Structural and Thermal Analysis of Disc Brake in Automobiles

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Abstract- The aim of this paper was to investigate the temperature fields and also structural fields of the solid disc brake during short and emergency braking with four different materials. The distribution of the temperature depends on the various factors such as friction, surface roughness and speed. The effect of the angular velocity and the contact pressure induces the temperature rise of disc brake. The finite element simulation for two-dimensional model was preferred due to the heat flux ratio constantly distributed in circumferential direction. We will take down the value of temperature, friction contact power, nodal displacement and deformation for different pressure condition using analysis software with four materials namely cast iron, cast steel, aluminum and carbon fiber reinforced plastic. Presently the Disc brakes are made up of cast iron and cast steel. With the value at the hand we can determine the best suitable material for the brake drum with higher life span. The detailed drawings of all parts are to be furnished.

Keywords – Disk Brake, Structural analysis, Thermal analysis, Ansys

I. INTRODUCTION

The disc brake is a wheel brake which slows rotation of the wheel by the friction caused by pushing brake pads against a brake disc with a set of calipers. The brake disc (or rotor in American English) is usually made of cast iron, but may in some cases be made of composites such as reinforced carbon–carbon or ceramic matrix composites. This is connected to the wheel and/or the axle. To stop the wheel, friction material in the form of brake pads, mounted on a device called a brake caliper, is forced mechanically, hydraulically, pneumatically or electromagnetically against both sides of the disc. Friction causes the disc and attached wheel to slow or stop. Brakes convert motion to heat, and if the brakes get too hot, they become less effective, a phenomenon known as brake fade.

Disc-style brakes development and use began in England in the 1890s. The first caliper-type automobile disc brake was patented by Frederick William Lanchester in his Birmingham, UK factory in 1902 and used successfully on Lanchester cars. Compared to drum brakes, disc brakes offer better stopping performance, because the disc is more readily cooled. As a consequence discs are less prone to the "brake fade"; and disc brakes recover more quickly from immersion (wet brakes are less effective). Most drum brake designs have at least one leading shoe, which gives a servo-effect. By contrast, a disc brake has no self-servo effect and its braking force is always proportional to the pressure placed on the brake pad by the braking system via any brake servo, braking pedal or lever, this tends to give the driver better "feel" to avoid impending lockup. Drums are also prone to "bell mouthing", and trap worn lining material within the assembly, both causes of various braking problems.

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II. PROBLEMS OCCURRED IN DISC BRAKES

Discs are usually damaged in one of four ways: scarring, cracking, warping or excessive rusting. Service shops will sometimes respond to any disc problem by changing out the discs entirely. This is done mainly where the cost of a new disc may actually be lower than the cost of workers to resurface the original disc. Mechanically this is unnecessary unless the discs have reached manufacturer's minimum recommended thickness, which would make it unsafe to use them, or vane rusting is severe (ventilated discs only). Most leading vehicle manufacturers recommend brake disc skimming (US: turning) as a solution for lateral run-out, vibration issues and brake noises. The machining process is performed in a brake lathe, which removes a very thin layer off the disc surface to clean off minor damage and restore uniform thickness. Machining the disc as necessary will maximize the mileage out of the current discs on the vehicle.

Braking systems rely on friction to bring the vehicle to a halt – hydraulic pressure pushes brake pads against a cast iron disc or brake shoes against the inside of a cast iron drum. When a vehicle is decelerated, load is transferred to the front wheels – this means that the front brakes do most of the work in stopping the vehicle.

Scarring can occur if brake pads are not changed promptly when they reach the end of their service life and are considered worn out.

Cracking is limited mostly to drilled discs, which may develop small cracks around edges of holes drilled near the edge of the disc due to the disc's uneven rate of expansion in severe duty environments.

The discs are commonly made from cast iron and a certain amount of what is known as "surface rust" is normal.

Sometimes a loud noise or high pitched squeal occurs when the brakes are applied. Most brake squeal is produced by vibration (resonance instability) of the brake components, especially the pads and discs (known as force-coupled excitation). This type of squeal should not negatively affect brake stopping performance.

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III. ANSYS

Ansys is useful software for design analysis in mechanical engineering. That's an introduction for you who would like to learn more about Ansys. Ansys is a design analysis automation application fully integrated with ProEngineer. This software uses the Finite Element Method (FEM) to simulate the working conditions of your designs and predict their behavior. FEM requires the solution of large systems of equations. Powered by fast solvers, Ansys makes it possible for designers to quickly check the integrity of their designs and search for the optimum solution.

A product development cycle typically includes the following steps:

• Build your model in the proEngineer system.
• Prototype the design.
• Test the prototype in the field.
• Evaluate the results of the field tests.
• Modify the design based on the field test results

IV. PROPERTIES OF MATERIALS

A. Nickel Chrome Steel

Table -1 Properties of Nickel Chrome Steel

Name	**Nickel Chrome Steel**
Model type	**Linear Elastic Isotropic**
Default Failure Criterion	**Max von Mises Stress**
Yield Strength	**1.72339e+0.008 N/m^2**
Tensile Strength	**4.13613e+0.008 N/m^2**
Elastic Modulus	**2e+011 N/m^2**
Poisson's Ratio	**0.28**
Mass Density	**7800 kg/m^3**
Shear Modulus	**7.7e+010 N/m^2**

Isentropic Thermal Conductivity	**60.5 W/mC**
Specific Heat	**434 J/kgC**

B. Aluminium Alloy

Table -2 Properties of Aluminum Alloy

Name	**Aluminum Alloy**
Model type	**Linear Elastic Isotropic**
Default Failure Criterion	**Max von Mises Stress**
Yield Strength	**1.65e+0.008 N/m^2**
Tensile Strength	**3.0e+0.008 N/m^2**
Elastic Modulus	**7e+011 N/m^2**
Poisson's Ratio	**0.33**
Mass Density	**2600 kg/m^3**
Shear Modulus	**3.189e+010 N/m^2**
Isentropic Thermal Conductivity	**60.5 W/mC**
Specific Heat	**874 J/kgC**

C. Cast Iron

Table -3 Properties of Cast Iron

Name	**Malleable Cast Iron**
Model type	**Linear Elastic Isotropic**
Default Failure Criterion	**Max von Mises Stress**
Yield Strength	**2.75742e+0.008 N/m^2**
Tensile Strength	**4.13613e+0.008 N/m^2**
Elastic Modulus	**1.9e+011 N/m^2**
Poisson's Ratio	**0.27**
Mass Density	**7300 kg/m^3**
Shear Modulus	**5.6e+010 N/m^2**
Isentropic Thermal Conductivity	**52 W/mC**
Specific Heat	**447 J/kgC**

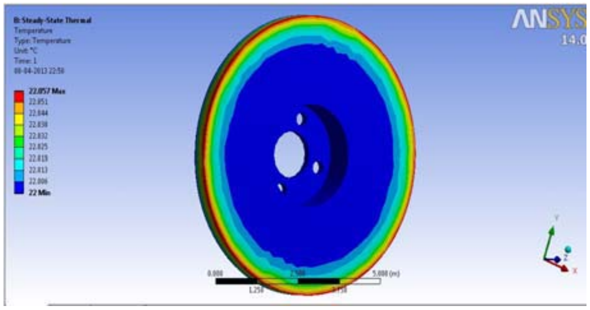
D. Carbon Reinforced polymer

Table -4 Properties of Carbon Reinforced polymer

Name	**Carbon Reinforced polymer**
Model type	**Linear Elastic Isotropic**
Default Failure Criterion	**Max von Mises Stress**
Yield Strength	**1.75742e+0.008 N/m^2**
Tensile Strength	**4127 Mpa**
Elastic Modulus	**1.9e+011 N/m^2**
Poisson's Ratio	**0.3**
Mass Density	**1800 kg/m^3**
Shear Modulus	**8.6e+010 N/m^2**
Isentropic Thermal Conductivity	**700 W/mK**
Specific Heat	**547 J/kgC**

VI. EXPERIMENTAL RESULTS WHILE ANALYSING

A. *Thermal Analysis- Nickel Chrome Steel*



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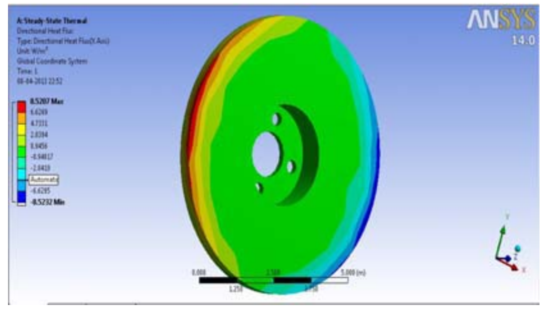

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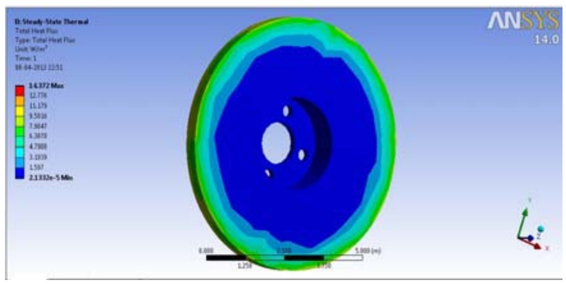
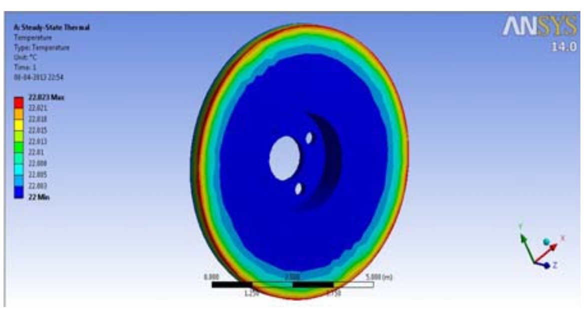


(c)

Figure 1. (a) Temprature (b) Directional heat Flux (c) Total Heat Flux

B. *Thermal Analysis- Aluminium Alloy*



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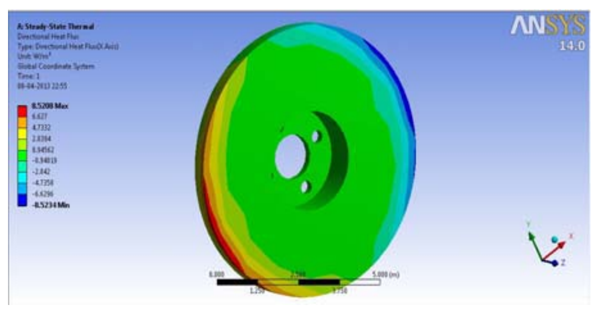

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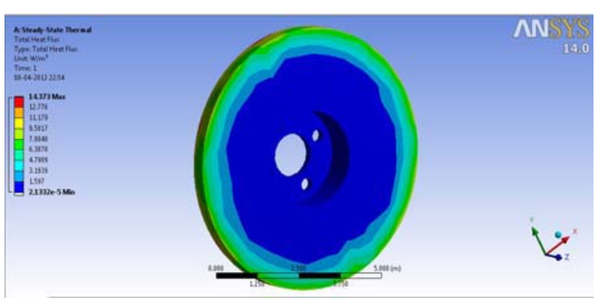

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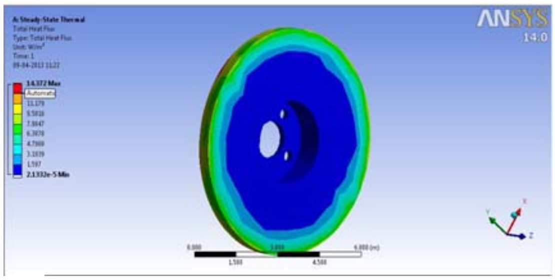
Figure 2. (a) Temprature (b) Directional heat Flux (c) Total Heat Flux

C. Thermal Analysis- Cast Iron



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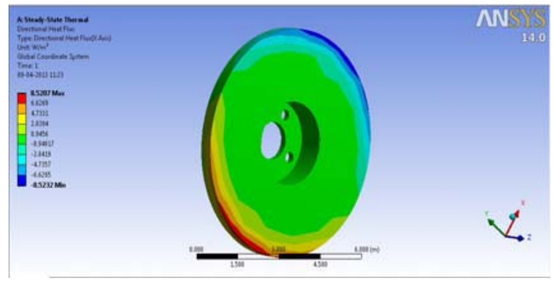

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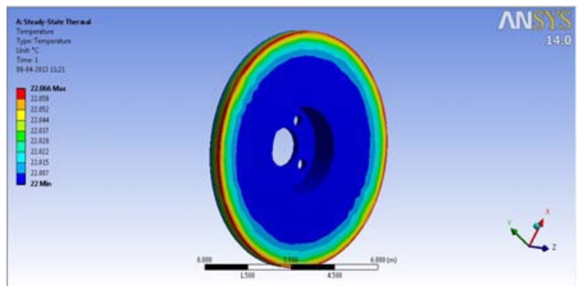
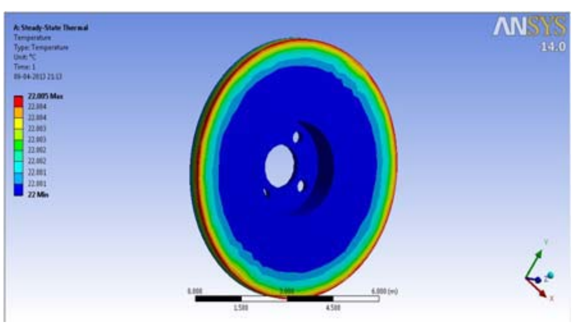


(c)

Figure 3. (a) Temprature (b) Directional heat Flux (c) Total Heat Flux

D. Thermal Analysis- Carbon Reinforced Polymer



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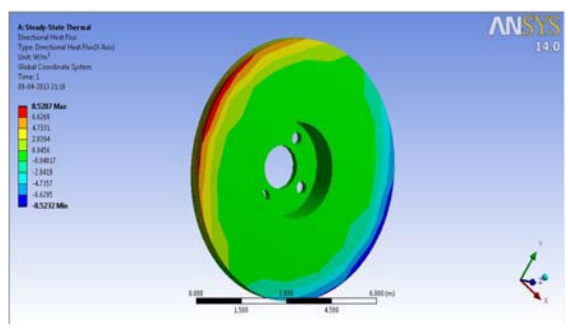

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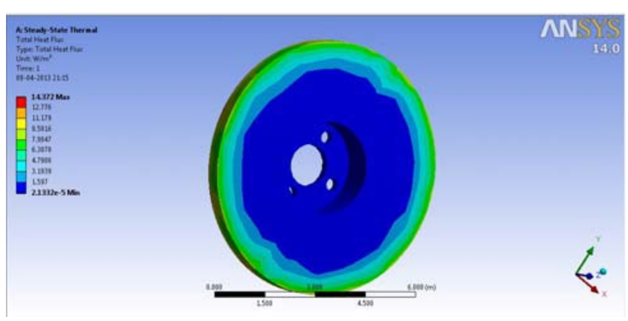

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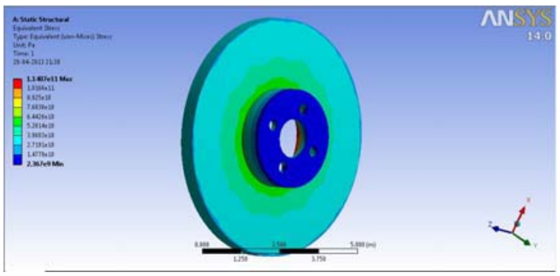
Figure 4. (a) Temprature (b) Directional heat Flux (c) Total Heat Flux

E. Structural Analysis- Nickel Chrome Steel



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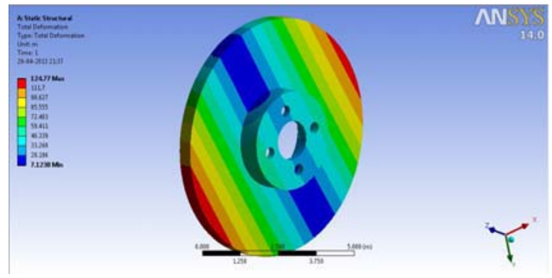

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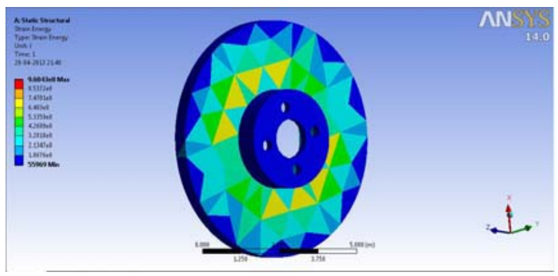
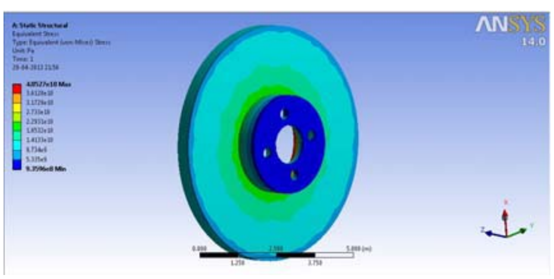


(c)

Figure 5. (a) Equivallent Stress (b) Total Deformation (c) Strain Energy

F. Structural Analysis- Aluminium Alloy



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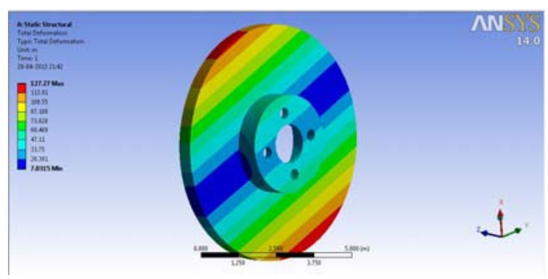

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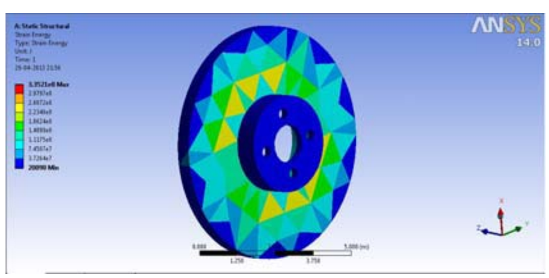
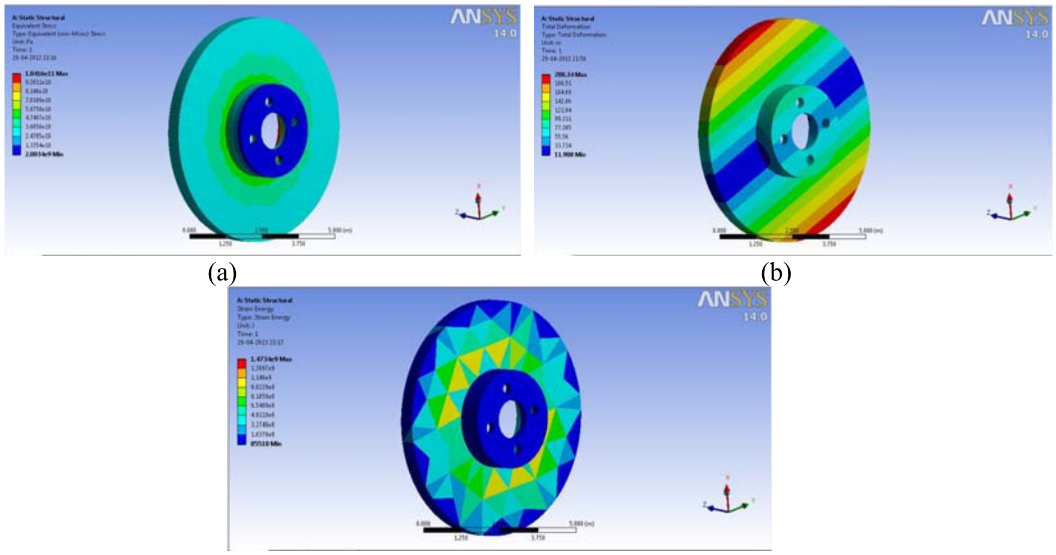


(c)

Figure 6. (a) Equivallent Stress (b) Total Deformation (c) Strain Energy

G. Structural Analysis- Cast Iron

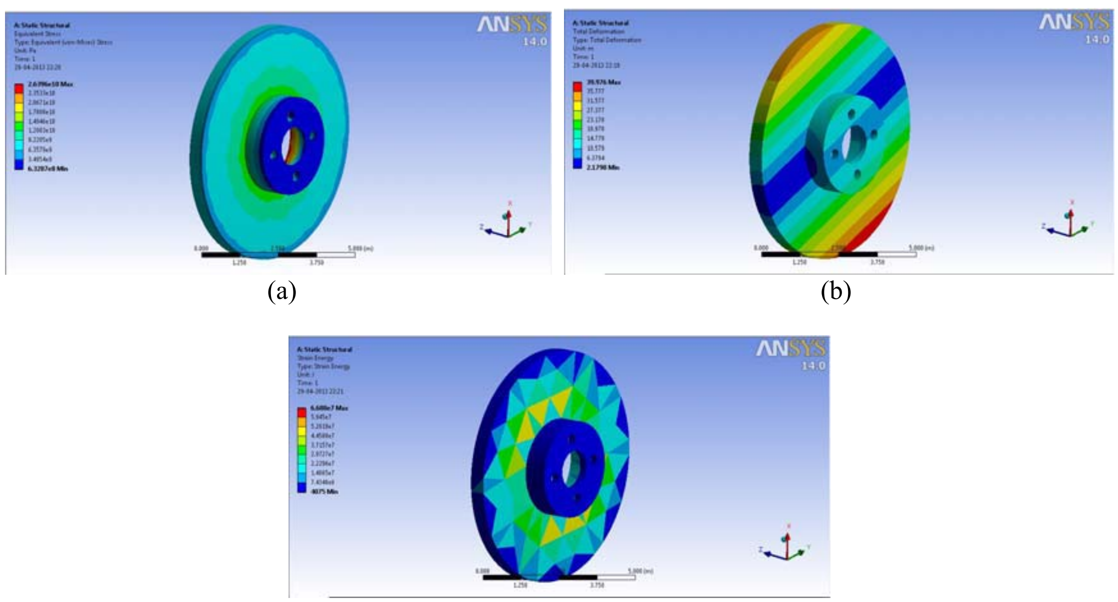


(a) (b)

(c)

Figure 6. (a) Equivallent Stress (b) Total Deformation (c) Strain Energy

H. Structural Analysis- Carbon Reinforced Polymer



(a) (b)

(c)

Figure 6. (a) Equivallent Stress (b) Total Deformation (c) Strain Energy

VI.CONCLUSION

By observing the Structural analysis and Thermal analysis results using Aluminum alloy and Carbon Reinforced Polymer the stress values are within the permissible stress value. So using Aluminum Alloy and Carbon Reinforced Polymer is safe for Disc Brake. By observing the frequency analysis, the vibrations are less for Aluminum Alloy than other two materials since its natural frequency is less. And also weight of the Aluminum alloy reduces almost 3 times when compared with Alloy Steel and Cast Iron since its density is very less. Thereby mechanical efficiency will be increased. But the strength of Carbon Reinforced material is more than Aluminum Alloy. Since the Thermal

Analysis also Carbon Reinforced is also permissible. By observing analysis results, Carbon Reinforced Polymer is best material for Disc Brake.

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