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"A REVIEW ON THERMAL ANALYSIS ON CAR DISC BRAKE ROTOR"

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ABSTRACT

Safety aspect in automotive engineering has been considered as a number one priority in development of new vehicle. Brakes convert friction to heat, but it the brakes get too hot, they will cease to work because they cannot dissipate enough heat. Ventilated disc brake is the state of the art technology in automobile brake system .In this study FEA approach has been conducted in order to identify the temperature distributions and behavior of disc brake rotor in transient state. This paper reviews work of previous investigators on Structure and transient analysis on the vented disk rotor and rotor designs to evaluate and compare their performance.

Keyword: *Structure and Transient analysis, ANSYS, FEA, Ventilated disc brake*

I. INTRODUCTION

The disc brake is of two type solid full and ventilated. The disc brake is a device for slowing or stopping the rotation of a wheel. A brake disc (or rotor) usually made of cast iron or ceramic composites (including carbon, Kevlar and silica), is connected to the wheel and/or the axle. To stop the wheel, friction material in the form of brake pads (mounted on a device called a brake caliper) is forced mechanically, hydraulically, pneumatically or electromagnetically against both sides of the disc. These brakes offer better stopping performance than comparable drum brakes, including resistance to "brake fade" caused by the overheating of brake components, and are able to recover quickly from immersion (wet brakes are less effective). Discs have now become the more common form in most passenger vehicles, although many (particularly light weight vehicles) use drum brakes on the rear wheels to keep costs and weight down as well as to simplify the provisions for a parking brake. As the front brakes perform most of the braking effort, this can be a reasonable compromise.

Friction brakes act by generating frictional forces as two or more surfaces rub against another. The stopping power or capacity of a friction brake depends on the area in contact and coefficient of friction of the working surfaces as well as on the actuation pressure applied. Wear occurs on the working surfaces, and the durability of a given brake (or service life between maintenance) depends on the type of friction material used for the replaceable surfaces of the brake. If drake disc are in solid body the Heat transfer rate is low. Time taken for cooling the disc is low. If brake disc are in solid body, the area of contact between Disc and Pads are more, so efficiency of brake is high. We introduced variation in vanes pattern on the disc in ventilated disc brake. The Heat transfer rate is increase. Time taken for cooling the disc is high. It has been seen that the generation of huge amount of temperature on disc surface during braking needed to be dissipated as efficiently and soon as possible.

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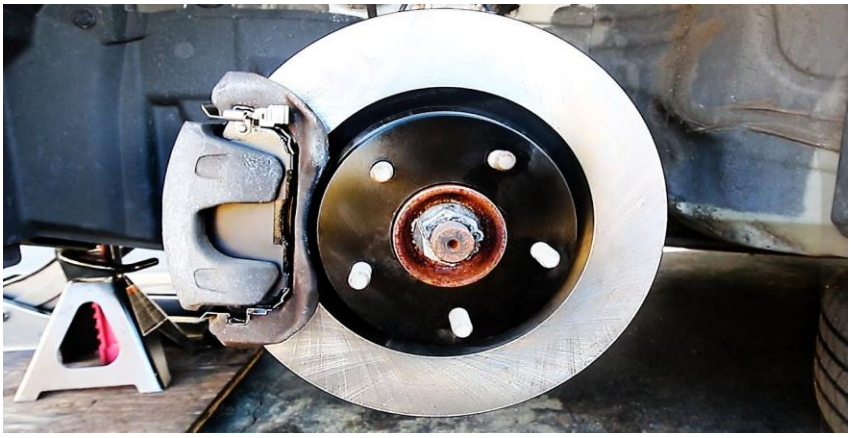

Fig.1 Car Rotor Disc

It's observed that many factors are responsible which restricts heat dissipation, ultimately leading to brake failure due to situation like brake fade and judder. Factors such as Vehicle speed, type of braking (Emergency braking or repetitive breaking), rotor geometry and dimension, disc or pad materials (Cast iron, Aluminium metal matrix composite, ceramics etc), contact pressure distribution etc are some certain factors which can be varied to achieve a satisfactory heat dispersion.

II. LITERATURE REVIEW

Pravin Mohan and Patel Sudheendra S **[2017]** The following work studies a conceptual design of a disc brake system. Disc brakes offer higher performance braking, simpler design, lighter weight, and better resistance to water interference than drum brakes. The aim of this conceptual design was to increase the strength of the caliper, without increasing the weight of the caliper by a large amount and reducing the thermal deformation at high operating temperatures. Since titanium is difficult to machine the mono block design of conventional machined caliper was not used in this work but an attempt was made to build a brake caliper with different parts and assembled together to make a single unit. Also titanium parts used were machined from plates with no complicated shapes to save on machining costs in future. Since titanium has higher mass density care was taken while designing the new brake system to keep the weight increase to minimum. The existing brake caliper was analyzed for given load conditions with new material suggested.
The results were studied for displacements and stresses along with thermal effects. The new modular caliper was analyzed for pressure and tangential load sand the results were studied for displacements/deformation and stresses with temperature effects.

[1] S. Arvin Rao, Muhamad Anuwar Jusoh, Abd Rahim Abu Bakar***,(2017)**Brakes squeal has remained to be one of the major Noise, Vibration and Harshness (NSH) challenges in brake system design and development. It has been a concern for automotive industry for decade. Brake researchers have proposed many brake squeal reduction and prevention methods in order to overcome and reduce the squeal that emanates from the brake disc systems. In this paper, the effectiveness of constrained layer dampers (CLD) in reducing disc brake squeal noise was investigated. CLD isolates the brake squeal noise through shear deformations of the viscoelastic materials. Two sets of brake tests were conducted using the brake test dynamometer with the application of CLD. Two different types of CLD were used which are three-layer constrained layer damper and four-layer constrained layer damper. Squeal tests were carried out using brake noise test rig based on the global standard procedure SAE J2521. From the test, four-layer CLD configuration works more efficient than three-layer CLD configuration. CLD made up of nitrile butadiene rubber, silicone rubber and mild steel proved to be the most effective noise insulator at hydraulic pressure range of 5 bar to 30 bar and temperature range of 50^{o}C to 200^{o}C with a maximum noise reduction of 11.3 dBA. Thus, CLD technique was proven to be an effective method in reducing brake squeal noise.

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[2] Mahmood Hasan Dakhil[1]el (2015) paper presents optimized design of performance of disc brake using finite element analysis is to evaluate the performance under severe braking conditions. Cast iron and stainless steel are used as disc brake materials. ANSYS 12.0 is a dedicated Finite element package used for determining the temperature distribution, variation of stresses and deformation across the disc brake. It has been made to investigate the effect of the temperature distribution with the deformed shape and stress distribution of disc brake rotor design by using different braking conditions. From the results of the above data, the service life and long term stability is ensured. A steady static structure analysis has been carried out to investigate the temperature variation across the disc using the axis symmetric finite elements. Further structural analysis is also carried out by Coupled Field Analysis. An attempt is also made to suggest a best combustion of material, flange width and wall thickness used for disc brake rotor, which yields a low temperature variation across the rotor, less deformation and minimum Von-misses stress possible.

Calculations for 10mm flange width:

Step-1: Kinetic Energy (K.E) = ½*m*v^2
= ½*1800*31.112
= 871048.89 Joules
The above said is the total kinetic Energy induced while the vehicle is under motion [12].

Step-2: The total kinetic energy = The heat generated
Q_g = 87104.889 Joules
The heat generated / wheel = 87104.89/4 Joules
=217762.222 Joules

Step-3: the heat generated by four wheels is obtained from the above calculation i.e. 217762.222 Joules.
The Area of the rubbing faces A = 2* Π * (0.2 – 0.1036) * 0.01 = 0.00605 m^2
Heat Flux = Heat Generated / Time / twice the projected area
= 217762.222 / 4 / 2 * 0.00605
= 4499219.4 Watts / m^2

The analysis is done by taking the Brake Efficiency of 30% and hence the distribution of braking torque between the front and rear axle is 70:30. Thus Heat Flux = 4499219.4 * 0.7 = 3149453.62 Watts / m^2 since the wall thickness did not involve in the disc brake calculations; the valve of the heat flux does not change wall thickness.

[3] Yugesh Anil Kharche and Prof. Dheeraj Verma [2014] The disc brake is a device for decelerating or stopping the rotation of a wheel. Braking is a process which converts the kinetic energy of the vehicle into mechanical energy which must be dissipated in the form of heat. This paper presents the analysis of the contact pressure distributions at the disc interfaces using a detailed 3-dimensional finite element model of a real car disc brake. Finite element (FE) models of the brake-disc are created using Pro-E and simulated using ANSYS which is based on the finite element method (FEM). It is also investigates different levels in modelling a disc brake system and simulating contact pressure distributions at varying load. It covers Finite Element Method approaches in the automotive industry the Contact analysis and thermal analysis. The effect of the angular velocity and the contact pressure distribution on temperature rise of disc brake was investigated. Wear in friction material means that reduction of its life span. The more the wear, the sooner the frictional material needs to be replaced. Different Brake pad material is tested as compared with the existing one. Finally comparison between analytical results and result obtained from Ansys carried out, and all the values obtained from the analysis are less than their allowable values. Hence on the basis of thermal and contact stress analysis best suitable material is suggested.

[4] K. M. Muniswamy et al. (2013), heat transfer enhancement on ventilated brake disk with blade inclination angle variation. The objective of the current study is to investigate the potential heat transfer enhancements in ventilated brake disk by varying the geometrical parameters of the blades inside the flow passage. The thickness remains constant and only the length can be changed to fit the inner and outer radius. The computational model constructed in GAMBIT. The models are solved using ANSYS-FLUENT proprietary software package. The results show a tremendous increase in the

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heat transfer rate with blade inclination angle configurations as compared to conventional straight blade. The Nusselt number is found to be in a power-law relationship with the Reynolds number. Distinct relationship between laminar and turbulent condition is predicted.

[5] K. Sowjanya & S.Suresh (2013), presented paper on Structural analysis of disk brake rotor. Disc brake is usually made of Cast iron, so it is being selected for investigating the effect of strength variations on the predicted stress distributions. Aluminum Metal Matrix Composite materials are selected and analyzed. The domain is considered as axis-symmetric, inertia and body force effects are negligible during the analysis. The model of Disc brake is developed by using Solid modeling software Pro/E (Cero-Parametric 1.0).Further Static Analysis is done by using ANSYS Workbench. Thermal solution to the structural analysis and the maximum Von Misses stress was observed to be 50.334 M Pa for CI, 211.98 M Pa for AlMMC1, and 566.7 M Pa for AlMMC2, the Brake disc design is safe based on the Strength and Rigidity Criteria.

[6] Zhang Jiang& Xia Changgao (2012), research of the transient temperature field and friction properties on disc brakes. The 3D transient and cyclic symmetry finite element model of the temperature field of the ventilation caliper disc brake in a long downhill braking condition was established in this paper. The finite element modeling for three-dimensional transient cyclic symmetry during the long downhill braking is established. The variation of the friction factor combined with the temperature characteristics of the friction factor during the braking are analyzed. Analysis is done by using finite element software ANSYS. During the braking, the temperature of the brake rises increasingly and reaches the top temperature of 316.04℃ at the end of braking process; the high temperature section concentrates in the far area of the friction surface. The maximum rate of recession is 8.16%, friction coefficient is always stable within a reasonable range, and the obvious thermal recession is not happened

.[7] Piotr Grzes & Adam Adamowicz (2011), presented paper on analysis of disc brake temperature distribution during single braking under non-axisymmetric load . First step of the analysis based on the previously developed model where the intensity of heat flux was assumed to be uniformly distributed on the friction surface of disc during braking process, and the heat is transferred exclusively in axial direction, whereas during the second, the three dimensional rotor is subjected to the non-ax symmetric thermal load to simulate realistic thermal behaviour of the brake action. Operation conditions, thermo-physical properties of materials and dimensions of the brake system were adopted from the real representation of the braking process of the passenger vehicle. Arbitrarily selected four values of the velocities at the moment of brake engagement were applied to the models so as to investigate theirs influence on the obtained solutions of the temperature evolutions on the contact surface of the disc volume referring to two separated finite element analysis.

[8] JIANG LAN et al. (2011), presented paper on thermal analysis for brake disk of Sci/6061 Al.Alloy co-continuous composite for CRH3 during emergency braking considering air flow Cooling. The thermal and stress analyses of SiCn/Al brake disk during emergency braking at a speed of 300 km/h considering airflow cooling were investigated using finite element(FE) and computational fluid dynamics (CFD) methods. All three modes of heat transfer wereanalyzed. The highest temperature after emergency braking was 461 °C and 359 °C without and with considering airflow cooling, respectively. The equivalent stress could reach 269 MPa and 164 MPa without and with considering airflow cooling, respectively. The airflow through and around the brake disk was analyzed using the Solidwork2012 simulation software package. The results suggested that the higher convection coefficients achieved with airflow cooling will not only reduce the maximum temperature in the braking but also reduce the thermal gradients, since heat will be removed faster from hotter parts of the disk.

[9] Oder G. et al. (2009), worked on thermal and stress analysis of brake discs in railway vehicles. Performed analysis deals with two cases of braking; the first case considers braking to a standstill; the second case considers braking on a hill and maintaining a constant speed. In both cases the main boundary condition is the heat flux on the braking surfaces and the holding force of the brake calipers. In addition the centrifugal load is considered. Finite element method (FEM) approach is been used, 3D model has been modelled for analysis. Brake disc material is rounded graphite; two types of disc considered for studies one without wear and one with 7mm wear on both sides. Maximum speed is 250 km/hr and the ambient and initial disc and surrounding temperature is 50 C Temperatures and stress in discs under different loads

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are very high. Although they are fulfilling the buyer's requirements for safety, this investigation not considered shearing forces, residual stress and the cyclic loads during brake discs lifespan. The results need to be compared with experimental results.

[10] Zaid, *et al*. (2009) presented a paper on an investigation of disc brake rotor by Finite element analysis. In this paper, the author has conducted a study on ventilated disc brake rotor of normal passenger vehicle with full load of capacity. The study is more likely concern of heat and temperature distribution on disc brake rotor. In this study, finite element analysis approached has been conducted in order to identify the temperature distributions and behaviors of disc brake rotor in transient response. Modeling is done in CATIA & ABAQUS/CAE has been used as finite elements software to perform the thermal analysis on transient response. Material used is Grey cast iron, with maximum permissible temperature 550 C. For load analysis 10 cycles of breaking and 10 cycles without breaking (idle) operation is considered total of 350 seconds. Result provided during 1st, 5^{th} and during 10th cycle. Thus, this sure study provide better understanding on the thermal characteristic of disc brake rotor and assist the automotive industry in developing optimum and effective disc brake rotor.

[11] Talati and Jalalifar (2009), presented a paper on Analysis of heat conduction in a disk brake system. In this paper, the governing heat equations for the disk 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 disk 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 disk and the pad should be ideally dissipated to the environment to avoid decreasing the friction coefficient between the disk and the pad and to avoid the temperature rise of various brake components and brake fluid vaporization due to excessive heating

.[12] Choi and Lee, (2004) presented a paper on Finite element analysis of transient thermo elastic behaviors in disk brakes. A transient analysis for thermo elastic contact problem of disk brakes with frictional heat generation is performed using the finite element method. To analyze the thermo elastic phenomenon occurring in disk brakes, the coupled heat conduction and elastic equations (cylindrical coordinates) are solved with contact problem. Material used is carbon-carbon composite and wear is assumed negligible. The numerical simulation for the thermo elastic behaviour of disk brake is obtained in the repeated brake condition. The computational results are presented for the distributions of pressure and temperature on each friction surface between the contacting bodies. It is observed that the orthotropic disc brakes can provide better brake performance than the isotropic one because of uniform and mild pressure distribution.

III. CONCLUSION

The disc brake is a device for decelerating or stopping the rotation of a wheel. Braking is a process which converts the kinetic energy of the vehicle into mechanical energy which must be dissipated in the form of heat. This paper presents the analysis of the contact pressure distributions at the disc interfaces using a detailed 3-dimensional model of a real car disc brake. Determination of the braking force is the most crucial aspect to be considered while designing any braking system. The generated braking force should always be greater than the required braking force. The calculation of required clamping force helps us to decide the parameters of the disc brake rotor. Modeling and analysis o disc brake rotor is done to select the best material which is more durable. Space and assembly constraints are also an important factor while designing the rotor body. Find out the value of deformations and stresses due to cause of pressure.

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