

TEMPERATURE DISSIPATION AND THERMAL EXPANSION OF AUTOMOTIVE VEHICLE MULTI HOLES AND VANES IN BRAKE DISC

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Abstract: In automotive engineering, the safety aspect has been considered as a number one priority in development of a new vehicle. Each single system has been studied and developed in order to meet safety requirements. Instead of having air bags, good suspension systems, good handling and safe cornering, one of the most critical systems in a vehicle is the brake system. The objective of this work is to investigate and analyze the temperature distribution of rotor disc during braking operation using ANSYS Multi physics. The work uses the finite element analysis techniques to predict the temperature distribution on the full and ventilated brake discs and to identify the critical temperature of the rotor. The analysis also gives us the heat flux distribution for the two discs.

Keywords: Disc brake, Natural convection ,ANSYS, Disc Brake rotor, Structural analysis, Thermal stresses.

1. Introduction

The frictional heat is generated when two bodies slide against each other with a relative speed and a contact pressure. This frictional heat is generated at sliding or rolling interface of heel/brake shoe contact and wheel/rail contact.

The thermal aspect around the contact region can be studied by examining the heat transfer between stationary brake shoe and a moving body (relative to the heat source). The slip between wheel and braking system causes friction heating of both bodies. When a brake is working, the transformation of kinetic energy of moving masses into thermal energy takes place.

This kinetic energy is dissipated between two bodies and appreciably raises their temperature at the area of the sliding contact. Two aspects are of special importance in this analysis - the nature and distribution of heat partition into each body at the interface and the resultant temperature fields in the two bodies both at the interface and with respect to dept. While the time for reaching the quasi-steady-state conditions can be very short for a moving body, it can be relatively long for a stationary body.

Thus, it may require a long time to arrive at steady-state conditions for sliding. In this case, the heat partition fractions for the two bodies may also vary for

a long time before reaching steady-state value. The thermal distortion of a normally flat surface into a highly deformed state, called thermo elastic transition. It sometimes occurs in a sequence of stable continuously related states s operating conditions change. This invokes a feedback loop that comprises the localized elevation of frictional heating, the resultant localized bulging, a localized pressure increases as the result of bulging, and further elevation of frictional heating as the result of the pressure increase.

While railway wheels are heating by friction in the contact patch and in the contact brakes, there is also heat loss due to conduction through the contact patch into the rail and into brake shoe. A literature survey revealed that considerable attention has been devoted to the cooling and heating of rolling elements.

In a disc brake, the fluid from the master cylinder is forced into a caliper where it presses against a piston. The piston in turn squeezes two brake pads against the disc (rotor), which is attached to wheel, forcing it to slow down or stop. Similar to a bicycle brake where two rubber pads run against the wheel rim creating friction. But in a disc brake, the brake pads squeeze the rotor instead of the wheel, and the force is transmitted hydraulically instead of through a cable.

2. Literature Review

Ali Belhocine and Mostefa Bouchetara[1] presented a paper Investigation of temperature and thermal stress in ventilated disc brake based on 3D thermomechanical coupling model. The objective of this study is to analyze the thermal behavior of the full and ventilated brake discs of the vehicles using computing code ANSYS. The modeling of the temperature distribution in the disc brake is used to identify all the factors. A. Belhocine a, A.R. Abu Bakar b, et.al.[2] presented a paper Modeling of Disc Brake System in Frictional Contact. The objective of this work is to investigate and analyse the temperature distribution of rotor disc during braking operation using ANSYS Multiphysics. The work uses the finite element analysis technique to predict the temperature distribution on the full and ventilated brake disc and to identify the critical temperature of the rotor by holding account certain

parameters The analysis also gives us, the heat flux distribution for the two discs.

Hassene Djemel, Mohamed Kaffel, et.al.[3] presented a paper Survey of the Streamlined and Thermal Behavior of a Ventilated Disc Brake. In this work, a thermo-mechanical modeling of an automotive braking system was presented. For this purpose, three dimensional calculations are carried out in laminar, transitional and turbulent flow in ventilation ducts of brake disc. Model taking into account the friction of the pad against the movable disk, developing a new so-called "Sliding Boundary Condition" technique that allowed to take into account the spatial and heat flux generated by friction, and update its depending on the amount and speed of braking scenario.

Jos'e Luis Reyes P'erez_, Andreas Heckmann, et al.[4] presented a paper A Thermo-elastic Annular Plate Model for the Modeling of Brake Systems. The present paper proposes a modeling concept that is targeted on this field of application and introduces the new Modelica class Thermo-elastic Plate, which is implemented in the DLR Flexible Bodies library. Er. N. B. Shindel and Prof. B.R. Borkar[5] presented a paper C.A.D. & F.E.M. analysis of disc brake system. The aim of my paper is to show how to perform a crash worthiness simulation in the automobile industry using Finite Element Method, Repetitive braking of the vehicle leads to heat generation during each braking event. Problems such as premature wear of brake pads and thermal cracking of brake discs are attributed to high temperatures. Michal Kuciej and Piotr Grzes[6] presented a paper The comparable analysis of temperature distributions Assessment in disc brake obtained using analytical Method and fem model. In this paper the one-dimensional analytical formulation as well as the two-dimensional FE model to study the temperature distributions in the pad/disc brake system during an emergency braking process was proposed.

Shah E Alam¹, Yuvraj Vidhyadhar, et.al[7] presented a paper Thermal Analysis of disc Brakes Rotor: A comparative Report. In this paper, authors present our results of thermal analysis of disc brake rotor used by two-wheelers in India. Thermal analysis is done for two different models of rotors. One is a simple rotor without vents and holes and the other perforated (consists of holes). Alin-Marian PUNCIOIU, Ioan VEDINAȘ, et.al.[8] presented a paper Overheating analysis of the special vehicles braking Systems. This paper shows the basis of thermal calculation of the special vehicle brake. During the braking the vehicle's kinetic energy is converted to heat. Calculation of a special vehicle brake heat can be based on experimental data on actual conditions in the cooling of the brakes braking or can be simulated using finite element method.

A. Belhocine and O. I. Abdullah[9] presented a paper Finite Element Analysis of Automotive Disc

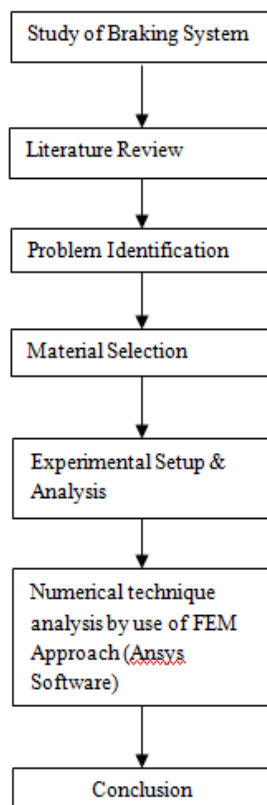
Brake and Pad in Frictional Model Contact. The purpose of this work is to present a study of the thermomechanical behavior of the automotive disc brake during the braking phase. Structural performance of the disc-pad model such as deformation and Von-Mises stress is predicted. Stanisław F. Scieszka and Marcel Zolnierz[10] presented a paper Study on thermo-mechanical instability in the industrial brakes. This paper presents disc brake surface temperature field measurements, during emergency braking in real industrial conditions, by means of the thermovision infrared camera. The temperature field assessment enables the verification of the numerical modeling of the brake performance in the succeeding step. Faramarz Talati and Salman Jalalifar[11] presented a paper 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 dependent 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.

Mr. P. N. Gunjal and Prof. Hredeya Mishra[12] presented a paper Design, Analysis & Optimization of Disk Brake. The main goals of this paper which presents the results of a thermal analysis of a braking system of two wheel vehicles using analytical and numerical modeling of thermal effects during long-term braking for maintaining a constant speed on a downgrade railroad in order to analyze damages of solid wheels braked by blocks, especially on railway. Vivek Agnihotri and Dr. M.K. Chopra[13] presented a paper Optimized Thermo-Structural Analysis of Solid and Vented Disc Brake Using Finite Element Method (A Case Study). This paper studies about the model of a disc brake used in the analysis is also done by changing the design of disc brake. Actual disc brake has no holes; design is changed by giving holes in the disc brake for more heat dissipation. Mirela Pamant and Florin Bogdan Marin, et.al[14] presented a paper algorithm for assessment of truck brakes temperature evolution using svm. In this paper, an algorithm is proposed for a new system for trucks with heavy loading operating in steep grade conditions. The algorithm proposed in this paper is using SVM (Support Vector Machine) algorithm to predict brakes temperature evolution which is processing previously CFD of the brake components' cooling for the truck model. Saeed Abu Alyazeed Albatlan[15] presented a paper Study Effect of Pads shapes on Temperature Distribution for Disc Brake Contact Surface. This study describes an inertial dynamometer system which has been applied to the testing of disc brake pads at different operating conditions. Two sets of brake pads are tested. This study explains the temperature distribution obtained by

experiments on two different shapes of brake discs/pads affected by the types of shapes of brake discs/pads, disc geometry and operating conditions.

3. Methodology

Flow Chart



4. Problem Identification

- Nowadays braking system in automotive vehicle is challenging task.
- Disc brake with axial loading condition of an automotive vehicle to identify heat transfer rate within the standard and recommended values.
- By the method of FEM approach to solve the brake disc and validate through hand calculation.

4.1 Braking requirements:

1. The brakes must be strong enough to stop the vehicle with in a minimum Distance in an emergency.
2. The driver must have proper control over the vehicle during braking and the vehicle must not skid.
3. The brakes must have good antifade characteristics i.e. their effectiveness should not decrease with constant prolonged application.

4. The brakes should have good anti wear properties.

4.2 Classification of brakes (based on transformation of energy)

- Hydraulic brakes.
- Electric brakes.
- Mechanical brakes.

The mechanical brakes according to the direction of acting force may be sub divided into the following two groups:

1. Radial brakes.
2. Axial brakes.

Radial brakes:

In these brakes the force acting on the brake drum is in radial direction. The radial brake may be subdivided into external brakes and internal brakes.

Axial brakes:

In these brakes the force acting on the brake drum is only in the axial direction.

e.g. Disc brakes, Cone brakes.

4.3 Disc brakes:

A disc brake consists of a cast iron disc bolted to the wheel hub and a stationary housing called caliper. The caliper is connected to some stationary part of the vehicle, like the axle casing or the stub axle and is cast in two parts, each part containing a piston. In between each piston and the disc, there is a friction pad held in position by retaining pins, spring plates etc. passages are drilled in the caliper for the fluid to enter or leave each housing. These passages are also connected to another one for bleeding. Each cylinder contains rubber-sealing ring between the cylinder and piston.

5. Material Selection

On the basis of the current work, it is concluded that the different material has different quality as used for brake disc.

5.1 Gray Cast Iron

The cast iron has the maximum temperature produced is about 605.3K which is low as compare to ceramic but the rate of losing the heat is good as compare to aluminum alloy. Gray Cast Iron is a material that is most extensively used material in engineering applications. Gray Cast iron has high thermal conductivity. Cast iron possesses carbon in the form of graphite flakes in a matrix that comprises of pearlite, ferrite or a combination of the two. The other alternative materials selected.

5.2 Stainless Steel

Stainless steels are widely used for brake discs and automotive components in general because of their cost

effectiveness, mechanical properties and their ease of manufacturability.

5.3 Aluminum Alloy

The aluminum alloy has the maximum temperature produced is about 559.2 K. Aluminum is a most abundantly used light weight metal. It is soft and durable. Aluminum has several important properties such as conductivity, low density, strength, durability, versatility, workability, corrosion resistance and recyclability.

5.4 Carbon Ceramics

The ceramic has minimum weight among other material and the maximum temperature produced is about 769K which is highest as compare to other material but the rate of losing the heat is greatest in ceramic as compare to other material. A special feature of carbon-ceramic brake disks is the ceramic composite material they are made from. Both the carbon-ceramic brake disk body and the friction layers applied to each side consist of carbon fibre-reinforced silicon carbide. Finally selected the grey cast iron to conduct the experiment.

Table 5.1 Material Properties

Properties	Gray Cast iron
Density(kg/m^3)	7050
Young's modulus(Gpa)	116
Poisson's ratio	0.27
Specific heat J/Kg-k	550
Thermal expansion(K^{-1})	11
Thermal Conductivity W/m-k	54

6. Experimental Setup and Analysis

Disk brakes wear longer, are less affected by water, are self-adjusting, self-cleaning, less prone to grabbing or pulling and stop better than any other system around. The main components of a disk brake are the Brake Pads, Rotor, Caliper and Caliper Support.



Figure 6.1 View of brake disc



Figure 6.2 Disc with caliper



Figure 6.3 Experimental Setup

6.1 Axisymmetric Analysis

Due to the application of brakes on the car disk brake rotor, heat generation takes place due to friction and this thermal flux has to be conducted and dispersed across the disk rotor cross section. The condition of braking is very much severe and thus the thermal analysis has to be carried out.

The thermal loading as well as structure is axisymmetric. Hence axisymmetric analysis can be performed, but in this study we performed 3-D analysis, which is an exact representation for this thermal analysis.

In this experiment to conduct different geometry models of brake disc 8holes, 16holes brake disc and vane profile is included in the brake disc is to be analyzed. The material is used Gray cast iron with their properties for all the geometry models of brake disc 8holes, 16holes brake disc and vane profile brake disc. Temperature and radiation of atmospheric air is affecting on the brake disc during the applying brake in automobiles. Vehicles continuously running conditions n number of times we applied the brake. Then to applying specific conditions of brake disc and solved by use of ANSYS Software. Results of temperature Distribution and total heat flux and Directional heat flux of following results are given below:

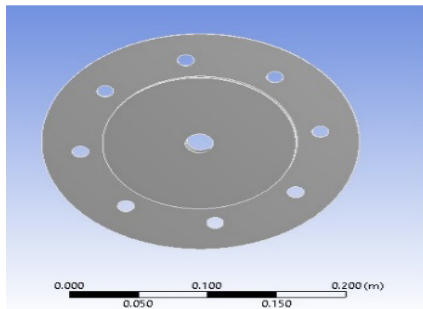


Figure 6.4 Solid disc brake with 8 holes

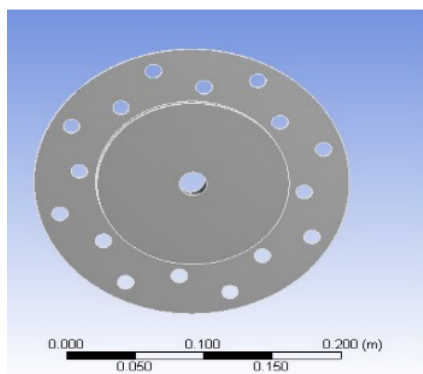


Figure 6.5 Multi hole with brake disc

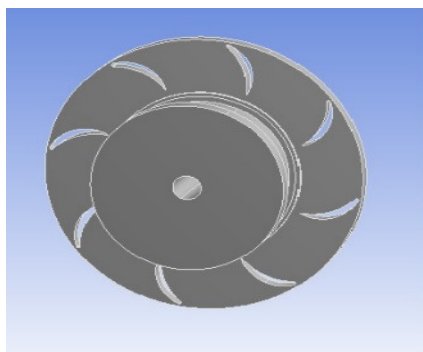


Figure 6.6 Vanes with brake disc

6.2 Finite Element Analysis

There are three main steps, namely: pre-processing, solution and post processing. In pre-processing model definition includes: define the geometric domain of the problem, the element types to be used, the material properties of the elements, the geometric properties of the elements length, area, and the like, the element connectivity mesh the model, the physical constraints boundary conditions and the loadings.

In solution phase, the governing algebraic equations in matrix form are assembled and the unknown values of the primary field variables are computed. The computed results are then used by back substitution to determine additional, derived variables, such as reaction forces, element stresses and heat flow. Actually, the features in this step such as matrix manipulation, numerical integration and equation solving are carried out automatically by commercial software. In post processing, the analysis and evaluation of the result is conducted in this step.

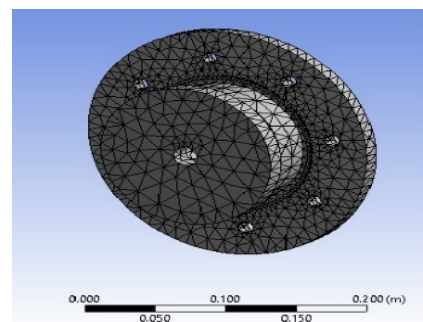


Figure 6.7 Meshing disc brake with 8 hole

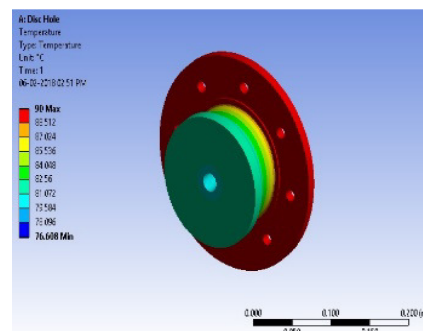


Figure 6.8 Temperature distribution of brake disc

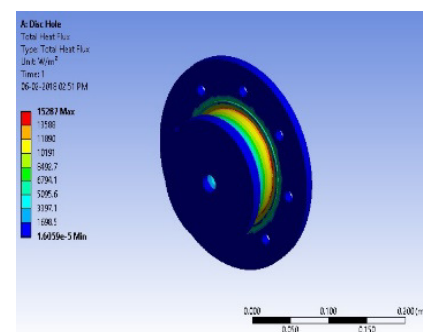


Figure 6.9 Total heat flux of brake disc

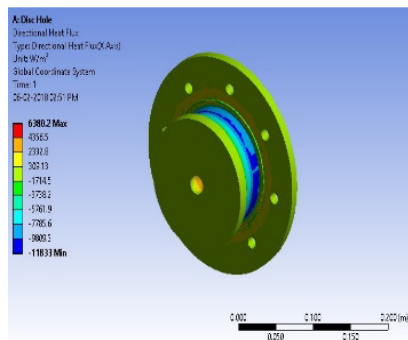


Figure 6.10 Directional heat flux of brake disc

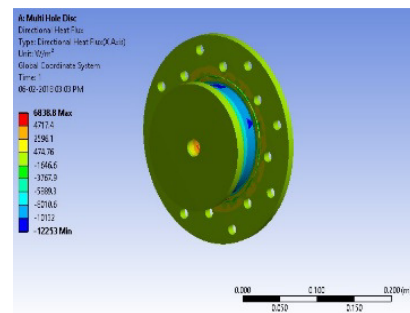


Figure 6.14 Directional heat of multi holebrake disc

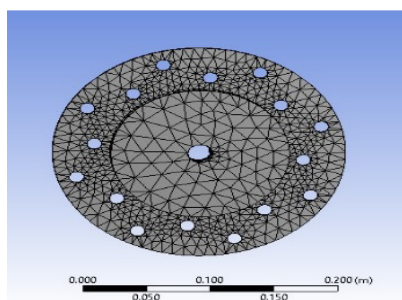


Figure 6.11 Meshing multi hole with brake disc

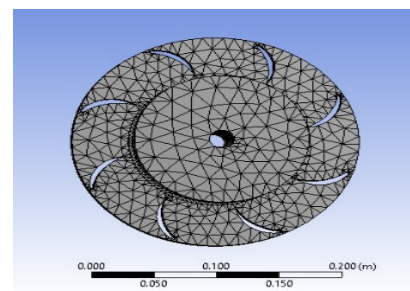


Figure 6.15 Vanes meshing brake disc

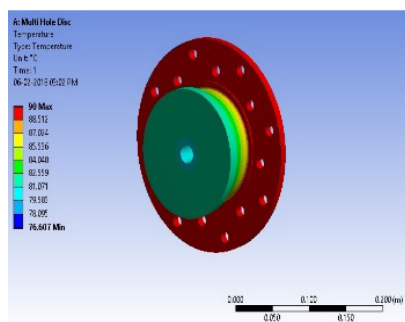


Figure 6.12 Temperature distribution of multi holebrake disc

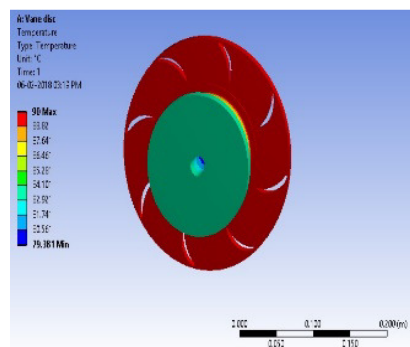


Figure 6.16 Temperature distribution of vanes brake disc

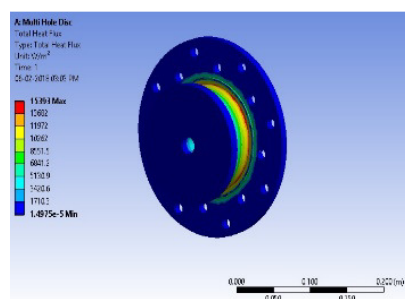


Figure 6.13 Total heat flux of multi holebrake disc

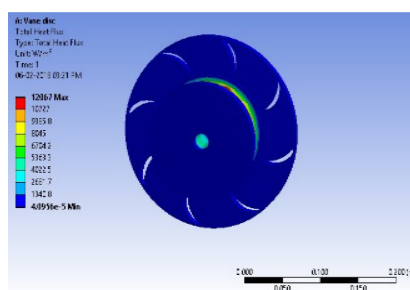


Figure 6.17 Total heat flux of vanes brake disc

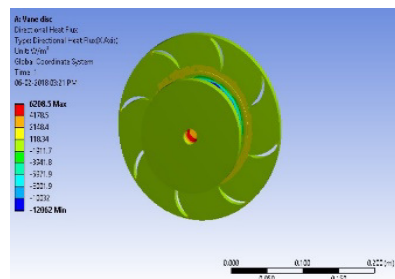


Figure 6.18 Directional heat flux of vanes brake disc

7. Conclusion

Based on the current work, it is concluded that the different geometry models like brake disc 8holes, 16holes brake disc and vane profile with material is used Gray cast iron with their properties.

The numerical simulation shows that 16holes or multi holes brake disc plays a very significant role in cooling of the disc during the braking phase. Through the numerical simulation, we could note that the quality of the results concerning the temperature field is influenced by several parameters such as:

- (i) Technological parameters illustrated by the design.
- (ii) Numerical parameters represented by the number of elements and the step of time.
- (iii) Physical parameters expressed by the types of materials.

Regarding the calculation results, we can say that they are satisfactorily in agreement with those commonly found in literature investigations. It would be interesting to solve the problem in thermomechanical disc brakes with an experimental study to multi hole with vane profile geometry of the numerical results in order to demonstrate a good agreement between the model and reality.

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