature are the thermal boundary conditions beyond the contact region. The sliding speed and frictional warmness flux are time dependent, and the stress rising model has an intensity component. Solid disc brakes are often utilised on brakes that are smaller in width, lighter, and less expensive than vented disc brakes, which are typically used on heavy brakes. Each solid disc has a different establishing profile, such as drilled, grooves, and aggregate. Stable discs with openings of various profiles were chosen for this task, including daily disc brakes, drilled disc brakes, grooves disc brakes, and combination drilled and grooved disc brakes.

### 1.2 Braking system

A brake is a device that provides simulated frictional resistance to a spinning machine component in order to stop the machine from moving. The brakes absorb both the kinetic energy of the moving member and the ability of electricity given up by items lowered by hoists, elevators, and other mechanisms in the process of acting on this feature. The energy collected by the brakes is released as heat within the vehicle. To prevent the vehicle from overheating, this heat is dispersed into the surrounding environment, therefore the braking system must meet the following requirements:

- In an emergency, the brakes should be strong enough to bring the vehicle to a complete stop within a short distance.
- At some point while braking, the driver must have adequate control over the car, and the vehicle must no longer slide.
- The brakes must have precise anti-fade characteristics, which means that their effectiveness should not diminish with time.

Anti-wear properties should be included in the brakes.

Based on mode of operation brakes are categorized as follows:

- Hydraulic brakes.
- Electric brakes.
- Mechanical brakes.

The mechanical brakes may be subdivided into the following companies in conjunction with the action pressure:

i. Radial brakes:

The pressures on the brake drum are radial with these brakes. The external brakes and internal brakes may be split into the radial brake.

ii. Axial brakes:

The best strength in the axial route is the braking force on the brake drum. Disc brakes, cone brakes.

### 1.3 Heat transfer in Disc brake:

When a system has a temperature different from its atmospheres, Nature tries to preserve thermal balance. To accomplish this the thermal energy always flows from the higher temperature to the lower temperature system, as is explained by the Second thermodynamics Act.

Through one or more three main heat transport secures, conduction, convection & radiation, this transmission of thermal energy happens.

### 1.4 Conduction:

Is the transfer of heat via direct molecular transmission, that is, the physical interaction of particles within a medium or between mediums, which occurs in gases, liquids, and solids, while in conduction, none of the material mediums move.

The Fourier's law of heat conduction is the governing equation for conduction, and it states that heat flow per unit area is proportional to the normal temperature gradient, with the proportionality constant being thermal conductivity:

$$q = -kA\frac{\partial T}{\partial x}$$

### 1.5 Convection:

When a heated fluid flows away from the heat source, convection is used to transfer heat via mass motion of the fluid. It combines conduction with the effect of a fluid current that moves hot particles to cooler regions and updates them with cooler ones. The float may be caused by buoyant forces (natural convection) or by currents created intentionally (compelled convection).

The equation that describes convection is of the form and originates from Newton's cooling regulation:

$$q = -hA(T_\infty - T_s)$$

Where h is the coefficient [W/ (m2K)] of convective heat transport; T DER is the cold fluid temperature; and TS is the body surface temperature.

## 2. FINITE ELEMENT ANALYSIS

The finite element technique is a powerful tool for addressing a broad variety of engineering problems numerically. "The technique is flexible enough to handle any complicated form or geometry for any material with a range of constraints and loading circumstances. The breadth of the finite element method is ideally adapted to the analytical requirements of today's complex engineering systems and designs, which do not usually offer closed form solutions to control balance equations." It is an efficient design tool for carrying out parametric design studies and evaluating them in the optimization of the design by utilising different design scenarios, such as shapes, materials, loads, and so on. In the aerospace sector, the method was developed as a tool for stress analysis in complex aircraft structures. It's a kind of matrix analysis utilised in aircraft design. It is based on the concept of. The method has gained popularity among both academics and practitioners. The fundamental idea behind the finite element method is to split a body or structure into tiny, finite components known as "finite elements." As a result, this is regarded as the combination of these components, which are linked by a limited number of nodes or nodal points. "The finite element method is a piece-by-piece approximation technique in which a structure or body is divided into small, finite elements called endite items, and the original body or structure is then a compound of these elements connected by an infinite number of joints known as nodal points or node." Because the actual changes in field variables like displacement, stresses, temperature, pressure, and speed in the continuum are unknown, a simple function may be used to approximate the variation of the field variable within the finite element.

## 3. DESIGN AND ANALYSIS OF DISC BRAKE

### 3.1 Modeling of Disc brake

In this research, two different metals were utilized to create disc brakes: cast iron and stainless steel. The disc brake was designed using SolidWorks, and the thermal analysis was done with ANSYS. The practical application of finite element modelling is known as FEA, and it is best understood while addressing real-world problems. The automobile industry has long relied on FEA. In the technique of product expansion, it is a highly common tool for design engineers. Design engineers may use FEA to evaluate their designs while they're still in the process of creating an adjustable computer-aided design (Solidworks) model. This allows design engineers to move back and forth to incorporate the FEA study findings into the overall design process and enhance the model. To make FEA an effective design tool, it is necessary to grasp the fundamentals of FEA, modelling methods, inherent flaws, and their impact on the quality of the results. Engineering issue studies are also carried out using FEA as a computer technique.

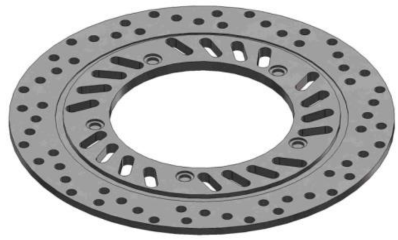

**Figure 2: Geometry of disc brake**

### 3.2 Dimensions of Disc brake

Dimensions of disc brake are explained in figure 3.

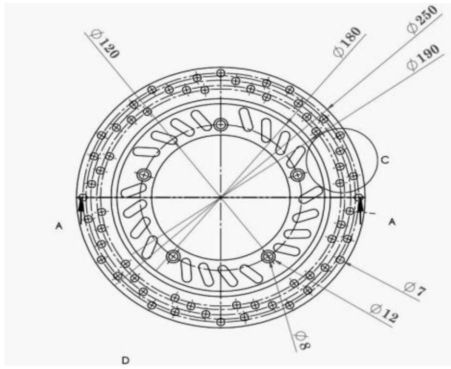


**Figure 3: Geometry dimensions of disc brake**

### 3.3 Applying boundary conditions

Figure shows the boundary conditions applied to the disc brake when the convection was applied to the top of the disc break to maximize disc breakage. The figure illustrates the circumstances of the disc brake border applied.

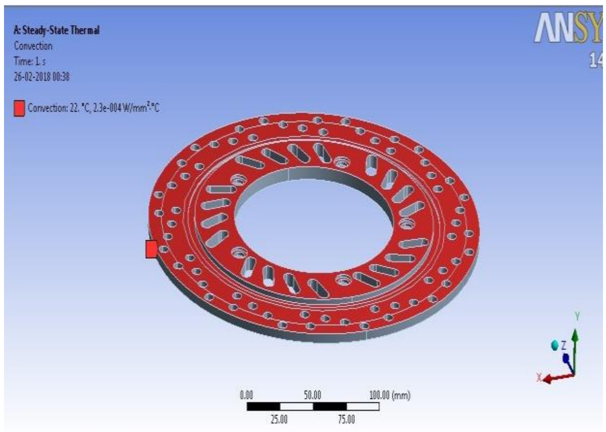


**Figure 4: Boundary conditions**

## 4. MATERIAL PROPERTIES

Stainless steel and Cast iron considered as material in present study. Two types of material design of disc brake used in this study Properties of material are described below.

**Table. 1: Material Properties for Stainless Steel and Cast Iron**

| **Material Properties** | **Stainless Steel (Model I)** | **Cast Iron (Model II)** |
|---|---|---|
| Thermal conductivity(w/m k) | 36 | 50 |
| Density , ρ (kg/m3) | 7100 | 6600 |
| Specific heat , c (J/Kg c ) | 320 | 380 |
| Thermal expansion , α (10-6 / k ) | 0.12 | 0.16 |
| Elastic modulus, E (GPa) | 210 | 110 |
| Coefficient of friction, μ | 0.5 | 0.5 |
| Film co-efficient h(w/km2 ) | 240 | 280 |
| **Operation conditions** | | |
| Angular velocity,( rad /s) | 50 | 50 |
| Braking Time Sec | 5 | 6 |
| Hydraulic pressure, P (M pa) | 1 | 1 |

To determine, the temperature analysis and different thermal quantities exchanged over time are used. Changes in temperature distribution over time are significant in many applications and are included in warmth studies. The effects of thermal stresses that may lead to failure are also considered. In these cases, the brief thermal evaluation yielded a temperature for thermal stress assessment. Different format discs have a heat flow of 3.9417E-002 W/mm2. Figure 5 shows the results of a thermal study of disc brakes.

## 5. Calculation for Input Parameters:

Braking performance of cars was a key problem with regard to automotive accident prevention. For moving vehicles at a speed of 27.77 m/s, the heat fluid rotor model is computed and determined as follows:

"**Procedure:** Data:

1) Mass of the vehicle = 300 kg

2) Initial velocity (u) = 22.22 m/s (80 kmph)

3) Vehicle speed at the end of the braking application (v) = 0 m/s

4) Brake rotor diameter = 0.262 m

$$\frac{\textit{static front axle load}}{\textit{Total motor cycle load}} = (\gamma) = 0.3$$

6) Percentage of kinetic energy that disc absorbs (90%) k=0.9

7) Acceleration due to gravity g =9.81m/s2

8) Coefficient of friction for dry pavement μ=0.45.

**(a) Energy generated during braking**:

$$K.E. = \gamma k \frac{m(u-v)^2}{2}$$

**(b) To calculate deceleration time:**

v = u + at

Deceleration time = Braking time = 5s

**(c) Braking Power:** Braking power is gained by distinguishing energy from time during continuous braking

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

**(d) Calculate the Heat Flux (Q):** Heat flux is the heat transfer quantity per unit area per unit time."

## 6. RESULTS AND DISCUSSION

As shown in figure 6 thermal analysis was conducted on the cast iron brake disc and maximum temperature observed is 56.932 °C and minimum temperature observed is 33.674 °C.

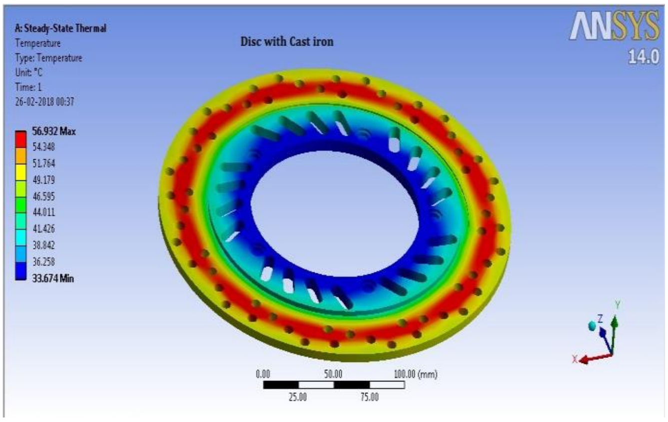


**Figure 5: Temperature distribution of cast iron disc brake (Model-I)**

As shown in figure 6 thermal analysis was conducted on the stainless-steel brake disc and maximum temperature observed is 69.819 °C and minimum temperature observed is 25.642 °C.

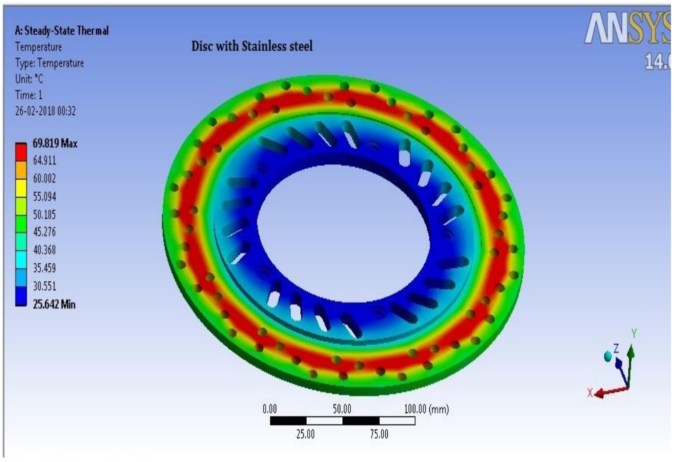


**Figure 6: Temperature distribution of Stainless-steel disc brake (Model-II)**

From the figures 6, given above, we can summarize the results in the following manner: -

**Table 2: Maximum and minimum Temperature Distribution**

| Materials | Temperature Distribution (°C) | |
|---|---|---|
| | Min | Max |
| Stainless Steel | 33.67 | 56.93 |
| Cast Iron | 25.64 | 69.81 |

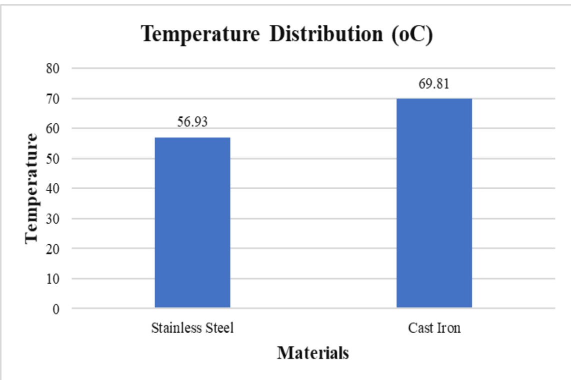


**Figure 7: Temperature Distribution in disc brake**

As shown in figure 8 thermal analysis was conducted on the cast iron brake disc and maximum Heat flux observed is 8.2427 W/mm² and minimum Heat flux observed is 1.6624e-5 W/mm².

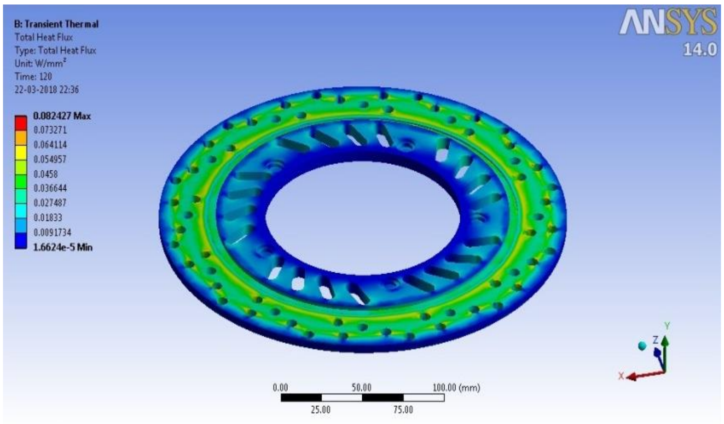


**Figure 8: Heat flux of cast iron disc brake (Model-I)**

As shown in figure 9 thermal analysis was conducted on the stainless-steel brake disc and maximum Heat flux observed is 7.6624 W/mm² and minimum Heat flux observed is 1.2645e-6 W/mm².

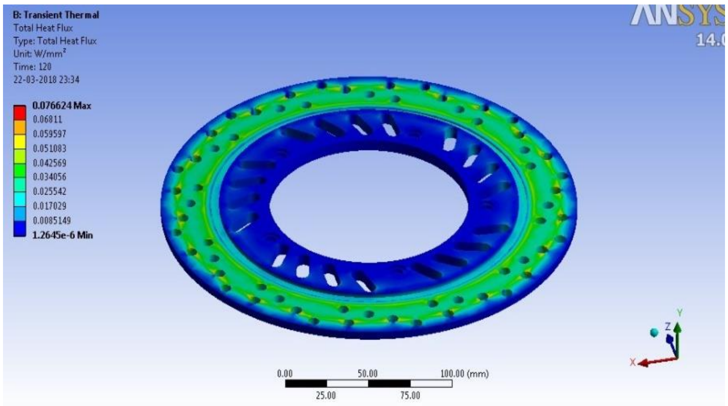


**Figure 9: Heat flux of Stainless-steel disc brake (Model-II)**

Table shows the heat flux variations of cast iron and stainless-steel disc brake.

Table no. 3: Maximum and minimum Total Heat Flux

| Materials | Total Heat Flux (W/mm²) | |
|---|---|---|
| | Min | Max |
| Stainless Steel | 1.2645e-6 | 7.6624 |
| Cast Iron | 1.6624e-5 | 8.2427 |

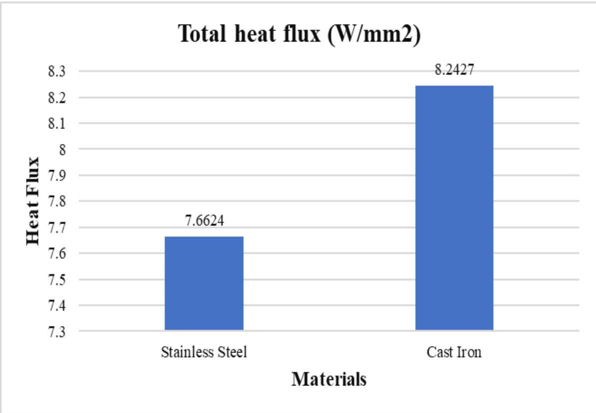


**Figure 10: Total heat flux in disc brake model**

Graph 11 shows the Maximum heat loss of cast iron disc brake with respect to time.

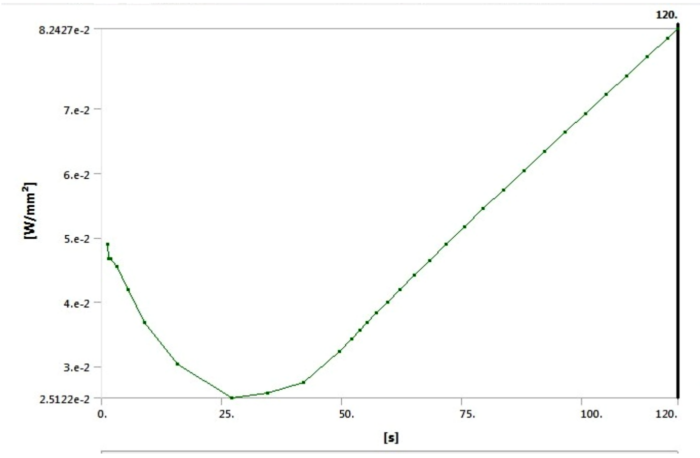


**Figure 11: Maximum heat loss Vs Time of Cast iron disc brake**

Graph 12 shows the Maximum heat loss of Stainless-steel disc brake with respect to time.

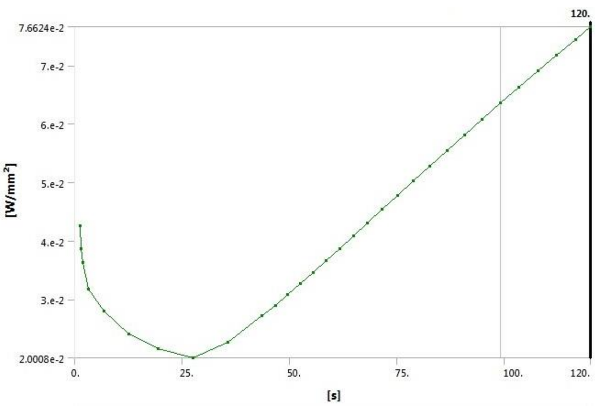


**Figure 12: Maximum heat loss Vs Time of Stainless-steel disc brake**

## 7. CONCLUSIONS

The findings of the study may be utilised to improve the design of disc brake systems and their braking efficacy. We found that the maximum temperature rise of cast iron discs is much lower than that of stainless steel, and that, based on thermal study, cast iron is the most desirable material for disc brake manufacturing as a result of the aforementioned results. Because cast iron disc brakes corrode when exposed to moisture and cannot be used on two-wheelers, we opt for stainless steel.

The findings of this study may be utilised to create a useful design tool and improve disc brake system braking performance. The study produced findings that were lower than those that were permitted. As a consequence, if the strength and stiffness criteria are fulfilled, the brake Disc analysis is safe. The following findings are drawn from the aforementioned research work:

- Cast iron profiles offer a higher heat dissipation rate, but they are prone to corroding when exposed to water or moisture. As a result, it is unsuitable for manufacturing.
- The maximum temperature on a cast iron disc brake is 56.93 degrees Celsius, with a temperature decrease of 33.67 degrees Celsius.
- The maximum temperature on a stainless steel disc brake is 69.81 degrees Celsius, with a temperature decrease of 25.64 degrees Celsius.
- The maximum temperature decrease on a stainless steel disc was discovered, indicating that this material is appropriate for design.

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