

# International Journal of Innovative Research in Science, Engineering and Technology

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## Thermal and Structural Analysis of Two Wheeler Disc Brake Using Softwares

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**ABSTRACT:** Braking is a process which converts the kinetic energy of the vehicle into mechanical energy which must be dissipated in the form of heat. The disc brake is a device for decelerating or stopping the rotation of a wheel. A brake disc (or rotor) usually made of cast iron or stainless steel, is connected to the wheel and/or the axle. Friction material in the form of brake pads (mounted on a device called a brake calliper) is forced mechanically, hydraulically, pneumatically or electromagnetically against both sides of the disc to stop the wheel. The motive of undertaking this project of “Thermal and Structural Analysis of Two Wheeler Brake Disc” is to deal with the modelling and analysis of brake disc using Solidworks and Ansys benchmark. Solidworks package is used for modelling the disc brake. Ansys workbench package is a dedicated finite element package used for determining the temperature distribution, variation of stresses and deformation across the disc brake profile. In this present work, an attempt has been made to investigate the effect of stiffness, strength in disc brake rotor design on the predicted stress and temperature distributions. A Steady state thermal analysis has been carried out to investigate the temperature distribution across the disc profile. Further structural analysis is also carried out by coupling thermal analysis. An attempt is also made to suggest a best combination of material (Cast Iron & Aluminium Alloy) used for disc brake rotor, which yields a low temperature variation across the rotor, less deformation, and minimum vanishes stress possible. Comparison can be done for deformation, stresses, and temperatures for the three materials to suggest the best material for BAJAJ 150cc Pulsar’s disc brake.

**KEYWORDS:** Brake disc, Thermal Analysis, stress, deformation.

### I. INTRODUCTION

An extensive literature review on disc brakes was performed by Ganesh, P et al [1] describes that disc brake is a device for slowing or stopping the rotation of a wheel. Friction causes the disc and attached wheel to slow or stop. Brakes convert friction to heat, but if the brakes get too hot, they will cease to work because they cannot dissipate enough heat. This condition of failure is known as brake fade. Disc brakes are exposed to large thermal stresses during routine braking and extraordinary thermal stresses during hard braking. In the present work actual disc brake rotor has no holes; design is changed by giving holes in the disc brake rotor for more heat dissipation.

P.K.Zaware et al [2] investigated on “Design modification & optimization in stress, deformation & weight of Disc brake rotor”, which studies about on disc brake rotor by modelling & analysis of different shapes of slots of different vehicles disc brake rotor with same outer diameter & inner mounting position of holes on wheel hub as like Bajaj Pulsar 150. Analysis done on real model of disc brake rotor of Bajaj pulsar 150 and disc brake Rotor of different shapes of slots of different vehicles in one Disc brake rotor. Therefore, it gives optimize stress, deformation & weight of the modified disc brake rotor & also good heat dissipation.

Praveena S et al [3] aims to study the Thermal analysis of the Materials. A comparison between the four materials for the Thermal values and material properties obtained from the Thermal analysis low thermal gradient material is

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preferred. Hence best suitable design, low thermal gradient material Grey cast iron is preferred for the Disc Brakes for better performance.

Blot [4] defined several numerical procedures for the temperature analysis of brake discs and revealed that the FE technique was the fastest and most accurate for the investigation of brake disc performance. Furthermore, the time and cost of prototype manufacture and test could be significantly reduced.

Medonos [5] investigated the mechanical and elastic thermal stresses using the FE technique with temperature dependent properties. A full three dimensional model was necessary in order to take the braking drag load and the circumferential variation of thermal stresses into account. The results revealed that the effect of mechanical stresses due to the braking pressure load, deceleration forces and centrifugal forces were minor and could be neglected. However, the friction braking drag load induced significant shear stress in the disc.

Praveena S et al [6] aims to study the Thermal analysis of the Materials. A comparison between the four materials for the Thermal values and material properties obtained from the Thermal analysis low thermal gradient material is preferred. Hence best suitable design, low thermal gradient material Grey cast iron is preferred for the Disc Brakes for better performance. From the above literature, it is understood that various researchers considered different parameters to study the effect of stress distribution. But obtaining weight reduction on different materials with desirable life of disc brake is a challenging task. Hence, in this work the author have chosen different materials for analysis of thermal and structural analysis of disk brakes and has planned to study the effect of deformation and stress distributions and temperature distribution

## II. PROBLEM DEFINITION

During braking, the kinetic energy of a moving vehicle get converted into thermal energy by friction between the brake disc and pad. The heat generated between the brake pad & disc is to be dissipated into the surrounding atmosphere. This heat transfer takes place by conduction, convection and somewhat by radiation. Braking performance of vehicle can be significantly affected by the temperature. Poor heat dissipation may cause brake fade, pneumatic wear, brake fluid vaporization, bearing failure, noise, thermal cracks and hotspots. Then it is important to analyse the thermal performance of the disc brake system to predict the increase in temperature during braking. By minimizing the effects of temperature on brake disc, thermal as well as static structural analysis are carried out by changing the material of the brake disc. Initially, steady state thermal analysis is carried out and then the thermal loads are given as the input for the static structural analysis to find out the temperature distribution, von misses stresses and total deformation.

## III. OBJECTIVES

The main objective is to predict. The temperature distribution throughout the brake disc. The coupled field analysis i.e. thermal to static structural analysis which gives thermal stresses and their corresponding displacement in the brake disc due to the application of temperature. Best material for the brake disc based on the comparison of above results.

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## IV. EXPERIMENTAL RESULTS

### DISK BRAKE CALCULATION

#### SOLIDWORKS MODEL OF PULSAR BRAKE DISC:

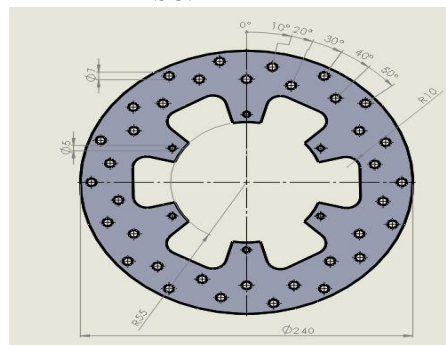


Fig [1] Dimensions of brake disc(solidworks model)

Brake disc material	Gray cast iron.
Outer Diameter of the brake disc	240mm
Inner Diameter of the brake disc	110mm
Diameter of hole on the brake pad area	7mm
No of holes in the brake pad area	36
Diameter of hole in the holding wheel hub	5mm
No of holes in the holding wheel hub	6
Inner radius of the brake pad from the centre	89mm
Outer radius of the brake pad from the centre	115mm
Kerb weight of the vehicle	144kg
Thickness of the brake disc	4mm

Table [1] Brake disc specification

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## BRAKE PAD SPECIFICATION

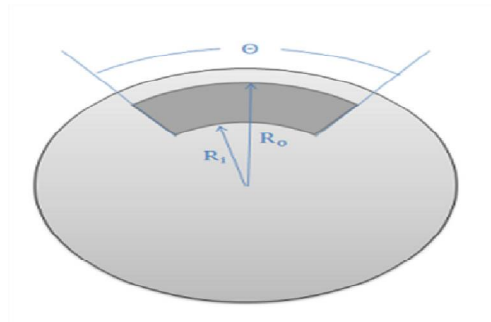


Fig [2] Brake pad Area

Where Inner Radius  $R_i = 89\text{mm}$ , Outer Radius  $R_o = 115\text{mm}$ .

### CALCULATIONS

Speed of the vehicle,  $v = 54\text{km/hr.} = 54*(5/18) v = 15\text{m/s}$ .

We know that velocity,  $v = u + at$  (Final velocity  $u = 0$ , Braking time = 4s)

$$15 = 0 + a(4); a = -3.75\text{m/s}^2.$$

Braking distance,  $x = ut + (1/2)at^2 = (15*4) + \{0.5*(-3.75)*4^2\}; x = 30\text{m};$

Kinetic energy  $KE = (1/2)mv^2 = (0.5*200*15^2); KE = 22500\text{ J};$

Rubbing Area  $A = 2\pi r^2 = 2*3.14*(0.115^2 - 0.089^2); A = 0.0333\text{m}^2;$

Drag force  $F_d = 1/2*\mu^2*\rho*C_d*A = 0.5*15^2*0.5*(0.45*1.866); F_d = 56.679\text{ N};$

Friction force  $F_n = \mu w = 0.65*9.81*100; F_n = 637.65\text{ N};$

Total heat generated =  $KE - (\text{drag force}*\text{Distance}) - (\text{friction force}*\text{Distance})$

$$= 22500 - (56.679*30) - (637.65*30) = 1670.13\text{ J};$$

The analysis is carried out by taking the brake efficiency as 15% for the calculation of heat flux. Thus, total heat generated =  $1670.13*0.15 = 250.5195\text{ J}$ .

Heat Flux,  $\phi = \frac{\text{heat generated}}{\text{time}*\text{rubbing area}}$

$$= \frac{250.5195}{4*0.0333}$$

$\phi = 1880.7770\text{ w/m}^2.$

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## ANALYSIS OF DISC BRAKE

### BOUNDARY CONDITION AND TEMPERATURE DISTRIBUTION

Heat flux = 1880.77 w/m<sup>2</sup>k ; Convective heat transfer coefficient = 100 w/m<sup>2</sup> °c

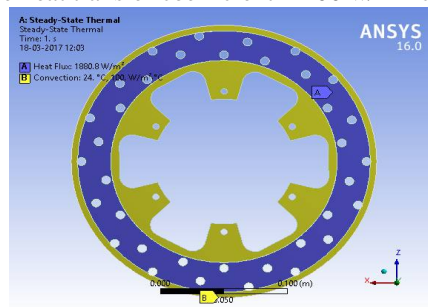


Fig [3] temperature distribution of GCI disc

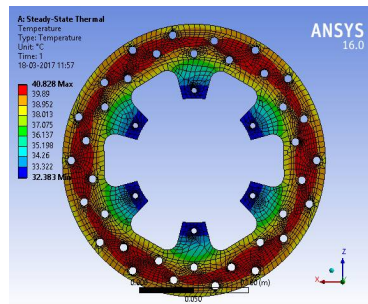


Fig [4] Applied thermal boundary condition

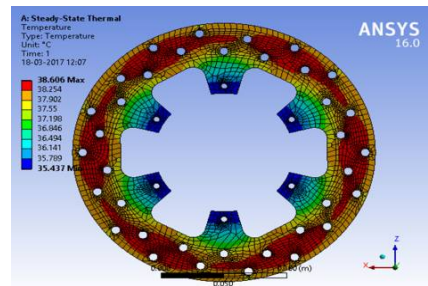


Fig [5] Temperature distribution of Al6061 disc

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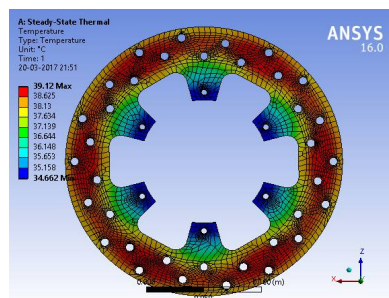


Fig [6] Temperature distribution of Al5083 disc

## STATIC STRUCTURAL ANALYSIS

### BOUNDARY CONDITION, THERMAL STRESS & DEFORMATION

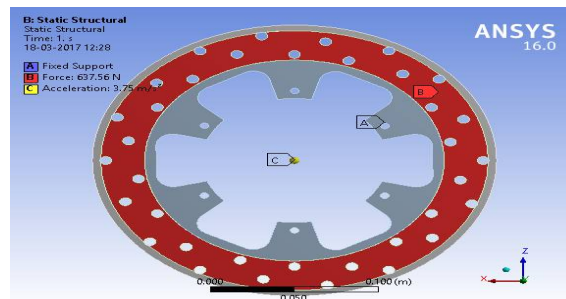


Fig [7] Applied Structural boundary condition

Fix six bolted holes are constraints. Force applied on the rubbing area is 637.65N.

Acceleration applied on the brake disc is  $-3.75\text{m/s}^2$ . Thermal loads are imported.

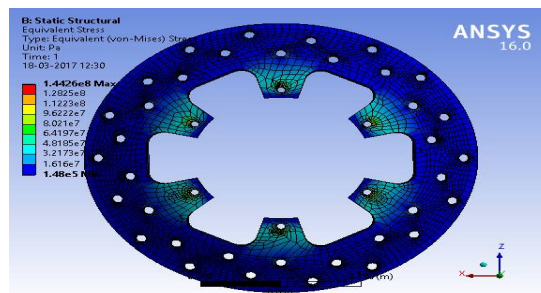


Fig [8] Equivalent stress of GCI brake disc



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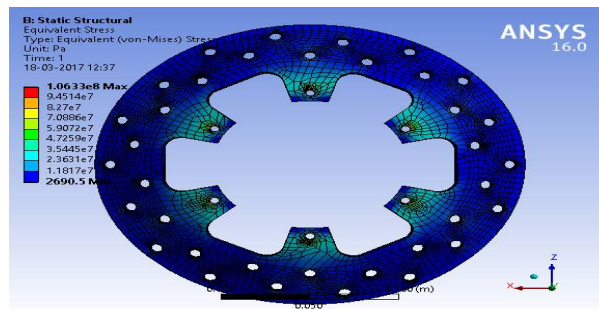


Fig [9] Equivalent stress of Al6061 brake disc

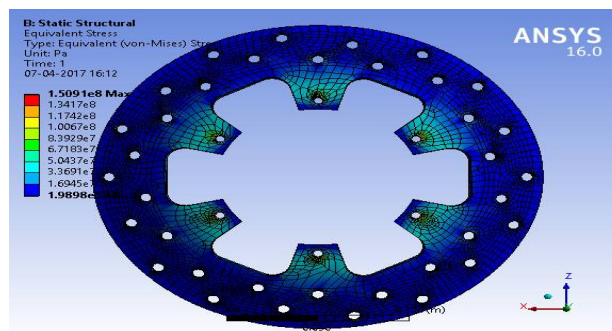


Fig [10] Equivalent stress of Al5083 brake disc.

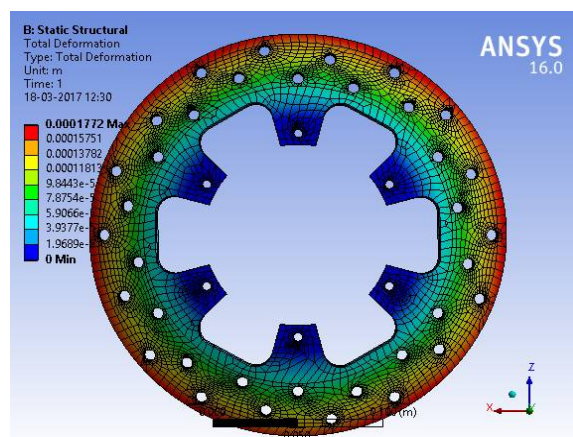


Fig [11] Total Deformation of GCI brake disc

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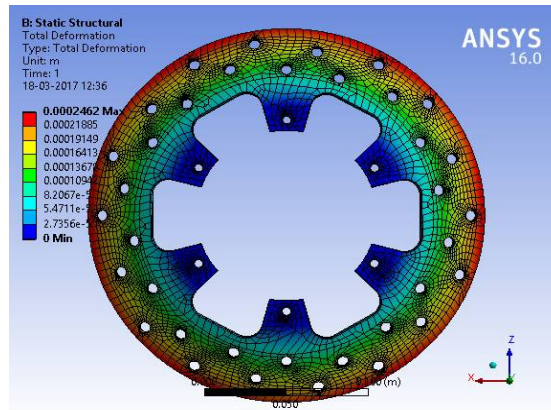


Fig [12] Total deformation of Al6061 brake disc

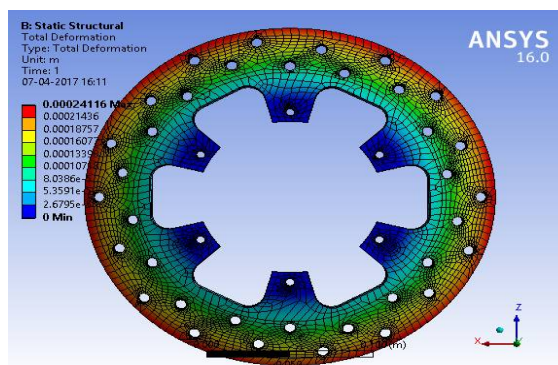


Fig [13] Total deformation of Al5083 brake disc

## RESULTS AND DISCUSSION

### THERMAL ANALYSIS RESULTS

MATERIALS	TEMPERATURE(MAX) °C
GRAY CAST IRON	40.828
ALUMINUM 6061 ALLOY	38.606
ALUMINUM 5083 H116	39.120

Table [2] Thermal Analysis results

From comparing the above results, it is clearly shows that the temperature distribution throughout the brake disc is low in aluminium 6061 alloy as 38.606 °c & high values in gray cast iron as 40.828 °c. Temperature distribution is followed as Gray cast iron > Aluminium 5083 H116 > Aluminium 6061. From these temperature distribution results, aluminium 6061 is the best material from comparing the results.



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## STATIC STRUCTURAL ANALYSIS RESULTS

MATERIALS	GRAY CAST IRON	ALUMINUM 6061 ALLOY	ALUMINUM 5083 H116
Equivalent stress (MPa)	144.26	106.33	150.91
Total deformation (m)	0.0001772	0.0002462	0.0002416

Table [3] Static structural analysis results.

From comparing the above results ,stress distribution throughout the brake disc is low in aluminium 6061 alloy as 144 MPa and high values in aluminium 5083 H116 alloy as 150.91 MPa .Equivalent stress distribution is followed as Aluminium 5083 H116 > Gray cast iron > Aluminium 6061.Total deformation obtained low in gray cast iron and high in aluminium 6061.By the values of equivalent stresses, aluminium 6061 is the best material from comparing the results.

## V. CONCLUSION

The following conclusions are drawn from the present work .Steady state thermal analysis is carried out for the application of braking force due to friction for time duration of 4 seconds .The maximum temperature obtained in the disc is at the contact surface and is observed to be 40.828°C.And the minimum temperature is 38.606°C in Aluminium 6061.Static structural analysis is carried out by coupling the thermal solution to the structural analysis and the maximum equivalent stress(Von Moses stress) is observed to be 150.91MPa and the minimum stress is observed to be 106.33MPa in Aluminium 6061.The Brake disc design is safe based on the Strength and Rigidity Criteria.

To arrive at a best suitable material, Steady State Thermal and Structural Analysis for three different materials in each of the two different analyses are carried out and the results were compared .Comparing the different results obtained from the analysis, it is concluded that disc brake of material Aluminium 6061 is the best possible material for the present application.

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