# Scientific Study of Mechanical Cracking on Disc Brake

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**Abstract-Disc brake are subjected to a large amount of frictional force during its regular working. In case of hard braking the temperature of the brake disc rotor rises above 700$^0$ C. High temperature results in plastic deformation of brake disc which to localized surface contact and development of hots spot. Hot spots develop large thermal gradient resulting in three possible outcomes: thermal shocks, low braking performance and low cycle thermal mechanical stresses which result in cracking of brake disc. An analysis of vehicle dynamics was performed to calculate the mechanical stresses developed in the rotor and to find heat flux equation. Heat flux equation was further used to estimate thermal stresses developed in the rotor. In order to improve braking performance by cooling of rotor, different fluids were used. Above results were simulated in ANNSYS software and the results obtained were interpreted with analytical results.**

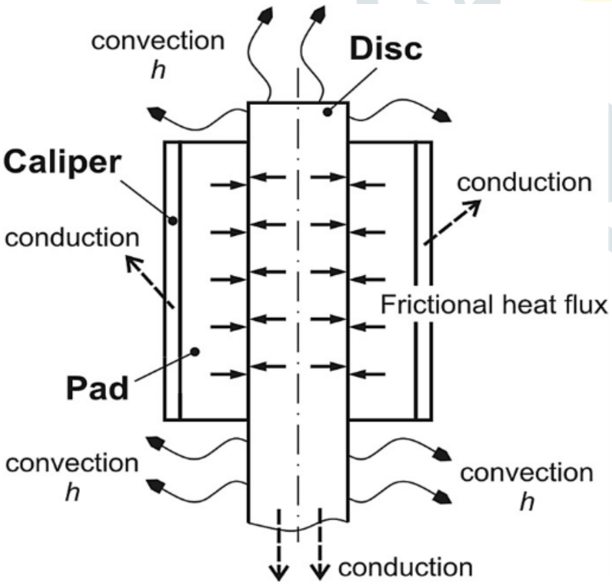
***Keywords—Disc Brakes, Hotspots, Thermal judder, Thermal cracking.***

## I. INTRODUCTION-

The braking system is a most important factor of design and manufacturing of any vehicle. The function of the braking system is to retard or stop the motion of the vehicle. The braking system is directly related to the safety of the driver, passengers, and people on the road. Generally, two types of braking systems are used in automobile sectors such as disc brakes and drum brakes. The basic principle of the braking system is to convert the kinetic energy of the vehicle into thermal energy. To stop the vehicle, friction is created between two mechanical components, giving rise to heat generated between those two components and reduction in kinetic energy of vehicle i.e. decreases vehicle velocity

### A. Disc Brake-

The disc brake is one of the latest technology in the automobile industry. Disc brake consists of four main parts such as disc rotor, caliper, pads and master cylinder which assembled together for the proper working of the disc brake. Disc rotor is rotating part of the disc brake assembly which is normally located on the front axle of the vehicle. Master cylinder is used to apply hydraulic pressure through brake fluid. When the brake pedal is pressed, the fluid from master cylinder pushes the piston from caliper and pad comes in contact with rotating disc. Friction between the pad and disc rotor retards the motion of the vehicle and finally vehicles stops.




### B. Thermal cracking –

Disc brakes are exposed to large thermal stresses during normal braking and very high thermal stresses during sudden and hard braking. Typical passenger vehicles generate almost as high as 900 $^0$C temperature in a fraction of a second. The possible outcomes of high-temperature excursions are:

Surface cracks developed due to thermal stresses; and/or large amounts of plastic deformation in the brake rotor. In the absence of thermal shock, a relatively small number of high-braking cycles are found to generate macroscopic cracks running through the rotor thickness and along the radius of the disc brake.

## II. LITERATURE REVIEW

❖ **RESEARCH WORK :-**

**Saiprasit Koctniyom** has experimented on **"Thermal Stress Analysis of Automotive Disc Brakes"**. The aim of this paper was to study and find out the thermal response of brake disc by using Finite Element Method. Rotor of disc brake is generally made up of Cast Iron. Due to friction, heat is generated between disc pad and rotor. This results in rise in temperature of rotor. Sometimes high thermal stresses developed in rotor which can lead to permanent plastic deformation in brake disc.

The experiment was carried out to investigate properties of rotor materials in compression and tension with respect to temperature. The results obtained from this experiment used to generate Finite Element material model which is used for analysis of stresses and temperature.

Experiment concludes that, Finite Element technique is used to plot approximate results of thermal stresses and temperature. Validity of these results depends on physical inputs, material properties and boundary conditions given to the system. Elastic Stress analysis failed to investigate thermal response but was used to find deformation in rotor of disc brake under thermal loading conditions.

**G P Voller et. al.,** have worked on "**Analysis of automotive disc brake cooling characteristics"**. The aim of the experiment was to study cooling characteristics of brake discs by using Computational Fluid Dynamics (CFD). All three modes of heat transfer were taken under consideration for the analysis of brake disc. Test rig was created to perform actual experiment in which disc is mounted on shaft and rotated at the speed of 1700 rpm. Sudden braking was implemented so that, due to friction between pad and disc the temperature of brake system was raised. Due to temperature difference heat gets transfer from surface of disc to the surrounding air. From experimentation convective heat transfer coefficient is calculated and results were compared with output obtained by CFD analysis.

This paper proposes that heat transfer in disc takes place in the form of conduction, convection and radiation. This experiment proves that 18% of heat transfers by conduction, 39% heat transfers by convection and 43% heat transfers by radiation. [4] Optimization and validation of thermal cracking phenomenon in disc brake by fluid films .

**Faramarz Talati et. al.,** have studied on **"Analysis of heat conduction in a disk brake system"**. In this paper analytical calculations were made for disc and pad in the form of transient heat equation by considering heat generation with respect to time and space. For calculating heat generated in brake disc, dimensions of rotor, speed of vehicle, material properties of disc and pad had been taken in to consideration. Calculations are made by considering two theories that are Uniform Pressure Theory and Uniform Wear Theory.

Results obtained from calculations prove that maximum temperature obtained in case of uniform pressure theory is higher than maximum temperature obtained by uniform wear theory. At the beginning of braking the heat generated due to friction is more as vehicle is moving with high velocity, sliding friction is more. Because of braking sliding friction decreases so, heat generation decreases. So at the end of braking i.e. when vehicle stops heat generated reduces to zero. Maximum temperature is obtained at the middle of braking period. For efficient working of rotor of brake disc, air should be circulated over the rotor to increase cooling rate.

**Pyung Hwang et. al.,** have worked on **"Investigation of temperature and thermal stress in disc brake based on 3D thermo-mechanical coupling model".** The objective of this paper is to obtain temperature and thermal stresses in rotor and pad during single brake. The assumption made in this paper is that rotor is decelerated with initial velocity with constant acceleration until rotor comes to stop.

For preparation of coupling model, calculations of contact pressure distribution in contact pair and heat flux were made to obtain the temperature field in the disc and pad. Then by using this temperature, thermal stress and thermal distortion in disc and pad calculated. To validate results, obtain by simulation, an experimental investigation is carried out to determine the temperature distribution in the brake disc.

This paper concludes that, the temperature of disc and pad affects the thermal expansion and leads to variation of contact pressure distribution. Due to the heat generation between disc and pad decrease, conduction in the disc and convection on the surface of brake disc decreases. Lower temperature in the vanes is due to the effect of disc conductivity and higher convection in the vanes. Fluctuations in node temperature are Optimization and validation of thermal cracking phenomenon in disc brake by fluid films present on the work surface of disc. The thermal strain and thermal stress distributions varies with the temperature distribution.

**V.M.M. Thilak et. al.,** have worked on **"Transient Thermal and Structural Analysis of the Rotor Disc of Disc Brake"**. The main objective of this paper is to observe performance of brake disc of car under various braking conditions. The aim of this paper is to improve braking efficiency and provide greater stability to vehicle by using new materials for assembly of disc brake. Attempts were made to find out new composite materials which are lighter than grey cast iron.

**Adam Adamowicz et. al., s**have worked on **"Influence of convective cooling on a disc brake temperature distribution during repetitive braking"**. The aim of this paper is to study the impact of convection heat transfer on temperature of surface of disc brake during constant braking condition. Due to sliding friction between pad and rotor of disc brake heat is generated in disc. The assumption made in this paper is vehicle is moving with constant velocity. Transient thermal analysis is used for determining temperature distribution on the surface of disc brake.

The paper concludes that, for single braking, convective heat transfer mode does not lower temperature of rotor significantly. Only 3% surface temperature decreases by convection mode of heat transfer. Convective heat transfer is unable to reduce overheating of rotor.

**A.A. Yevtushenko et. al.,** has proposed on **"Modelling of the frictional heating in brake system with thermal resistance on a contact surface and convective cooling on a free surface of a pad"**. In this paper mathematical model of frictional heating in disc and pad braking system is proposed. For this thermal resistance of disc and pad and convective mode of heat transfer taken in to consideration. This paper deals with numerical analysis of heat generated due to sliding friction assuming constant velocity and constant deceleration.
For experimentation, two types of sliding of the pad on the rotor of disc have been considered separately with a constant speed and with a constant deceleration. It concludes that, for the particular values of the input parameters, it follows the already known solutions from the obtained ones. In this paper main attention has been paid to study the influence of the Biot numbers on the temperature and heat transfer through the surface of friction and convective cooling on the free surface of the pad. This paper gives information about how to construct maps of isotherms of temperature in relation to the Biot numbers and beneficial to get information about how to select the Biot numbers such that required temperature level of the sliding surfaces of the pad and the disc can be achieved.

**A.A. Yevtushenko et. al.,** have worked on **"Mutual influence of the sliding velocity and temperature in frictional heating of the thermally nonlinear disc brake"**. This paper deals with FE analysis of transient temperature fields by using three dimensional FE contact model of a disc brake which is dependent on temperature coefficient of friction and thermos physical properties. In this paper, it was assumed that the contact pressure increases exponentially with time to nominal value.
This assumption helps to maintain the work done during braking equal irrespective of the changes in operating parameters. By this the transient temperature fields in the pad and the disc, braking time and the distance can be calculated and confronted with the data calculated at the constant coefficient of friction at atmospheric temperature. Due to the variation of contact pressure from zero at the initial point in braking time to nominal value there is slight decrease in sliding and heat flux acting which is on the friction surfaces first increases to maximum value and then decreases at the moment of stopping. [13] Optimization and validation of thermal cracking phenomenon in disc brake by fluid films.

**Ali Belhocine et. al.,** worked on **"Thermal analysis of a solid brake disc"**. Braking is a process which converts the kinetic energy of the vehicle into mechanical energy which must be dissipated in the form of heat. During the braking phase, the frictional heat generated at the interface disc pads can lead to high temperatures. This phenomenon is even more important that the tangential stress as well as the relative sliding speeds in contact is important. The aim of this paper was to analyse the thermal behaviour of the full and ventilated brake discs of the vehicles using computing code ANSYS. The modelling of the temperature distribution in the disc brake is used to identify all the factors and the entering parameters concerned at the time of the braking operation such as the type of braking, the geometric design of the disc and the used material. The results obtained by the simulation are satisfactory compared with those of the specialized literature.
This study concludes that; radial ventilation plays a very significant role in cooling of the disc in the braking phase. The heat dissipation in ventilated disc is more as compared to solid disc. So, the heat generated in ventilated disc is less and therefore, chances of failure of disc due to overheating reduce in case of ventilated disc.

**Jean Thevenet et. al.,** have experimented on **"Measurements of brake disc surface temperature and emissivity by two-colour pyrometry"**. In this paper a fibre optic two-colour pyrometer was developed for brake disc surface temperature and emissivity measurements. The two-colour pyrometer consists of a fluoride glass optical fibre, two Hg-Cd-Te detectors equipped with bandwidth filters and a data conditioning and acquisition device. The two-colour pyrometer measures the brake disc temperature in the 200 $^0$C to 800 $^0$C range with a time resolution of 8ls. The calibration formula for the signals obtained using a blackbody of known temperature was used to compute the true temperature. The uncertainty estimation for temperature and emissivity was obtained from the calibration results. Tests were carried out on known temperature target and a good correlation was found between results obtained with our two-colour pyrometer and those obtained with a commercial two-colour pyrometer. Hold braking and deceleration braking tests performed on a braking test bench enabled to reach the brake disc surface temperature and emissivity during braking. Experimental results show a significant Optimization and validation of thermal cracking phenomenon in disc brake by fluid films variation of emissivity during braking. Direct measurement of emissivity was carried out on the brake disc after braking and shows the emissivity dependence with the surface quality.
This paper concludes that, a fibre optic two-colour pyrometer with a short time response
(8ls) and a small measurement spot (2.4 mm) capable of measuring the brake disc surface temperature and emissivity in the 200 $^0$C to800 $^0$C range has been developed. The two-colour device consists of a fluoride glass fibre, two Hg-Cd-Te detectors equipped with band width filters and a data conditioning and acquisition device. The two colour pyrometer was calibrated using an extended blackbody. Tests were carried out on known temperature target and a good correlation was found between results obtained with two-colour pyrometer and those obtained with a commercial two-colour pyrometer. Some experiments carried out on a braking test bench enabled to reach the transient brake disc surface temperature during braking and proved the importance of the emissivity on the measurement of the disc surface temperature. A significant variation of the emissivity has been observed for both hold braking and deceleration braking. Direct measurement of emissivity carried out on the brake disc after braking shows the emissivity dependence with the surface oxidation. Further, the two-colour pyrometer can be used to investigate the temperature effect on the tribological behaviour of the brake disc during braking.

## III. FUTURE SCOPE –

- Effect of fluid film on brake disc is not much studied topic and therefore much more research needs to be done over it.
- The modifications suggested in this projects can be further improved and refined.
- The system if combined with brake booster could be a valuable replacement for ABS as control over the frictional forces is possible using fluid spray.
- Also the cost of the system in far less as compared to ABS.

- If circulation of fluid is possible via caliper, then it would help to reduce caliper temperature further reducing the boiling of brake fluid.

## IV. CONCLUSION –

When the vehicle is in the motion it possesses the kinetic energy to stop the vehicle. This kinetic energy should be converted into another form. Disc brakes are used to stop the vehicles or to reduce the speed of the vehicle.
In this process, when brakes are applied, brake pads come in contact with the disc so that friction is created and heat is generated.
To get proper braking efficiency and avoid failure of disc proper dissipation of heat is required. Heat can be dissipated in the form of conduction, convection or radiation. If the heat generated in the system is not dissipated in adequate amounts it results in the formation of hot spots and thermal judder which ultimately results in the formation of cracks.
To reduce this failure, the proper material should be selected for manufacturing of disc. Proper ventilation, if provided in the disc, can increase the airflow and improves the convection rate.Thus heat dissipation gets faster

## V. REFERENCES -

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