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Design and Experimental Analysis of Two-Wheeler Disc Brake for Performance Enhancement

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Abstract: *Building a Project plays a vital role in improving skills as well as in boosting career opportunities for an engineer. Designing and building any machine comes with its share of success and failures. This is a way of brainstorming, creating new ideas which help in betterment of our future and also opens to other new ideas. Disc brakes have evolved over time to be a reliable method of decelerating and stopping a vehicle. There have been different designs of disc brake systems for different applications. This review gives a description of different aspects of the components and the materials used in a disc brake system. In spite of all the improvements, there are still many operational issues related to disc brakes that need to be understood in greater detail and resolved. There has been a lot of research going on about these issues and at the same time different methods are being proposed to eliminate or reduce them. There has also been intensive fundamental research going on about the evolution of the interface of the disc-pad system. One major purpose of the present paper is to give a comprehensive overview of all such developments. The basic principle used in braking systems is to convert the kinetic energy of a vehicle into some other form of energy. For example, in friction breaking it is converted into heat, and in regenerative braking it is converted into electricity or compressed air etc. During a braking operation not all the kinetic energy is converted into the desired form, e.g., in friction breaking some energy might be dissipated in the form of vibrations.*

Keywords: Disc Brakes, Braking Systems, Electricity or Compressed Air, Kinetic Energy, etc.

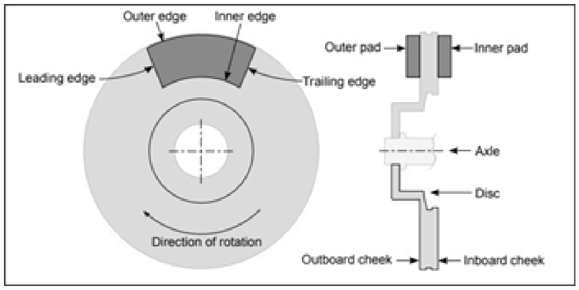
I. INTRODUCTION

A brake is a mechanical device that inhibits motion by absorbing energy from a moving system. It is used for slowing or stopping a moving vehicle, wheel, axle, or to prevent its motion, most often accomplished by means of friction. A disc brake is a type of brake that uses caliper to squeeze pairs of pads against a disc or "rotor" to create friction. Hydraulically actuated disc brakes are the most commonly used form of brake for motor vehicles. The disc 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 slow down the wheel, friction material in the form of brake pads, mounted on the brake caliper, is forced mechanically, hydraulically, pneumatically, or electromagnetically against both sides of the disc. The disc brake system works based on Pascal's law which states that " Pressure exerted anywhere in a contained incompressible fluid is distributed equally in all direction throughout the fluid". When you apply the brake, the caliper will receive the high-pressure hydraulic fluid from the brake master cylinder. The fluid will push the piston which makes the inner brake pad to squeeze against the disc rotor surface. The pad which is nearer to the center of the vehicle is called the inboard pad while the one that is away is called the outboard pad. Similarly, friction surface of the disc which faces towards vehicle is called inboard cheek and the one which faces away is called outboard cheek.

The edge of the pad which comes into contact with a point on disc surface first is called leading edge while the edge which touches that point last is called trailing edge. The edge of the pad with smaller radius is called inner edge while the one with larger radius is called outer edge.

Main three components of a disc brake:



Brake Disc: Brake disc also called brake rotor, is fixed to the axle, so it rotates with the same speed as the wheel. Braking power of a disc brake is determined by the rate at which kinetic energy is converted into heat due to frictional forces between the pad and the disc. For an efficient brake design, it is also important that heat is dissipated as quickly as possible otherwise the temperature of a disc might rise and affect the performance of a disc brake. So, to get an optimum performance in demanding applications, ventilation is introduced in the brake discs which increases the cooling rate.

Brake Pad: A brake pad consists of a friction material which is attached toa stiff back plate. shows a brake pad attached to a back plate. Sometimes the friction material and back plate together are called a brake pad. A brake pad usually incorporates slots on its face and chamfers at the ends. A pad can have more than one slot and it could be arranged in different orientations. One purpose to incorporate chamfers and slots is to reduce squeal noise. Relatively higher temperature at the pad surface than the interior will result in convex bending of the pad. A slot will allow the material to bend and help avoid cracks. Furthermore, it facilitates to clean the dust collected between disc and pad surfaces by offering an escape.

Brake Caliper: A brake caliper is an assembly which houses the brake pads. In addition, it also houses the pistons and provides the channels for the brake fluid which actuates the pistons. There are two types of calipers, fixed and floating. A fixed caliper does not move relative to the brake disc and houses the pistons on both sides of the disc when pressure is exerted both pistons move and push the brake pads. A floating caliper houses the piston only on one side of the disc when pressure is exerted, the piston moves and pushes the inner brake pad. When the pad contacts the disc surface, caliper moves in the opposite direction so that outer pad also contacts the disc surface.

Problem Statement: If the temperatures reached in braking become too high, deterioration in braking may result, and in extreme conditions complete failure of the braking system can occur. It can be difficult to attribute thermal brake failure to motor vehicle accidents as normal braking operation may return to the vehicle when the temperatures return to below their critical level.

1. Brake Fade
2. Excessive Component Wear
3. Thermal Judder
4. Brake Dust

Objective of the Project:

1. More heat should be dissipated in the braking system.
2. Reduce brake fade and Decrease disc distortion.
3. Reduce brake judder.
4. Use of external air ducts to increase cooling rate.

II. METHODOLOGY

Existing Brake Pad Material:

Currently semi-metallic brake pads, organic brake pads are widely used. Ceramic brake pads are used only in high performance cars. Metallic Fibers include steel, brass and copper. Metallic chips or granules are commonly used as reinforcing Fibers. The drawback of using steel Fibers is that they will rust, if the vehicle has an extended rest period or if the vehicle has been operating near a more moisture environment. Ceramic Fibers are a relatively new raw material in friction product compared to metallic Fibers like steel. They are typically made of various metal oxides such as alumina (aluminum oxide) carbides and silicon carbide. With a high thermal resistance, melting points ranging from 1850 to 3000 °C, light weight and high strength, they are very suitable as reinforcing Fibers.

They are preferred over metallic Fibers because their high strength weight ratio. Ceramic Fibers are a relatively new raw material in friction product compared to metallic Fibers like steel. They are typically made of various metal oxides such as alumina (aluminum oxide) carbides and silicon carbide. With a high thermal resistance, melting points ranging from 1850 to 3000 °C, light weight and high strength, they are very suitable as reinforcing Fibers. They are preferred over metallic Fibers because their high strength weight ratio.

Scope and Proposed Idea of the Project:

Metallic brake pads tend to be noisier and other alternatives like carbon ceramics being quite expensive and having a complex and a time-consuming process. So, in this review we are suggesting a material having equivalent properties. Addition of cooling duct for improving brake performance of a disc brake which will improve the heat convection of the brake disc by supplying more air flow.

III. DESIGN OF ROTORS AND BRAKE PAD

Designing in Catia V5

CATIA V5 is an advanced 3D product creation package... Mechanical Design Products allows the user to create parts in a highly productive and intuitive environment, to enrich existing mechanical part design with wireframe and basic surface features and then easily establish mechanical assembly constraints, automatically positions parts and checks assembly consistency. Advanced Drafting capabilities are also provided through the associative drawing generation from 3D part and assembly designs. By using CATIA V5 brake disc and brake pad were designed.

Designing of Brake Pad

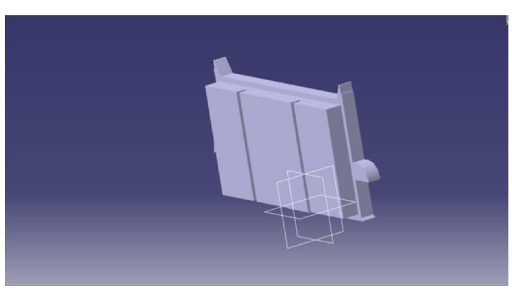


Figure: Brake pad design

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Designing of Brake Disc

Influence of Geometry of Rotor:

Earlier disc brake used had solid rotor, afterward disc brake rotor geometry evolves from just solid rotor to cross drilled, slotted rotor and combination of them. Solid rotor is the basic design and has advantages compare to cross drilled, slotted design. Blank design is more resistant to cracking & deformation compare to the other geometry. But for the high-powered automobile and heavy vehicles, manufacturer needed brake which can stop the vehicles in very less time. For that they needed the rotor which can remove the heat, generated during braking in very short time. Because of the material evolution, stress was not the factor so they started designing the rotor for better cooling to keep the braking performance intact even at higher temperature. Then came vented rotor's which had the better cooling performance then the solid rotor.

Vented rotor has small passage between two solid plate and air can flow through it, that's how we get the better cooling. Flow of air through the passage will increase with increasing the rotational speed. Comparing the solid and ventilated rotor thermal performance at higher rotor speeds, wherein the internal cooling may contribute as much as 50 or 60 percent to the total cooling. Now the research is done to further improve the geometry of the vented rotor. The aerodynamic characteristics of the mass flow were found to be reasonably independent of rotational speed, but highly dependent upon rotor geometry. We designed and analyzed disc rotor with slots and it showed significant increase in heat dissipation but affected the structural rigidity. While the drilled hole disc had better structural rigidity but had less heat dissipation. Hence, we combined both of these designs to create better overall design with better aerodynamic characteristics as well as required structural rigidity.

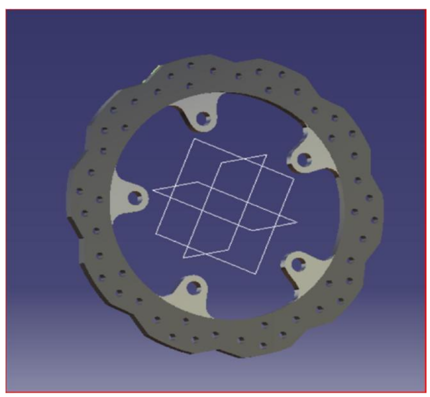


Figure: Standard Drilled Rotor

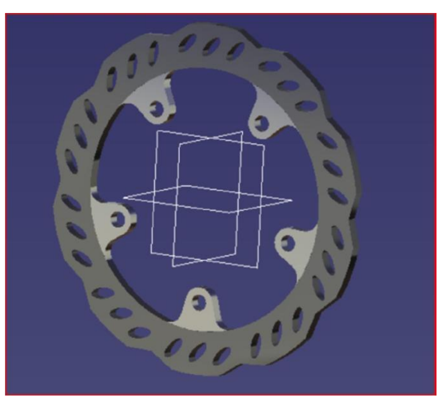
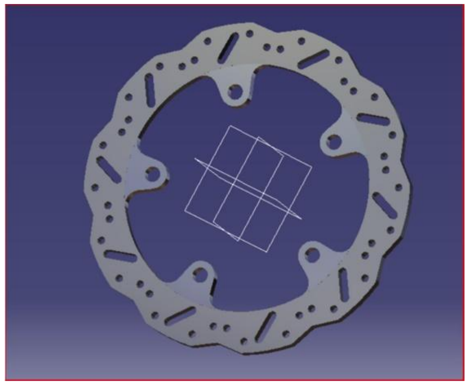
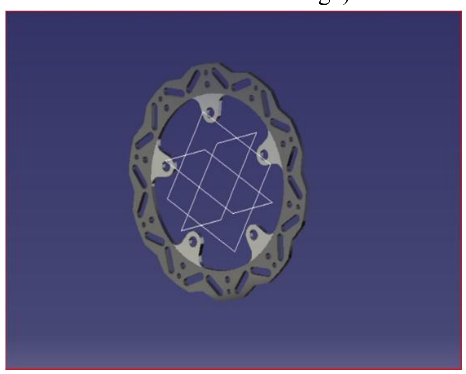


Figure: Slotted Rotor

Modified Design 1 (combination of both cross drilled + slot design)



Modified Design 2 (combination of both cross drilled + slot design)



IV. BRAKE PAD MATERIAL

Non-asbestos friction material with high amount of inorganic(Kevlar-119composite) and metallic (steel wool and brass chips) reinforcing fibre system, organic binding system by special by special synthetic resins and rubber, high friction level, high mechanical stability, stable friction coefficient at high temperatures, excellent wear resistance, salt water resistant Kevlar-119 extremely impervious to strain breakage - it made an excellence tire line, It was likely excessively great of a tire cord.

In its modern applications its rigidity load about 5:1 over steel. In a ballistic occasion, there's no time for a Newtonian response, similar to development. A projectile breaks fibre. In any case, if there are sufficient filaments to break, every breakage removes a tad of the vitality. In disk-brake manufacturing the Kevlar-119 supports with excellence in brake. It withstands high temperature and gives a high life of disk-brake as shown in below.

Function	Raw Materials	Density (kg/cm3) %	Volume
Binder	Silicon carbide	3.21	15
Filler	Baryte (BaSo4)	4.5	12
	Synthetic Graphite	2.32	8
Friction Modifier	Aluminia (Al2O3)	3.95	11
	Zinc	7.14	9
	Coke	1.506	8
Reinforcement	Copper Powder	5.7	19
	Iron Powder	7.874	18

Function	Raw Materials	Density (kg/cm3) %	Volume
Binder	Phenolic Resin	6.5	17
Filler	Baryte (BaSo4)	4.5	15
	Synthetic Graphite	2.32	11
Friction Modifier	Steel wool	7.56	16
	Copper	3.9	13
	Coke	1.506	9
Reinforcement	Kevelar Fibers	8.45	19

TEST REPORT

Coefficient of friction	0.45
(Tensile)Cross Breaking strength	5500 N/cm2
Compressive Strength	14500 N/cm2
Gliding Speed	40 m/s
Rivet Holding	1260 kg/cm2
Density	2.55 g/cm3
Max temp (Continuous) (Short time)	350C 600 C

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Wear Resistance Analysis

The wear resistance is a key factor in the service life of brake discs. In the friction and wear process of brake discs and brake pads, abrasive wear and adhesive wear are the two main ways of friction loss. Under the pressure and friction of the pairing materials, when the hardness of the hard phase of the cast iron is greater than the hardness of the matrix, the abrasive wear gradually appears on the surface of the matrix. Therefore, the hard phase contacts the friction of the pairing materials to form the first friction surface. The matrix and graphite constitute the second friction surface. According to the wear of brake discs and brake pads, the wear can be divided into three categories: mild wear, moderate wear, and heavy wear.

The study found that different wear mechanisms of different microstructures have different wear mechanisms. Mild wear, the friction surface is nearly intact and essentially free of deformation. The oxidized powder tightly covers the friction surface. Moderate wear, the friction surface is covered with discontinuous oxidation. There is micro -deformation and large particles of abrasive debris. Heavy wear, the friction surface is severely deformed, the roughness is increased. Additionally, it produces band-like loose wear debris.

Table: Wear Rate

Figure: Total wear 0.5mm

Figure: Total wear 0.3mm

Type of brake pad/ Mass of brake pad include the	Non-Asbestos	Kevelar Fribers	Semi Metallics
Total mass before test (g)	180	174	185
Total mass after test (g)	172	170	178
Total mass loss (g)	8	4	7
Percent mass loss (Total mass loss/ total mass before test X100)	4.45%	2.33%	3.79%

Sample	Braking Distance [60 – 0]	Heat Generated [Degree]
Oem Brake Pad and Disc	18 m	50
Kevelar Brake Pad and Slotted Disc	16.5 m	45

V. CONCLUSION

1. The present study can provide a useful design tool and improve the brake performance of disk brake system. Thus, the design of the duct is useful and it improves the heat convection of the disc rotor. The duct supplies more air flow to the disc rotor and it reduce the heat of the disc rotor and it improves the life and the performance of the disc rotor.
2. Kevlar®-119 Composite Disk Brake shows an Excellent resulting in disk- Brake, Kevlar is a thermo- safe composite which it ensued the stress factor which it is slightly higher compared to C/Sic carbon ceramic and Al-Al2O3 Ceramics and the deformation range is very less as compared to any other material in this paper. Its Safety factor gives an excellence of the disk-brake. Thus, Kevlar shows very high capability to withstand in disc-brake application.
3. The pad with channels can assist in reducing the wear of the pad as they modified the wear particles and friction film present on the brake interface. The channels help to trap the wear particles and wipe away the friction film.
4. The outer radius of the disc deforms more, large deformations are found in solid disc compare to ventilated disc but stresses are reduced in solid disc.
5. Ventilated disc provides good temperature distributi1on effect compare to solid disc to dissipate heat to the surroundings.

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