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Thermal Analysis of Nonvented (Solid) Disc Brake Using ANSYS Software (A Review Paper)

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Abstract

The disc brakes are exposed to large thermal stresses and heat during routine braking. The extraordinary thermal stresses, tremendous heat occurred in the disc during hard braking. The aim of the project or research work is to design and analysis of disc. The modelling or design of the disc is done using solid works software. The Thermal analysis of disc brakes is to be done on the Non-vented condition using ANSYS software with different materials. The thermal analysis is done to analysis the thermal properties e.g. Thermal deformation and Heat flux. The comparison can be done for temperature distribution between different materials. In this analysis, the different materials to check which material are best. Solid works is a 3d modelling software widely used in the design process. The ANSYS software is general-purpose finite element analysis (FEA) software package for analysis. Finite Element Analysis is a numerical solution method of deconstructing the complex system into very small pieces called elements.

Keywords: ANSYS, rotor brake, solid works, structure and thermal analysis

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INTRODUCTION

The Brakes are the most important safety parts of the vehicles. The disc brake is a mechanical device to stop or slowing the rotation of the wheel. The braking pads are forced mechanically against the both surfaces on the rotor or disc which causes friction is always generated between the disc and pad. Friction causes the disc and attached wheel to slow or stop the vehicle. Due to the friction the heat is generated in the disc, but if the brakes get too hot, they will cease to work because they cannot dissipate enough heat. Disc brakes are exposed to huge thermal stresses or heat during routine braking. In short, the brakes change the kinetic energy of the car into heat energy, thus slowing its speed. Compare to the drum disc brake, the non-vented (solid) disc brakes get back to the normal temperature. In the case of non-vented disc, the disc is allow to additional air flow as compared to the drum brakes offer better stooping performance, because the disc is more readily cooled.[1]

LITERATURE OF REVIEW

Enderson *et al.* (1990) investigated the hot spotting in automotive friction system. When the sliding bodies of disc brake occurred significant frictional heating, thermo elastic deformation of the disc brake may lead to a change from smoothly distributed severity contact to a condition where the surfaces are supported by few thermal asperities. This situation may be associated with a change to a condition of severe wear because of the exalted contact pressure and temperature, and it is also because of production of tensile stresses.

This stress component may lead to heat evaluate upon which the rough checked surface acts to abrade the mating material.[2–6]

Floquet *et al.* (1994) determined the temperature distribution and comparison of simulation and experimental results in the disc brake by 2D thermal and structural analysis using axis-symmetric model. The disc brake used in the vehicle and the disc brake is divided into two parts rotating axis-symmetrical disc and other are stationary pads. The friction heat generated between disc and pad which cause high temperature occurred in the disc during the braking process. The effect of initial velocity and retardation on cooling of the brake disc was also observed. The thermal simulation is used to indicate the temperature distribution field of the disc with the appropriate boundary conditions.

A Finite element method was developed for determining the crucial sliding speed for thermo-elastic instability of an axis-symmetric clutch or brake. Linear jumbles on the stationary-speed solution were required that vary in sinusoidal form, in the circumferential way and grow exponentially in time.

These factors stop in the governing thermo-elastic and heat-conduction equations, leading to a linear Eigen value issue for the exponential growth rate on the two-dimensional cross-sectional field for each Fourier ripple number. The imaginary part of this increase rate corresponds to a migration of the perturbation in the circumferential direction.

The algorithm was experienced against a logical solution for a layer sliding between two half-planes and provided tremendous agreement, for both the crucial speed and the migration speed. Criteria were developed to determine the mesh refinement essential to give an adequate separate description of the thermal boundary layer adjacent to the sliding interface.
The process was used to determine the unstable mode and crucial speed in geometries similar to current multi-disc clutch practice.

Lee *et al.* (1995) studied the effect of intermittent contact on the stability of thermo-elastic Contact**,** the frictional heat generated during hard braking in the disc brake which causes thermo-elastic distortion that modified the contact pressure distribution. When the sliding speed of the disc brake was sufficiently high, that could lead to frictionally excited thermo-elastic instability. In automobile applications, a particular area of concerned the relation between thermo elastically induced hot spots in the brake discs and noise and vibration in the brake system.

Tsinopoulos *et al*. (1999) studied an advanced boundary element method was properly combined with the fast Fourier transform (FFT) to analysis general axis-symmetric problems in frequency domain. In this study the problems were classified by axis-symmetric geometry and non-axis-symmetric boundary conditions. The boundary quantities were prolonged in complex Fourier series in the circumferential way and the problem was efficiently decomposed into a series of trouble, which were solved by the BEM for the Fourier boundary quantities, discretizing only the surface generator of the axis-symmetric body. The quadratic boundary elements were used and BEM integrations were finished by FFT algorithm in the circumferential way and Gauss quadrature in the generator direction. The Fourier transformed solution was numerically inverted by the FFT, provided the final solution.[7–15]

Gao *et al*. (2007) investigated the Stress Analysis of Thermal Fatigue Fracture of

Brake Discs Based on Thermo-mechanical Coupling. The three dimensional thermal-structure coupling model, implemented transient stress analysis of thermoelastic contact of disc brakes with a frictional heat variation were developed and identified the source of the thermal fatigue. The transient thermoelastic analysis of disc brake rotor in an emergency brake application has been performed in this study. The thermal and structure coupling model was developed and applied to thermoelastic contact with frictional heat generation. The frictional heat flux coupling between the working surface of the disc and the pad was investigated, and the variation of the rotating speed during the braking process been taken to account. The analysis and simulation identified the interaction of frictional heat generation, thermal distortion and hot spot occurred at the working-surface of the disc, which was a precursor of critical hot spotting.

Kang (2009) studied the dynamic instability of a car brake system with a rotating disc in contact with two constant pads was investigated. For the actual geometric approximation, the disc was modelled as a hat disc shape structure by the finite element method. The contact pressure between the disc and pads was described in this study. The corresponding gyroscopic matrix of the disc is constructed by introducing the standardized planar-mesh method. The dynamic instability of a gyroscopic non-conservative brake system is numerically predicted with respect to structure parameters. The results illustrate that the squeal tendency for rotation speed depends on the vibration modes participating in squeal modes. In addition, it is highlighted that the negative slope of friction coefficient takes a significant role in generating squeal in the in plane torsion mode of the disc.

Soderberg and Andersson (2009) worked on simulation of wear and contact pressure distribution at the pad to disc (rotor) interface in a disc brake using finite element analysis software. The wear of the pad to rotor interface can be determined using finite element analysis software (Ansys software). A three dimensional finite element model of disc brake was developed to calculate the pressure distribution in the pad to disc or rotor contact. A wear simulation procedure based on a generalized form of Archard's wear law and obvious Euler integration is used to simulate the wear of the brake pad under steady state drag conditions.

The model can be used to study the behaviour of the pad to contact interface (disc) under different loads and running conditions. In its present condition the model is very easy and is therefore only suitable for design trend analysis, not for prediction of absolute values.

Shahzamanian *et al.* (2010) worked on the transient and thermal contact analysis for the elastic behaviour of brake disc due to mechanical and thermal loads. The transient and contact analysis of functionally graded (FG) brake disc was presented in the study. In this study the analysis of disc brake was carried out using ANSYS parametric design language (APDL). The brake disc was made of metal ceramic material. The material properties vary in radial direction with the values from full metal at the inner radius of the disc and full ceramic at the outer radius of the disc.

In this present study, FG brake disc was in contact with one pure pad disc and contact friction is considered as heat source. The non-dimensional results are obtained for the specific value of grading index (n=1) by considering different material property partitions of 25, 50, 100 and 200. The results are obtained for the pressure

distribution, total stress, strain, pad penetration, friction stress, heat flux and temperature during contact, for different values of contact stiffness factor, F_{kn}, which depends on the assets gradation of FG brake disk with 200 material property divisions. The results show that the contact pressure, deformation, temperature distribution and total stress increase with increasing values of F_{kn}. Hence, it can be concluded that the metal ceramic material have significant effect in the thermomechanical response of FG brake disks.

Thilak *et al.* (2011) investigated into the usage of new materials is required which improve the braking efficiency and give the better stability to vehicle. This investigation can be done using ANSYS software (FAM). ANSYS 11.0 is a dedicated finite element method used for determining the thermal and structural analysis. The variations of the stresses, strain deformation and temperature across the disc brake profile. In the present study investigate the suitable hybrid composite material which is lighter than as compared to cast iron and have good Young's modulus, Yield strength and density properties. Aluminium base metal matrix composite and high strength glass fibber composites have liberal friction and wear behaviour as a Disk brake rotor. The transient thermo elastic analysis of disc brakes in repeated braking applications have been performed and the results were compared. The suitable material for the braking operation was S2 glass fibber and all the values obtained from the analysis were less than their allowable values. Hence, the design of disc brake was safe based on the strength and rigidity criteria. By identifying the accurate design features, the extended service life and long term stability is assured.

Babukanth and Teja (2012) studied on the transient analysis of disc brake using ansys software. Due to the application of brakes in the car disc brake rotor, heat generation takes place due to friction between disc and pad. The thermal heat flux had been conducted and dispersed across the disc rotor cross section. The condition of braking was very much severe and thus the thermal analysis was carried out.

Belhocine and Bouchetra (2012) investigated on analysis the thermal behaviour of the full (non-vented) disc brake of the vehicle using ANSYS 11 software. The modelling of the temperature distribution in the disc brake is used to identify all the factors and the entering parameter anxious at the time of the braking operation such as the type of braking, the geometric of the disc, pad and the used material. The thermal and structural behaviour of three types of cast iron (AL FG 25, FG 20, FG 15) was done by ANSYS 11 for a determined braking mode. After the analysis the braking mode on the thermal behaviours of the discs brake were observed. The numerical simulation shows that solid disc plays a less significant role in cooling of the disc as compared vented disc in the braking phase.

Shahzamanian *et al.* (2013) studied on the finite element contact analysis of a functionally graded (FG) brake disc in contact with a pad. The brake disc is subjected to rotation, contact pressure, frictional heat. The material properties of disc brake are always varied through the thickness according to a power law characterized by a grading index, *n*. The contact surfaces of disc are full ceramic with full-metal free surface in the disc brake system. The effects of *n* on the deformation, contact status, strain, stress and temperature distribution are investigated. From the analysis, thermoelastic and contact results are tremendously dependent on *n*. Hence, *n* is a significant criteria for the design of FG brake disks for automotive and aircraft applications.

Parab *et al.* (2014) worked on structure and thermal analysis of disc brake. The aim of the present study is to design and model a disc. The modelling of the disc was done using catia software. The Structural and Thermal analysis was to be done on the disc brakes using with three materials Cast iron Stainless Steel and carbon-carbon composite materials. In this study structural analysis is done on the disc brake to validate the strength of the disc brake rotor and thermal analysis is done to analysis the thermal properties of the material. The comparison can be done for displacement, strain, stresses and temperature. Form the three materials to check which material is best for disc and pad. The Catia software is a 3d modelling software and widely used in the design process. ANSYS is the general-purpose finite element analysis (FEA) software package used for structure and thermal analysis. The Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces called elements.

Swapnil and Bhaskar (2014) studied the design and analysis of disc brake and shown the role of analysis of disc brake in present market conditions and identified some major problems in this field and their solutions from individual point of view. The action force and friction force on the disc brake are always occurred during braking. The new material which was used in disc brake works more efficiently and helps to reduce the accident that may happen in each day.

Tiwari *et al.* (2014) worked on finite element analysis of disc brake using ANSYS software. The utilization of new materials are needed which improve the braking efficiency and allow for larger reliability to vehicle. The suitable hybrid composite and ceramic materials which are lighter than as compared to structural steel and have good modulus of elasticity, density quality, Yield and ultimate strength. The low weight, hardness, static features moreover in case of high pressure and temperature of the resistance to thermal shock and the ductility provide long life time of the disk brake and keep off all difficulty leading of loading, which are typical for the classic grey cast iron brake disks.[2–8]

The thermo elastic analysis of disc brakes in replied brake applications has been executed. ANSYS work bench software is implemented to numerical and thermo elastic contact problem with frictional heat generation. To found the simulation of thermo elastic behaviour appearing in disc brakes, the heat conduction and elastic contact problems equations are solved. The effects of the friction material properties on the contact ratio of friction surfaces are examined and the larger significant properties are investigated to be the thermal expansion coefficient and the elastic modulus. It is analysed that the disc brakes can provide better brake performance than the because of uniform and mild pressure distributions. This study was provided useful design tool and improve the brake performance of disc brake system.

Nimhal *et al.* (2016) investigated the thermoelastic analysis of disc brake using ANSYS software. The solid (non-vented) type disc brake rotor of a vehicle was taken for investigation. The usage of Martensitic stainless steel and Ceramic material were done to improve the braking efficiency and provide better stability to the vehicle. The solid (non-vented) system plays the important role of cooling for the discs and provides a good elevated temperature resistance. Results after the analysis showed that, temperature, heat flux, deformation field, stress and strain filed in the process of braking phase were fully coupled. The Static structural

analysis is carried out by coupling the thermal solution to the structural analysis. The similar work was done to analysis disc assembly with the ceramic material having normal (non-vented) disc and the better results were found than that of using martensitic stainless steel.[10,11]

CONCLUSSION

After the analysis of disc brake with both material (Martensitic stainless steel and ceramic material), the Martensitic stainless steel was given better results as compared to other materials and the use of Non-Vented disc with Ceramic material is the best material for future scope due to its mechanical and material properties e.g. strength, heat resistance and wear resistance capacity.

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