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# Static Structure and Steady State Thermal Analysis of Two Wheeler Disc Brake

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**ABSTRACT:** These day technologies go beyond us. For automotive field, the technology of engine develops very fast even the system of the bike, car, and luxury or comforts everything that develops by the innovation of engineer. Main problem dealing with disc brakes is the heat generated due to the braking forces and friction forces thus design and material used which are best suited to dissipate most of the heat thus increasing the life span of the disc brakes. The disc brake is a mechanism that used for reducing speed or discontinuing the cycle of the vehicle. Many times using the brake for vehicle starts to heat producing during braking process, such that disc brake undergoes breakage due to high Temperature. Thus, safety is the first important thing we must focus. This paper is presented with “Static structural and Steady State Thermal analysis of disc brake” we can optimize number of shapes of slot to estimate the good thermal conductivity of the disc brake rotor. In this paper, Thermal analysis done on real model of disc brake rotor of Bajaj Pulsar 220 and Thermal analysis of disc brake rotor. To reduce the weight of disc rotor and for good thermal conductivity. Hopefully this paper will help everyone to understand Thermal analysis of disc brake rotor and how disc brake work more efficiently, which can help to reduce the accident that may happen in each day. Modeling was done using AUTOCAD software and Static and Transient Thermal Analysis was done using ANSYS 19 software.

**KEYWORDS:** Disc Brake Rotor, Static Structural, Steady State Thermal, AutoCAD, ANSYS 19 Workbench.

## I. INTRODUCTION

A brake is a device used to generate an artificial frictional which is applied to moving member of machine, for stopping motion. For execution of braking operation, the brakes pad and disc absorb the kinetic energy from wheel. The energy absorbed by brake is generating heat. This heat is passing in to the atmosphere and stops the vehicle. The disk brake is basically a kind of wheel brake that helps in slowing down the rotation of the wheel using the friction; this friction is generated by pressing brake pads against the brake disk which involve the set of calipers. The brake disk of the vehicle has a cast iron, ceramic composites including carbon, aluminum, Kevlar as its main parts for the slowing down the vehicle. A friction material which is being produced in the form of brake pads is forced mechanically, hydraulically, pneumatically and electromagnetically against the both sides of the disk thereby causing heat generation. This friction makes the disc and join wheel to slow or to stop the vehicle. The study of brake analysis is very significant due to safety issues. The brakes should apply such that vehicles would not skid and would take minimum time to stop. Also vehicle produces huge amount of heat. Braking performance is largely affected by the temperature rise in the braking components. High temperature may give thermal cracks, brake fade, wear and reduction in coefficient of friction. Thus thermal analysis is done to model the situation of real life and alter the design specification. During the course of braking, thermal energy generated from the translation of kinetic and potential energies of a moving vehicle due to friction in the brakes. To have appropriate output flux of the disc and the pads by convection and radiation study of the heat transfer process between disc, pad and the air medium is essential. Then it is very much important to analyze the thermal performance of the disc brake system to predict the rise in temperature during braking. Convective heat transfer model has been made to analyze the cooling performance.

## II. RELATED WORK

Heat is the transfer of thermal energy. Heat is always transferred from an object of higher heat to one with lower heat. Exchange of heat occurs till body and the surroundings reach at the same temperature. The high-temperature body passes energy to the low-temperature one, eventually achieving thermal equilibrium. The tendency to thermal

equilibrium, or even distribution of kinetic energy, is an expression of the second law of thermodynamics, the driving force of heat transfer. According to the second law of thermodynamics, „Where there is a temperature difference between objects in proximity, heat transfer between them can never be stopped“; it can only be slowed down. Heat is the energy in transit between systems which occurs by virtue of their temperature difference when they communicate. Heat transfer is a discipline of thermal engineering that concerns the generation, use, conversion, and exchange of thermal energy (heat) between physical systems. Heat transfer is classified into various mechanisms, such as thermal conduction, thermal convection, thermal radiation, and transfer of energy by phase changes. Engineers also consider the transfer of mass of differing chemical species, either cold or hot, to achieve heat transfer. While these mechanisms have

distinct characteristics, they often occur simultaneously in the same system. Heat conduction, also called diffusion, is the direct microscopic exchange of kinetic energy of particles through the boundary between two systems. When an object is at a different temperature from another body or its surroundings, heat flows so that the body and the surroundings reach the same temperature, at which point they are in thermal equilibrium. Such spontaneous heat transfer always occurs from a region of high temperature to another region of lower temperature, as described in the second law of thermodynamics.

### III. METHODOLOGY FUNCTION OF DISK BRAKE ROTOR IN AUTOMOBILE

Brake rotors of disc brakes rotate with the wheels, and brake pads, which are fitted to the brake calipers, clamp on these rotors to stop or decelerate the wheels. The brake pads pushing against the rotors generate friction, which transforms kinetic energy into a thermal energy. Disc brakes are generally used in passenger cars, but due to their stable performance at higher speeds and resistance to brake fade, they are gradually spreading into the commercial vehicle segment, where drum brakes were traditionally chosen for their longer service life. There is increasing demand from customers for longer service life and higher quality, and Akebono is committed to meeting them through further development of the disc brake's reliability. There are two types of disc brakes.

The "opposed piston type disc brake" has pistons on both sides of the disc rotor, while the "floating type disc brake" has a piston on only one side. Floating caliper type disc brakes are also called sliding pin type disc brakes. This thermal energy generates heat; this heat can be diffused efficiently. This heat-dissipating property reduces brake fade, which is the phenomenon where braking performance is influenced by the heat. Another advantage of disc brakes is its resistance to water fade, which occurs when the water on the brakes significantly reduces braking force.

When the vehicle is in motion, the rotor spins at high speeds and this rotational motion discharges the water from the rotors themselves, resulting in stable braking force.

When the driver steps on the brake pedal, the power is amplified by the brake booster (servo system) and changed into a hydraulic pressure (oil-pressure) by the master cylinder. The pressure reaches the brakes on the wheels via tubing filled with brake oil (brake fluid). The delivered pressure pushes the pistons on the brakes of the four wheels. The pistons in turn press the brake pads, which are friction material, against the brake rotors which rotate with the wheels. The pads clamp on the rotors from both sides and decelerate the wheels, thereby slowing down and stopping the vehicle. The brake rotor or brake disk is the main rotating part of the disc brake assembly. It is the component by which the brake caliper clamps its hold to stop the wheel rotation. It is hard wearing and resists high temperatures that occur during braking.

It is generally made of cast iron. In high performance vehicles composite materials such as ceramics or carbon fiber are used to make rotors. Since some of the rotors have directional vanes they can be fitted to only one side of the vehicle. The size of disc/rotor plays an important role in the efficiency of disc brake. In India, we find mostly 240-300 mm front discs on motorcycles. One example of a large rotor was this Buell XB12SX Lightning City X which used 375 mm front disc brake.

The front disc is always larger than the rear disc because the front brake is more effective in stopping a two wheeler than the rear brake. In general, the larger the rotor/disc the better is the braking of the motorcycle. There are following reasons behind the same. When a brake lever or pedal is pressed, the push rod which is pedal and master cylinder piston pushes. This movement causes brake pads to stick to the brake disc which creates friction and stops the brake disc/rotor from rotation.

### DIFFERENT METHODS OF DISC BRAKE

There are two main types of disc brakes:

- Mechanical
- Hydraulic

## MECHANICAL

Which works with cables (just like rim brakes). At one end of the spectrum we have cable actuated brakes, sometimes referred to as mechanical disc brakes. These function in much the same way as a rim brake, relying on a braided steel cable to move the pistons. The upside of this design is it works in conjunction with your normal, rim brake compatible shifters. Just like rim brakes, they can suffer from cable contamination and are on the whole notoriously fiddly to set up perfectly without rubbing. Mechanical brakes use stainless steel cables between the lever and caliper, resulting in a very simple brake system. Replacement inner and outer cables can be found in any bike shop in the world, and they're easy to change yourself – which is why I've long recommended mechanical disc brakes for touring and bike packing. I adopted Avid BB7 brakes for touring back in 2012, and while they weren't the highest performing brakes available, they were plenty powerful for touring, especially with large rotors. But more importantly, they were a fool-proof brake system. Lubricating the inner and outer cables was easy and it almost always brought my brakes back to their on/off brake bite after feeling a bit gunky.

One thing I found a bit annoying was the need for constant adjustment. As my brake pads would wear, I would need to add cable tension. This was done easily by adjusting the barrel adjuster, but I found I needed to make fine adjustments at the Avid BB7 caliper too, or my brakes would rub.

My TRP Spare disc brakes required a little less tinkering as both brake pads pulled inwards at the same time, but still – the inner brake pads always wear quicker than the outer pads, so caliper adjustment is inevitable.

- Easier to maintain yourself, but require more maintenance generally
- Powerful enough for most touring applications
- More of an on/off brake feel
- Very unlikely to fail in remote areas
- Typically cheaper, although not so much these days

## HYDRAULIC

Which replaces the cables with hydraulic fluid in a fully sealed line. When you brake, the pressure forces the fluid to move into the caliper, pressing the pads against the disc. In contrast hydraulic disc brakes use a sealed, fluid filled system as the means of actuation. This allows the highest level of braking consistency due to reductions in friction and the fact that both brake pads can move in and out as required. Downside is the considerable expense of dedicated shift levers and system and the comparable lack of simplicity for home mechanics. Hydraulic disc brakes have a fluid inside the brake lines, much like those in a car or motorbike. When you pull the brake lever, the fluid rushes down to the caliper, closing the brake pads. This type of brake line is sealed away from the elements, so they tend to work well in any riding conditions. A big advantage for users is that as the pads wear, the pistons move inwards, keeping the same pad-to-rotor clearance. This self-adjustment just means they require less tinkering to keep them running well.

I was originally a little hesitant travelling with hydraulic disc brakes on my multi-year bike trips, as I have the propensity to disappear into remote areas with poor weather conditions. I also don't like working on my bike if I don't have to. But KOGA assured me that Shimano XT brakes had been working reliably for their customers, so I took their word and figured I could always switch to mechanical brakes if I needed. Turns out, my Shimano XT brakes have been fantastic! Hydraulic brakes simply have more power.

Than mechanical brakes, but additionally, they usually have a more „modulated“ feel too. This just means that you can ramp up the braking power at a more measured pace. I did have to bleed a rear brake early-on as it must've been a bit dodgy from the factory, but otherwise, I bleed my brakes once every 12-18 months and swap my pads when they wear out. I went through just five sets of brake pads in South America, which is pretty incredible given the terrain.

As hydraulic brakes can have issues with oil leaks and brake bleeds from the factory, I recommend using your brakes for a minimum of three months before going rogue. This should iron out any kinks and give you confidence that your system will work as advertised.

- Self-adjusting and low in maintenance (usually!)
- More powerful, more effortless braking
- Gradual power delivery
- Cylinder, piston and general oil leaks can render brakes useless.



- Perform better than mechanical brakes as the conditions get worse (system is sealed).

#### **TYPE OF VEHICLE DISC BRAKE**

- Plain
- Drilled
- Slotted
- Drilled and Slotted
- Cross Drilled Rotor
- Cross Slotted Rotor

#### **VI. LITERATURE SURVEY**

Before starting with actual working, it's always helpful to study literature and work already carried out in similar field. This study helps to decide project outline and flow. Some research papers, articles are available in which similar type of issues, case studies have discussed. In this chapter, summary of such papers and literature published by various researchers is described.

N.Balasubramanyam, Smt. G. Prasanthi In this project, three-dimensional modeling and meshing Structural & thermal analysis using the simulation program ANSYS were successfully implemented. This has allowed for greater flexibility and accuracy in the results achieved. They were taken 3 different materials of disc brake using constant hydraulic pressure 1 Mpa at time of running condition & analysis. On the basis of various results gathered from the analysis, it is decided that grey Cast Iron is the suitable material for disc brake. Subhasis Sarkar, Pravin P. Rathod In automobile brake system ventilated disc brake is the art of technology. This research paper reviews work of previous investigators on transient thermal analysis on the design rotor and ventilated rotor disc is to compare and evaluate their performance.

The aim of this research paper review work is to study various research done in past to improve heat transfer rate of ventilated disc brake by changing material and vane geometry. If vane is angled and of alternate length other than straight radial vane. Contact time between air flow and vanes is also important factor in heat transfer from Disc rotor. There is also scope of research in improvement of heat transfer of rotor by increasing the contact time between vanes and air flow by design modification of vane Aggarwal. This research paper explains the design and finite element analysis model of brake disc by which deflections in X, Y, Z direction and Von Mises stress can be calculated by applying boundary conditions.

Ameer Fareed Basha Shaik, Ch. Lakshmi Srinivas the paper presented here is a study of model of a disc brake of Honda Civic. In this paper Structural & Thermal analysis was done in the brake disc. After changing the design of disc brake analysis was done. The material used as Cast Iron. Actual disc brake has no holes, changing the design of the disc brake by giving certain holes for more heat dissipation. Modeling was done in Catia and Analysis is done in ANSYS. Study the amount of deformation due to pressure

The modular brake was then analysed using a nodal temperature of 300°F. These results were used to study the increase in deformation in the caliper at high temperatures. The displacement increased as compared with the previous case. Since race cars brakes always operate at high temperature the thermal deformation/displacement results are important.

Zheng han in this final year project, three-dimensional modeling and meshing using the simulation program ANSYS were successfully implemented. This has allowed for greater flexibility and accuracy in the results achieved. The mechanical performances of a conventional disc brake system and the parametric disc brake system under three different simulation environments were studied and compared. Under tensional strength simulation, the parametric disc brake performs better with its maximum values of First Principal Stress and Von Mises Stress being significantly lower than those in the conventional brake-disk. Under lateral strength simulation, the parametric brake-disk yielded almost similar results to that of the conventional brake-disk. For both the static tests mentioned, the maximum stresses (weak points) in the Parametric brake-disk occur at the mounting holes. These maximum stresses occur at the holes.



This is due to the design of the brake-disk which concentrates the stress on the inner diameter during expansion and contraction. This indicates that the number of potential points for crack initiation is higher. Daniel Das.A, Christo Reagan Raj.V, Preethy.S,Ramya Bharani.G The aim of this paper was to investigate the temperature 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, and deformation for different pressure condition using analysis software with four materials. The Disc brakes are made up of cast iron.

### V. DESIGN AND MODELLING OF DISC BRAKE BY USING AUTOCAD

AutoCAD used to design disc brake and ANSYS used to thermal analysis. It is a very popular tool for design engineers in the product enlargement method. Designs are still in the procedure of an adjustable computer aided design (AutoCAD) model. This helps and gives flexibility to the design engineers to go back and it is important to understand the FEA basics, modeling techniques, the inherent errors and their effects on the quality of the results. Modeling of disc brake is generated using SOLID WORKS. The model of brake disc as a 3D.

#### 1. DISC BRAKE DESIGN DATA

For modeling of disc brake using AutoCAD tool required design data which are represented in line diagrams.

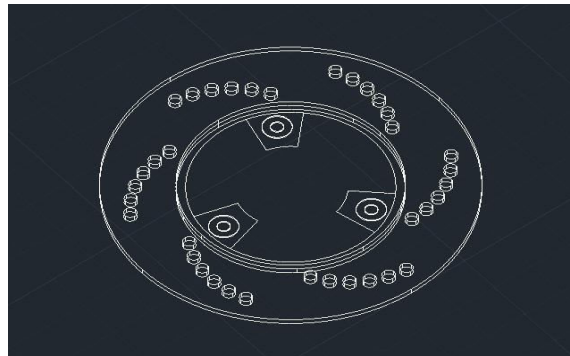


Figure 1: Line Diagram of Disc Brake Rotor

### VI. PERFORMANCE ANALYSIS OF DISC BRAKE ROTOR USING ANSYS

Once the modeling of Disc Brake completed using AutoCAD, the Analysis has been performed in workbench to identify the load carrying capacity of the Disc Brake at loading conditions. The steps followed to perform analysis are listed below.

#### MATERIAL PROPERTIES OF DISC BRAKE ROTOR BORON CARBIDE MATERIAL PROPERTIES

SL.NO	PROPERTIES	VALUE
1.	Young's Modulus	362Gpa
2.	Poisson's ratio	0.21
3.	Density	2.52 g/cm <sup>3</sup>

Table 1: Boron Carbide Material Properties



**IMPORTED DISC BRAKE ROTOR**

**MESH MODEL OF DISC BRAKE ROTOR**



Figure 2: Imported Disc Brake Rotor

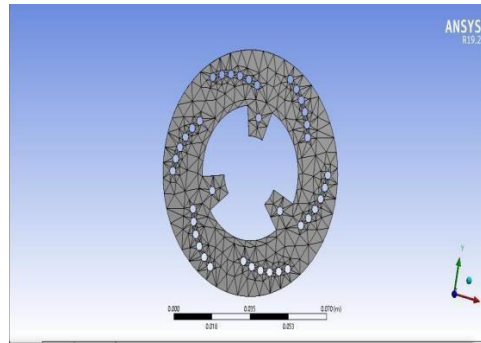


Figure 3: Mesh Model of Disc Brake Rotor

**STATIC STRUCTURAL ANALYSIS OF DISC BRAKE ROTOR OBSERVATION OF TOTAL DEFORMATION OBSERVATION OF VON MISSES-STRAIN**

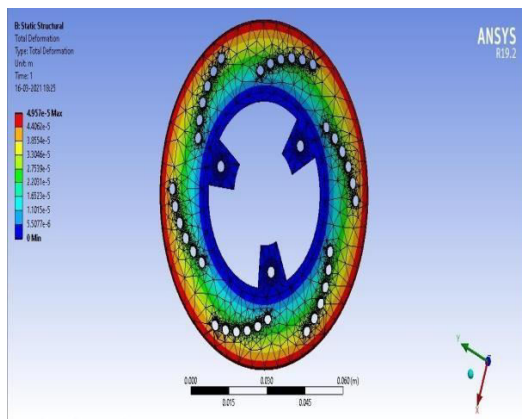


Figure 4

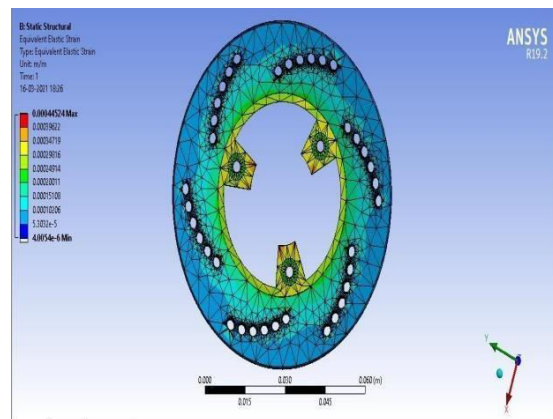


Figure 5

**OBSERVATION OF SHEAR ELASTIC STRAIN**

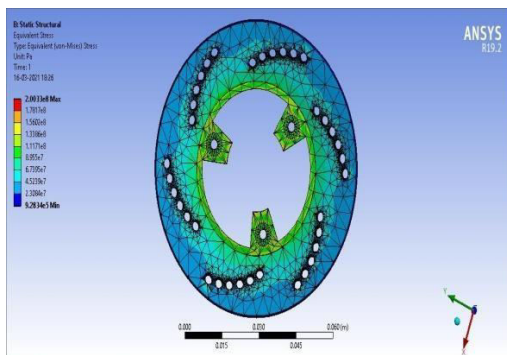


Figure 6

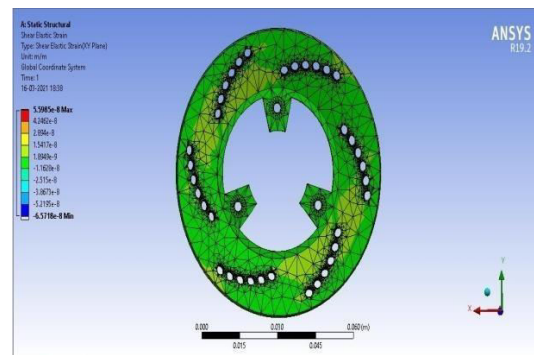


Figure 7

**STEADY STATE THERMAL ANALYSIS OF DISC BRAKE ROTOR OBSERVATION OF TEMPERATURE OBSERVATION OF TOTAL HEAT FLUX**

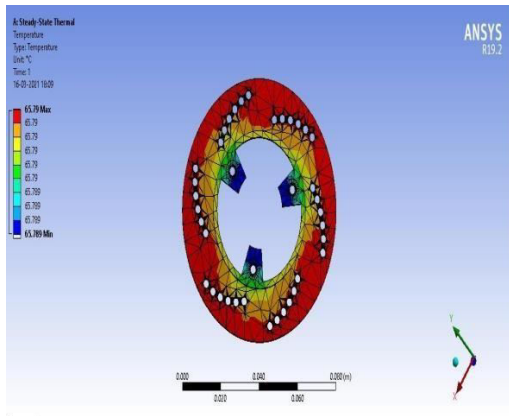


Figure 8

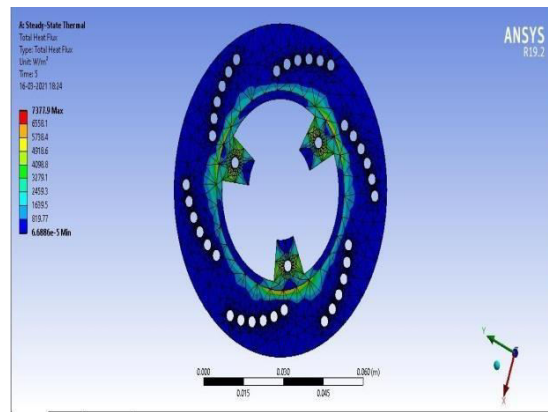


Figure 9

**OBSERVATION ON DIRECTIONAL HEAT FLUX**

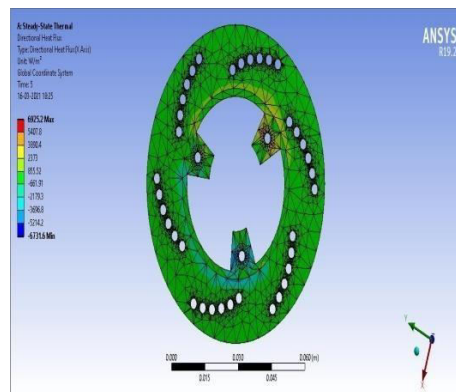


Figure 10

**VII. RESULTS AND CONCLUSION**

In this work, I selected Boron Carbide material for Disc Brake Rotor but Boron Carbide is not suitable for Production because of high cost. With compared to Pulsar Disc Brake the static structural analysis of Stress and Deformation and steady state thermal analysis of Temperature is done. Hence, the design is safe. The values we found of Stress, Deformation and Temperature is less than original Disk Brake and the values are tabulated below.

**TABULATION**

STATIC STRUCTURAL ANALYSIS	STRESS	DEFORMATION
Pulsar Disc Brake	19.083 N/m <sup>2</sup>	0.003695
New Brake	2.0033e <sup>8</sup> N/m <sup>2</sup>	0.002013

Table 2: Variation of Static Structural Analysis





STEADY STATE THERMAL ANALYSIS	TEMPERATURE
Pulsar Disc Brake	124.93 °C
New Brake	65.78 °C

Table 3: Variation of Steady State Thermal Analysis

### VIII. CONCLUSION

In this project we have analysed the disc brake rotor used in bike. We have modeled the disc brake rotor by using 3D parametric software AutoCAD. To validate the strength of our design, we have done structural analysis on the disc brake rotor. We have done analysis by component material Boron Carbide. By comparing the result for existed design and modified design, the stress, strain, temperature, heat flux, and total deformation are less for modified design. So we have conclude that as per our analysis using component material Boron Carbide for Disc Brake Rotor is best comparing with others and also our disc brake rotor design is safe.

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