Enhanced Temperature Control in Disc Brakes

P. Sylvester Selvanathan and R. Govindaraj

Abstract--- *In enhanced temperature control in disc brakes, the problems regarding the heat generation in the disc brakes have been taken into account and their solutions are provided. The notification of the temperature raise of the disc brakes is made available to the driver when the temperature reaches above the safe value.*

In addition, the problem of heat generation is minimized by using the forced convection technique. It is concluded that the heat generated due to friction between the disc and the pad should be minimized to avoid the loss of friction coefficient between the disc and the pad and to avoid the temperature rise of various brake components and brake fluid vaporization due to excessive heating.

Keywords--- *Disc Brakes, Temperature Problem, Convection Principle.*

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 prevent its motion, most often accomplished by means of friction.

A disc brake is a type of vehicle brake employing the friction of pads against a disc which is attached to the wheel. It uses calipers to squeeze pairs of pads against a disc in order to create friction that retards the rotation of a shaft, such as a vehicle axle, either to reduce its rotational speed or to hold it stationary. The energy of motion is converted into waste heat which must be dispersed. Hydraulic disc brakes are the most commonly used form of brake for motor vehicles.

When compared to the drum brakes, the disc brakes are good in their performance but they have some limitations too, which reduces their attractiveness to some degree. So our project aims to rectify these limitations in order to improve the attractiveness of the disc brakes.

The aims of this project are as follows:

- (i) To warn the driver when the temperature of the disc elements reaches above the safe value
- (ii) To reduce the temperature raise in the disc brakes by the forced convection technique

II. PARTS OF THE CUSTOMIZED DISC BRAKE

a. Brake Rotor or Brake Disc

A rotor is a round disc that is made of metal or can be made of composite carbons and ceramic materials. A rotor is clamped by the caliper and the brake pads when the brakes are applied. This in turn slows the wheel.

b. Brake Pad

A thin block of friction-producing material, that presses against a vehicle's brake disc or rotor to enable the wheel to stop. They are made up of materials like Non-metallic materials (cellulose, aramid, PAN, sintered glass), Semi-metallic materials (synthetic mixed with some proportion of flaked materials), Fully-metallic materials (composed of sintered steel without any synthetic additives) and ceramic materials (composed of clay and porcelain bonded to copper flakes and filaments).

c. Caliper

The brake caliper is the assembly which houses the brake pads and pistons. The pistons are usually made of plastic, aluminum, or chrome plated steel.

d. Master Cylinder

The master cylinder is a control device that converts non-hydraulic pressure (commonly from a driver's foot) into hydraulic pressure. This device controls slave cylinders located at the other end of the hydraulic system.

e. Brake Fluid

The fluid used in a brake system to transmit pressure from the brake pedal to the pistons at each wheel, producing the braking action

f. Temperature Sensor

A temperature sensor is a device, typically a thermocouple or RTD, which provides for temperature measurement through an electrical signal. A thermocouple made from two dissimilar metals that generate electrical voltage in direct proportion to change in temperature.

g. Nozzle

A nozzle is a device designed to control the direction or characteristics of a fluid flow (especially to increase velocity) as it exits (or enters) an enclosed chamber or pipes. A nozzle is often a pipe or tube of varying cross sectional area and it can be used to direct or modify the flow of a fluid (liquid or gas).

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DOI : 10.9756/BIJEMS.8316

h. Air Compressor

An air compressor is a device that converts power (using an electric motor, diesel or gasoline engines, etc.) into potential energy stored in pressurized air (i.e. compressed air).

III. LITERATURE REVIEW

Faramarz Talati and Salman Jalalifar (2009) presented Analysis of heat conduction in a disc brake system. In this paper, the governing heat equations for the disc and the pad are extracted in the form of transient heat equations with heat generation that is dependant to time and space. In the derivation of the heat equations, parameters such as the duration of braking, vehicle velocity, geometries and the dimensions of the brake components, materials of the disc brake rotor and the pad and contact pressure distribution have been taken into account. The problem is solved analytically using Green's function approach. It is concluded that the heat generated due to friction between the disc and the pad should be ideally dissipated to the environment to avoid decreasing the friction coefficient between the disc and the pad and to avoid the temperature rise of various brake components and brake fluid vaporization due to excessive heating.

Haripal Singh and Harshdeep Shergill (2012) presented Thermal Analysis of Disc Brake Using Comsol. This work deals with the analysis of heat generation and dissipation in a disc brake of an car during panic braking and the following release period by using computer aided engineering software for three different materials of rotor disc. The objective of this work is to investigate and analyze the temperature distribution of rotor disc during operation using COMSOL MULTIPHYSICS. The work uses the finite element analysis techniques to predict the temperature distribution on the brake disc and to identify the critical temperature of the brake rotor disc. All three modes of heat transfer (conduction, convection and radiation) have been analyzed. The results obtained from the analysis shows that different material on the same retardation of the car during panic braking shows different temperature distribution. Thus, a comparison is made between three different material used for brake disc and the best material for making brake disc based on the rate of heat dissipation have been suggested.

Manjunath TV and Dr Suresh PM (2013) presented Structural and Thermal Analysis of Rotor Disc of Disc Brake. The disc brake is a device for slowing or stopping the rotation of a wheel. Repetitive braking of the vehicle leads to heat generation during each braking event. Transient Thermal and Structural Analysis of the Rotor Disc of Disc Brake is aimed at evaluating the performance of disc brake rotor of a car under severe braking conditions and there by assist in disc rotor design and analysis. Disc brake model and analysis is done using ANSYS workbench 14.5. The main purpose of this study is to analysis the thermo mechanical behavior of the dry contact of the brake disc during the braking phase. The coupled thermal-structural analysis is used to determine the deformation and the VonMises stress established in the disc for the both solid and ventilated disc with two different materials to enhance performance of the rotor disc. A comparison between analytical and results obtained from FEM

is done and all the values obtained from the analysis are less than their allowable values. Hence best suitable design, material and rotor disc is suggested based on the performance, strength and rigidity criteria.

IV. PROBLEM STATEMENT

Long repetitive braking leads to temperature rise of various brake components of the vehicle that reduces the performance of the brake system. Long repetitive braking, such as one which occurs during a mountain descent, will result in a brake fluid temperature rise and may cause brake fluid vaporization. This may be a concern particularly for passenger cars equipped with aluminum calipers and with a limited air flow to the wheel brake systems. Braking performance of a vehicle can be significantly affected by the temperature rise in the brake components. High temperature during braking may cause brake fade, premature wear, brake fluid vaporization, bearing failure, thermal cracks, and thermally excited vibration. Therefore, it is important to predict the temperature rise of a given brake system and assess its thermal performance in the early design stage. Recently, brake fluid vaporization has been suspected as a possible cause of some collisions and a proper inspection procedure has been recommended.

Fig. 1: Thermal Stress in Disc Brake

Disc brakes are exposed to large thermal stresses during routine braking and extraordinary thermal stresses during hard braking. High-g decelerations typical of passenger vehicles are known to generate temperatures as high as 900 C in a fraction of a second. These large temperature excursions have two possible outcomes: thermal shock that generates surface cracks; and/or large amounts of plastic deformation in the brake rotor. In the absence of thermal shock, a relatively small number of high-g braking cycles are found to generate macroscopic cracks running through the rotor thickness and along the radius of the disc brake.

Heat generation due to friction in the sliding contact of two bodies influences friction and wear characteristics of brake systems. We note that numerous experimental evidences suggest that the contact area is generally circular, e.g. tread broke railway wheels exhibit circular thermally affected zones on the surface.

V. WORKING

The working of this project gets accomplished in four stages

Fig. 2: Parts of the Setup

Stage 1

The base forms the rigid construction, which supports the brake elements. In practical, the disc rotor of the disc brake rotates with the wheel of the car as it is coupled to the wheel. But here in order to make the disc rotor rotate, the three phase motor is coupled mechanically with the disc rotor. Thus, the disc rotor rotates with the motor drive.

The motor runs with the help of electrical energy. This in turn rotates the coupling rod. This coupling rod transmits its whole energy to the knuckle joint. The knuckle joint is used in order to make the energy transmission possible in some inclined positions also. Thereby the knuckle joint rotation delivers the motion in the coupling rod to the rod which connects the disc rotor. Since the disc rotor is connected to this rod by means of the fixed joint the same number of rotations is produced in the disc rotor also. Hereby this stage makes its work done with the transmission of motion from the motor to the disc rotor

Stage 2

In this stage the braking work is done.

The brake is applied through the lever. The lever actuated master cylinder distributes its pressure equally in the brake fluid through the brake line. The pressure is distributed equally due to the Pascal's law.

Pascal's law states that the pressure exerted anywhere in a confined incompressible fluid is transmitted equally in all directions throughout the fluid such that the pressure variations (initial differences) remain the same.

This pressure in the brake fluid is delivered to the disc brake caliper. The brake caliper constitutes the actuator which produces the linear motion from the pressure energy with the aid of piston and cylinder arrangement. The rod end of the cylinder is attached to the brake pad by means of resin. Thus the linear motion of the piston makes a linear movement of the brake pads.

Generally there are two brake pads situated on either sides of the disc brake rotor. These two brake pads work together

symmetrically to oppose the motion produced by the disc brake rotor to put an end to the rotation of the wheel.

When the brake pads come in contact with the brake rotor the frictional force is produced which is proportional to the pressure applied in the lever. This frictional force is the opposing force, which opposes the motion of the disc brake rotor. This frictional force stops the motion of the wheel by converting the kinetic energy of the rotating disc rotor into heat energy.

The typical generic "normal driving" temperature range for well balanced vehicle brakes is 100 to 200 degrees. A controlled mountain grade descent can produce brake temperatures between 200 to 400 degrees. In extreme cases the brake resin odor is produced at about 550 degrees and visible smoke is produced at 850 degrees. Thus this proves that the temperature rise in the disc brakes are destructive. Even in some cases this temperature would reach above the boiling point of the brake fluid. This in turn vaporizes the brake fluid which makes the brake jam.

Therefore in this stage the braking action is done where the heat is released which causes some alien actions.

Fig. 3: Setup after Fabrication

Stage 3

In this stage the heat generated in the disc brake rotor is alleviated. The forced convection is the salvager here.

Forced convection is a mechanism, or a type of transport in which fluid motion is generated by an external source. It should be considered as one of the main methods of useful heat transfer as significant amounts of heat energy can be transported very effectively.

The forced convection can be produced with the help of the fluids (either liquid or gas). After the disc brake rotor becomes red hot, if the chilled water is used for the forced convection it could drastically change the properties of the disc brake rotor since they are made up of the cast iron. Thus the usage of liquid for the forced convection is surely not a good idea. In addition, the storage of this liquid for the forced convection needs some extra effort and they gets pared from the usage. And hence they are not favorable for the continuous supply.

The next option is the forced convection technique with the help of the gas. Here the forced convection is produced

with the help of a mini car compressor because they can create the sufficient convection, besides they are compact. The mini car compressor can operate with the 12V direct current where the battery can offer this enough current. The mini car compressor can produce even 15 bar compressed air. The air is an inexhaustible gas which can be used for the continuous supply.

The air from the atmosphere is taken directly by the mini car compressor since they are inbuilt with the filter, regulator and lubricator. This air is compressed at about 15bar pressure and is delivered to the disc brake rotor through the convection line by means of a specially designed nozzle. This nozzle could further increase the velocity of air which is a present for the forced convection technique.

Thus this stage enhances the heat dissipation from the disc brake rotor by means of the forced convection technique.

Stage 4

Even though the forced convection technique is applied, the temperature of the disc brake rotor may increase above the safe value sometimes. If the driver runs the vehicle with this elevated temperature, it could possibly end up with the several disc brake problems like wear of the brake pads, wear of the rotor disc, reduction in the friction between the disc brake rotor and the brake pads, vaporization of the brake fluid resulting in the brake jam and so on.

So this stage helps to knock out the above mentioned problems. Here the non-contact type temperature detector is used to detect the temperature of the disc brake rotor. This non-contact type temperature detector is coupled to the micro controller chip. The micro controller is connected to the notification light present in the dash board of the car. Here the non-contact type temperature detector detects the temperature of the disc brake rotor and sends this signal to the micro controller. This micro controller analyzes this signal by comparing it with the stored data in its memory. The micro controller can distinct the favorable temperature of the disc brake rotor from the unfavorable temperature. Thus when the temperature of the disc brake rotor reaches the unfavorable temperature the micro controller notifies the driver through the notification light present in the dash board of the car.

Thus the driver gets the idea that if he runs the car further then it could result in the unfavorable reactions. This asks the driver that he could give some rest to his car by parking the car for some time until the temperature reaches the safe limit.

Thus this stage is the advantageous stage by which the above mentioned problems are completely eliminated.

VI. ANALYSING THE HEAT DISSIPATION

The heat dissipation of the disc brake rotor is compared before and after the installation of the enhanced temperature control in disc brakes. The results are taken in a graph by taking speed of the vehicle in x axis and the temperature of the disc brake rotor in y axis. The visual representations of the result are as follows and here the green line indicates the safe limit.

Fig. 4: Comparison of Temperature and Speed before the Installation of the Enhanced Temperature Control in Disc Brakes

Fig. 5: Comparison of Temperature and Speed After the Installation of the Enhanced Temperature Control in Disc Brakes

It is obvious from the above graphs that before the installation of the enhanced temperature control in disc brakes the temperature reaches above the safe value when the brakes applied at normal driving condition while the vehicles running at about 80 Km/hr.

Whereas after the installation of the enhanced temperature control in disc brakes the temperature value of the disc brake rotor lies below the safe vale. Thus there is a clear view that the enhanced temperature control in the disc brakes could considerably improve the heat dissipation in the rotor of the disc brakes and can probably improve the performance and life of the disc brakes.

VII. CONCLUSION

The provision of the compressed air unit and the sensor unit is not a serious problem as the space available in the automobiles is ample. Thus this installation can be easily carried out through the slight modification in the automobiles which is suitable for all the automobiles including from the low end cars. To wrap up, this enhanced temperature control in disc brakes assures that it can create an extra ordinary satisfaction in case of the disc brakes and can increase their attractiveness.

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