Optimization of Disc Brake Rotor for Two Wheeler

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1 INTRODUCTION

1.1 History of Brakes

Brakes and braking systems have really come a long way from their timber roots in the 19th century, when developing a car's stopping power had just begun. Initially, braking systems were composed of large wooden blocks placed near the wheels, and were controlled by a lever. However, this early braking system could be found on any vehicle with steel rimmed wheels, such as early steam powered automobiles and horse-drawn carriages. When the driver pulled the lever, the wooden blocks would press against the steel rimmed wheels and bring the vehicle to a stop.

Everything changed the day the Michelin brothers started to swap out steel rimmed wheels for rubber in the 1890s. Wooden blocks alone didn't do the trick when stopping rubber wheels, so a mechanical drum braking system was implemented instead. Designed and developed by Mr. Louis Renault in 1902, drum braking systems still involved the use of wood blocks, but added a cable wrapped around a drum that made braking easier. In many cases, Renault's braking design was considered the first legitimate example of a modern braking system.

1.2 Brake System

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. In an automobile vehicle, a braking system is an arrangement of various linkages and components (brake lines or mechanical linkages, brake drum or brake disc, master cylinder or fulcrums etc.) that are arranged in such a fashion that it converts the vehicle's kinetic energy into the heat energy which in turn stops or decelerate the vehicle.

The conversion of kinetic energy into heat energy is a function of frictional force generated by the frictional contact between brake shoes and moving drum or disc of a braking system. Most brakes commonly use friction between two surfaces pressed together to convert the kinetic energy of the moving object into heat, though other methods of energy conversion may be employed.

For example, regenerative braking converts much of the energy to electrical energy, which may be stored for later use. Other methods convert kinetic energy into potential energy in such stored forms as pressurized air or pressurized oil. Eddy current brakes use magnetic fields to convert kinetic energy into electric current in the brake disc, fin, or rail, which is converted into heat. Still other braking methods even transform kinetic energy into different forms, for example by transferring the energy to a rotating flywheel.

Brakes are generally applied to rotating axles or wheels, but may also take other forms such as the surface of a moving fluid (flaps deployed into water or air). Some vehicles use a combination of braking mechanisms, such as drag racing cars with both wheel brakes and a parachute, or airplanes with both wheel brakes and drag flaps raised into the air during landing.

1.3 Introduction to Disc Brake

Disc brake system is widely used on front wheels in mid-range two-wheeler such as – commuter & sports bikes. The Disc brake system is used on the front wheels of most hatchback cars, entry-level sedans & MUVs; whereas, it is also widely used on both front & rear wheels of high-end cars and SUVs in combination with hydraulic / vacuum brake actuating systems.

Disc brake got its name from the circular-shaped plate or disc or rotor; onto which the disc brake parts are mounted. A conventional Disc Brake system consists of a brake disc, two friction pads, and brake caliper. In the Disc brake system; the friction pads apply grip on the external surface of the disc to perform braking.

The brake disc (or rotor) is the rotating part of a wheel's disc brake assembly, against which the brake pads are applied. The material is typically gray iron, a form of cast iron. The design of the discs varies somewhat. Some are simply solid, but others are hollowed out with fins or vanes joining together the disc's two contact surfaces (usually included as part of a casting process). The weight and power of the vehicle determines the need for ventilated discs. The "ventilated" disc design helps to dissipate the generated heat and is commonly used on the more-heavily loaded front discs.

Discs for motorcycles, bicycles, and many cars often have holes or slots cut through the disc. This is done for better heat dissipation, to aid surface-water dispersal, to reduce noise, to reduce mass, or for marketing cosmetics.

Slotted discs have shallow channels machined into the disc to aid in removing dust and gas. Slotting is the preferred method in most racing environments to remove gas and water and to deglaze brake pads. Some discs are both drilled and slotted. Slotted discs are generally not used on standard vehicles because they quickly wear down brake pads; however, this removal of material is beneficial to race vehicles since it keeps the pads soft and avoids verification of their surfaces

1.4 Functions of Braking System

A brake system helps to stop vehicles within the smallest possible distance. This is achieved by converting the kinetic energy of the vehicle into heat energy.It also functions on a mechanical device where motion occurs, the brake is applied to stop it within a short period of time.

1.5 Principle of Disc Brake

Braking of a vehicle depends upon the static function that acts between tires and road surface. Brakes work on the following principle to stop the vehicle: “The kinetic energy due to motion of the vehicle is dissipated in the form of heat energy due to friction between moving parts (wheel or wheel drum) and stationary parts of vehicle (brake shoes)”

The heat energy so generated due to application of brakes is dissipated into air. Brakes operate most effectively when they are applied in a manner so that wheels do not lock completely but continue to roll without slipping on the surface of road. Brake rotors of disc

2 LITERATURE REVIEW

Manjunath et al [5] studied Transient Thermal and Structural Analysis of the Rotor-Disc of Disc Brake and aimed at evaluating the performance of disc brake rotor of a car under severe braking conditions and thereby assist in disc rotor design and analysis. Disc brake model and analysis were done using ANSYS workbench 14.5. The main purpose of their study was to analyze the thermomechanical behavior of the dry contact of the brake disc during the braking phase. The coupled thermal-structural analysis was used to determine the deformation and the Von Mises stress established in the disc for both solid and ventilated discs with two different materials to enhance the performance of the rotor disc.

Venkatramanan R et al [4] investigated and analyzed the temperature distribution of rotor disc during operation using Ansys. This was done to understand the pressure force and friction force on the disc brake material, which can help to reduce the accidents that may happen each day. In this research work design of a disc brake was proposed with copper liner, the heat transfer of existing and hybrid disc was calculated for finding the effectiveness of heat transfer and it was concluded that using a copper liner reduced the maximum temperature attained by the disc.

Belhocine et al [3] performed numerical simulation for the coupled transient thermal field and stress field was carried out sequentially with the thermal structural coupled method, based on ANSYS software, to evaluate the stress fields of deformations that are established in the disc with the pressure of the pads. The results obtained by the simulation are satisfactorily compared with those of the specialized literature.

While braking, most of the kinetic energy are converted into thermal energy and increase the disc temperature. This project consists of stress & thermal analysis on brake disc rotor of 2 wheelers for steady state and transient condition. In order to get the stable and accurate result of element size, time step selection is very important and all of these aspects are discussed in this paper. The findings of this research provide a useful design tool to improve the brake performance of disc brake system. The thermal stress due to the heat flux generation has a major influence on the fatigue stress and thermal cracking by proven to be strongly localized and possesses a sharp gradient in the both axial and radial directions. Deformation in frictionally heated contact wheel-mounted on disc brakes was exposed to severe non-symmetrical mechanical and thermal loads. The paper described the design process for two high-performances, hub mounted discs of different shape & cut pattern. The development was resulted in two very successful but fundamentally different hub designs and manufacturing methods. Initially, finite element analyses used in the design optimization were mainly concentrated on stress distribution & heat dissipation effects. Recently, in order further to improve the design. the changes in contact geometry caused by thermal deformation and thermo elastic instability, and the thermo mechanical stress distribution around the frictionally heated.

Transient thermal analysis is carried out using the direct time integration technique for the application of braking force due to friction for time duration of 4,5 and 6 seconds. The maximum temperature obtained in the disc is at the contact surface and is observed to be 240°C. The Brake disc design is safe based on the Strength and Rigidity Criteria.

Nakkanisanni babu, et al., in 2018 published a study in IJITR about the Design Analysis and Fabrication of Disc Brake did research on in this thesis study and analysis of stresses, strain and displacement, inflicted on area drum of brake system. Each material used aluminum 356, cast iron and composite material Kevlar has been shown through the analysis of stresses, strain and displacement, said more metals Al Kevlar which commonly used in industry drum for brake system. And during vehicle deceleration due to braking there is friction between the lining surface and the brake drum or disc. In this process the kinetic energy of vehicle is turned into thermal energy that raises temperature of the components.

Aman Sharma, et al., in 2018 published a paper in IRJET about 'fabrication of braking system'. An inboard braking is an automobile technology where the disc brakes are mounted to the driveshaft or a brake shaft, rather than directly on the wheel hub. The major advantage of using this braking technology is the reduction of unspring weight which improves handling and ride. The primary aim of this paper is to show the utility and performance of disc brakes with rear inboard braking system and to perform CAE analysis of components used in braking system.

M. Gopi Krishna Mallarapu, et al., in 2015 Conducted a study published in the IJMPERD about the MMCs are promising materials under constant development and their application in different industries is increasing. Aluminum is one such pioneer materials which is being used extensively in aerospace, automotive and the manufacturing industry. In the present study an analysis tool finite element analysis (FEA) will be used. The work presented in this paper is aimed at the study of vibration characteristics of aluminum A356 with different reinforcements. A356 alloy and Al–20Cu–10Mg alloy system has been investigated as matrix and reinforcements. through stir casting technique by dispersing high strength alloy particulates (HSAP) quickly and continuously to the vortex, and ingot into a Cast Iron cylindrical mould.

Shahriar Kosarieh, et al., in 2016 conducted and published journal in SAGE about the 'Material characterization of lightweight disc brake'. Alumina coated light weight brake rotors were investigated to evaluate the effect of coating properties on their friction performance and thermal durability. An alumina ceramic coating on AA6082 aluminum alloy (Al-Alloy) and on 6061/ 40SiC aluminum metal matrix composite (Al-MMC) prepared by plasma electrolytic oxidation was studied using a program of brake dynamometer and material characterization tests. The results showed that the plasma electrolytic oxidation alumina layer adhered well to the Al-alloy substrate and was more uniform and durable when compared to that on the aluminum metal matrix composite. The plasma electrolytic oxidation layer significantly improved the hardness of the rotor surface for both Al-alloy and aluminum metal matrix composite substrate. The coated Al-alloy disc brake rotor was demonstrated to give good thermal and friction performance up to high rubbing surface temperatures of the order of 550 C, but the rotor eventually failed due to temperature build-up at a critical location.

3.OBJECTIVE

The Main objective of this project is to minimize the cost of the materials used and to know how amount of material is needed for the manufacturing process of the disc brake system. This helps in knowing the material is required and how much material to be used for the brake.

The other objective is to optimize weight, reduce cost and improve strength to better heat transfer of the disc brake components and to increase the braking efficiency which can withstand with the less weight.
To Select the correct materials for the brake it should have properties like Tensile strength, it should withstand high pressure applied on the disc brakes.
The design of each and every component of the disc brake and the structural analysis of brake system is done using Solid Works. The shape and materials used in the disc brake components will be optimized.

4.WORKING PRINCIPLE

The disc brake system works on the principle of Pascal's Law.
Pascal's law: - A Pressure at any point in a static fluid is equal in all directions.
We know that the pressure is the ratio of force to the area and oil pressure (P) in hydraulic lines is constant. Thus for constant pressure P, as the bore area of the master cylinder decreases, the force required to press the brake pedal also decreases.
Similarly, for constant pressure P, at the brake caliper as the area of the piston at the brake caliper increases, the braking force applied on the disc also increases. Thus due to the smaller bore of the master cylinder and larger brake caliper piston, fewer efforts on the brake pedal can generate higher braking force at the disc.
The below figure shows the basic structure of the disc brake system used in vehicles.

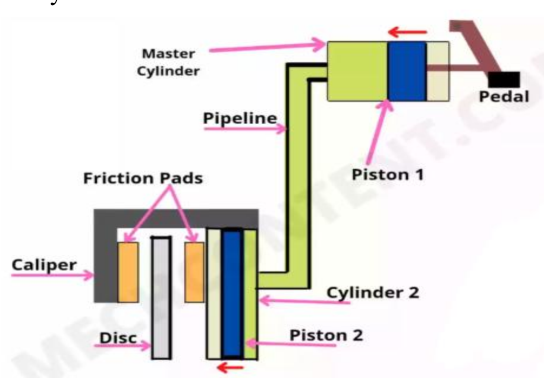

Fig. 5.1 Disc Brake

Following are the components of this braking system:
1) Brake Pads:
Brake pads convert the kinetic energy of the vehicle to thermal energy through friction. Two brake pads are contained in the brake caliper, with their friction surfaces facing the rotor. When the brakes are hydraulically applied, the caliper clamps or squeezes the two pads together onto the spinning rotor to slow and stop the vehicle. When a brake pad heats up due to contact with the rotor, it transfers small amounts of its friction material onto the disc, leaving a dull grey coating on it. The brake pad and disc, then stick to each other, providing the friction that stops the vehicle. In disc brakes, there are usually two brake pads per disc rotor. These are held in place and actuated by a caliper affixed to the wheel hub or suspension upright. Racing calipers, however, can utilize up to six pads, with varying frictional properties in a staggered pattern for optimum performance. Depending on the properties of the material, the weight of the vehicle and the speeds it is driven at, disc wear rates may vary. The brake pads must usually be replaced regularly to prevent brake fade. Most brake pads are equipped with a method of alerting the driver when this needs to be done. A common technique is manufacturing a small central groove whose eventual disappearance by wear indicates the end of a pad's service life. Other methods include placing a thin strip of soft metal in a groove, such that when exposed the brakes squeal audibly. A soft metal wear tab can also be embedded in the pad material that closes an electric circuit when the brake pad wears thin, lighting a dashboard warning light.
2) Rotor:
The disk rotor is made of iron with highly machined surfaces where the brake pads contact it. Just as the brake pads wear out over time, the rotor also undergoes some wear, usually in the form of ridges and groves where the brake pad rubs against it. This wear pattern exactly matches the wear pattern of the pads as they seat themselves to the rotor. When the pads are replaced, the rotor must be machined smooth to allow the new pads to have an even contact surface to work with. Only a small amount of material can be machined off of a rotor before it becomes unusable and must be replaced. A minimum thickness measurement is stamped on every rotor and the technician doing the brake job will measure the rotor before and after machining it to make sure it doesn't go below the legal minimum. If a rotor is cut below the minimum, it will not be able to handle the high heat that brakes normally generate. This will cause the brakes to fade, greatly reducing their effectiveness to a point where you may not be able to stop.
3) Caliper and Support:

There are two main types of calipers: Floating calipers and fixed calipers. There are other configurations but these are the most popular. Calipers must be rebuilt or replaced if they show signs of leaking brake fluid.

4) Single Piston Floating Calipers:

Single Piston Floating Calipers are the most popular and also least costly to manufacture and service. A floating caliper floats or moves in a track in its support so that it can center itself over the rotor. As you apply brake pressure, the hydraulic fluid pushes in two directions. It forces the piston against the inner pad, which in turn pushes against the rotor. It also pushes the caliper in the opposite direction against the outer pad, pressing it against the other side of the rotor. Floating calipers are also available on some vehicles with two pistons mounted on the same side. Two piston floating calipers are found on more expensive cars and can provide an improved braking feel.

5) Four Piston Fixed Calipers:

Four Piston Fixed Calipers are mounted rigidly to the support and are not allowed to move. Instead, there are two pistons on each side that press the pads against the rotor. Four piston calipers have a better feel and are more efficient, but are more expensive to produce and cost more to service. This type of caliper is usually found on more expensive luxury and high performance cars.

6) Brake fluid:

The brake fluid is used to create hydraulic pressure which is then used to force the piston outwards towards the disc rotor. They have high boiling point to sustain high temperature, chemically stable and have lubricating properties.

7) Fluid reservoir:

A tank or reservoir where the brake fluid is stored.

8) Disc brake working: