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COMPARATIVE ANALYSIS OF THE TEMPERATURE PROFILE OF THE SOLID BRAKE DISCS AND PERFORATED IN FUNCTION OF THE SPEED

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Abstract. *The safety requirement for each single system in automotive engineering is developed as the high pater, and between these systems, the one who requires even more care is the braking system. The objective of this paper is making a thermal analysis of a rotor disc during the brake process using ANSYS Multiphysics. The computational modeling was performed using the finite element method (FEM) to predict the distribution of temperature on the full and a drilled brake disc. Through the simulation it was possible to verify the maximum temperatures reached for vehicle speeds of 28 m/s. In addition, it was observed that the solid brake disc had the highest temperature compared to the drilled disc.*

Keywords: *Brake Disc, Finite element, Thermal Analysis*

1. INTRODUCTION

Since the beginning of the twentieth century the automotive sector has been evolving at an accelerated pace. The search for performance has led to the emergence of engines with a high performance and, consequently, with more power. Due to the increased power, high speeds can be achieved with great ease by automotive vehicles. After these facts, it is clear that safety factors must evolve in an equivalent way. And, in the case of safety, the brake system is the most important component for the safety of a car (Zhongzhe, 2008).

The bases of analysis of problems of heating in brake systems and the concurrent phenomena are solutions of thermal problems of friction – equations of motion, boundary-value heat conduction problems and laws of wear (Adamowicz, 2015). During the activation of the brake system there is friction generation between the pads and the disc. In this process the kinetic energy of the vehicle is transformed into thermal energy (Abebe et al., 2016), and part of that energy is absorbed by the brake system. Due to the generation of heat there is an increase in the temperature of the pellets and the disc. When such a rise in temperature exceeds the values supported by the materials of the brake system, failures such as premature wear of the pads, rolling failure, thermal cracking or vaporization of the brake fluid occur (Lee & Yeo, 2000). In addition, due to the high temperature, there is a drastic decrease in the coefficient of friction between the disc and the pads, and consequently, the reduction in braking efficiency is achieved.

The objective of the comparative analysis was to determine the temperature profile of two types of brake discs, full and drilled disc, as a function of the vehicle speed of 28 m/s. To perform the thermal analysis, the finite element method (MEF) was used with the aid of mechanical simulation software ANSYS, with the construction of temperature graphs as a function of time through the data obtained numerically for the set speed.

2. METHODOLOGY

2.1 Mathematical model

The mathematical model of the braking process is based on the first law of thermodynamics, where, during the braking process, the kinetic energy of the vehicle is converted into thermal energy due to the friction with the disc and the pads. Initially the thermal energy is transferred by the conduction process, due to the friction between the pads and the brake disc (Belhocine et al, 2014).

The initial thermal flux between the faces of the disk can be calculated directly by the formula (Reimpel, 1998):

$$q_0 = \frac{1-\phi}{2} \cdot \frac{m.g.V_0.z}{2A_d E_p} \tag{1}$$

Where $z = a/g$ is the braking effectiveness, a is the deceleration of the vehicle, ϕ it is a dimensionless factor that indicates braking forces distribution, A_d *[m²]* the contact area between the disc surface and the wafer, V_0*[m/s]* is the initial speed of the vehicle, E_p is a dimensionless factor of load distribution on the surface of the disk, *m[kg]* is the mass of the vehicle.

According to (Incropera & Dewitt, 2003) the heat equation, in differential form, in cylindrical coordinates is given by:

$$\frac{1}{r}\frac{\partial}{\partial r}\left(kr\frac{\partial T}{\partial r}\right)+\frac{1}{r^2}\frac{\partial}{\partial \phi}\left(k\frac{\partial T}{\partial \phi}\right)+\frac{\partial}{\partial z}\left(k\frac{\partial T}{\partial z}\right)+Q=\rho C_p\frac{\partial T}{\partial t} \tag{2}$$

Where r, ϕ *e* z*[m]* are the spatial coordinates of the heat flux, $Q[w/m^3]$ is the internal heat generation at volumetric level, $C_p[J/Kg°C]$ is the specific heat, $\rho[kg/m^3]$ is density, e $T[°C]$ is the temperature that varies with the coordinates and with time *t[s]*. In order to solve the second-order differential equation in relation to the spatial coordinates and the first one in relation to time, we need, according to (Çengel, 2009), two boundary conditions for e an initial condition for the model. The conditions of specified temperature, specified flow and convection boundary condition are indicated by Eq. (3) and Eq. (4):

$$T_s = T_1(r,\phi,z,t) \tag{3}$$

$$-q_0 = h(T_s - T_\infty) \tag{4}$$

Where $T_1[°C]$ is the specific surface temperature of the disc, $q_0[W/m^2]$ is the specified initial flow, $h[W/m^{2}\cdot k]$ is the coefficient of heat transfer by convection, $T_s[°C]$ is the unknown surface temperature, and T_∞ *[°C]* of the convection fluid.

2.2 Computational procedure

In the automotive market there are several types of brake discs, however, for this work, the solid and drilled brake discs have been chosen. The dimensions of the models chosen for the analysis follows the usual dimensions for a regular car.

Table 1. Disk dimensions

Disc Measures Value	Value
Diameter of the outer disk (D1), mm	262
Diameter of inner disc (D2), mm	151.3
Internal thickness (L1), mm	29
External thickness (L2), mm	51
Diameter of holes, mm	6

The geometry of the disks was created in ANSYS Workbench. As shown in Figure 1.

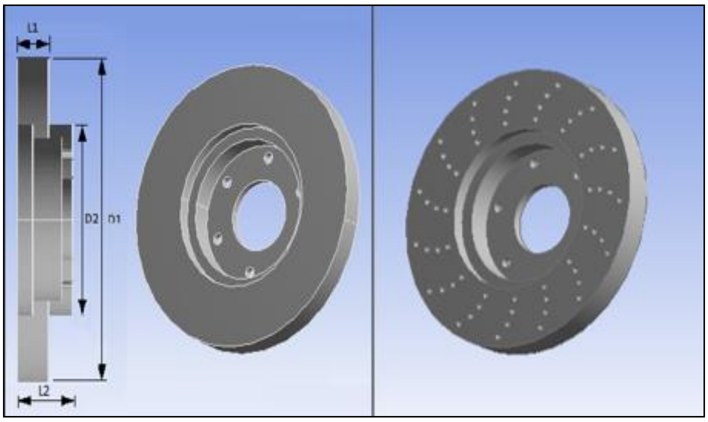

Figure 1. Geometric representation of the brake disc

Due to the complexity of the brake disc modeling, some considerations were made to facilitate the analysis:

- All vehicle kinetic energy is converted to thermal energy.
- The heat transfer involved for analysis is only a process of conduction and convection.
- The initial heat flow is applied only to the disc faces.
- The disc material is considered homogeneous and isotropic.

The modeling of the disks was performed considering the velocity 28 m/s, and the following input parameters for Eq. (1) the total heat flux through the brake disk is 4.53 MW / m ².

For a comparison of the solution of the problem to the solid brake disc was performed considering the velocity of 28 m / s and the geometric data of the disk presented by the simulation of Belhocine et al (2014). According to the preformed result of temperature obtained was equal to that presented by Belhocine, with the same method, the relative error was low, which shows reliable numerical results.

3. RESULTS AND DISCUSSIONS

To solve the equations of the presented models, the finite element method (FEM) was used with the aid of the commercial software ANSYS mechanical. Initially a disk mesh was generated with 148497 nodes and 92880 elements. In the contact areas between the disc and the pads, where the flux was applied, a refinement was applied to the mesh. The Figure 2 shows the mash.

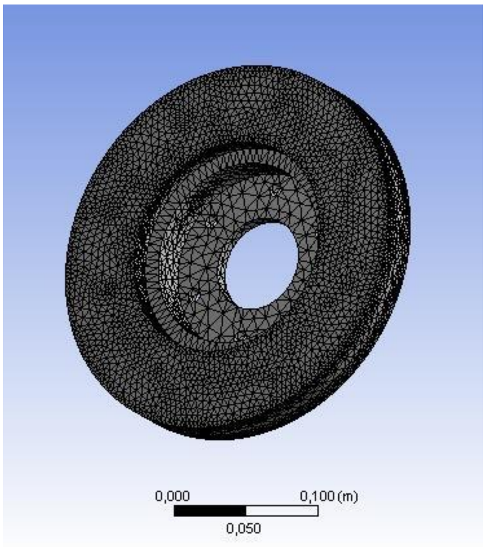

Figure 2. Mesh representation on disk

The comparative analysis of the solid and drilled brake discs was done in order to obtain the temperature profile. For this, the disk simulations were performed considering the velocity of 28 m / s and the initial heat flux of 4.53 MW / m². The Figure 3 shows the three-dimensional distribution of temperature, it's easy to the maximum temperature in the full disc. As well the drilled and de full disc have a much higher temperature in the surface of the disc, which is caused by the friction with the brake pads.

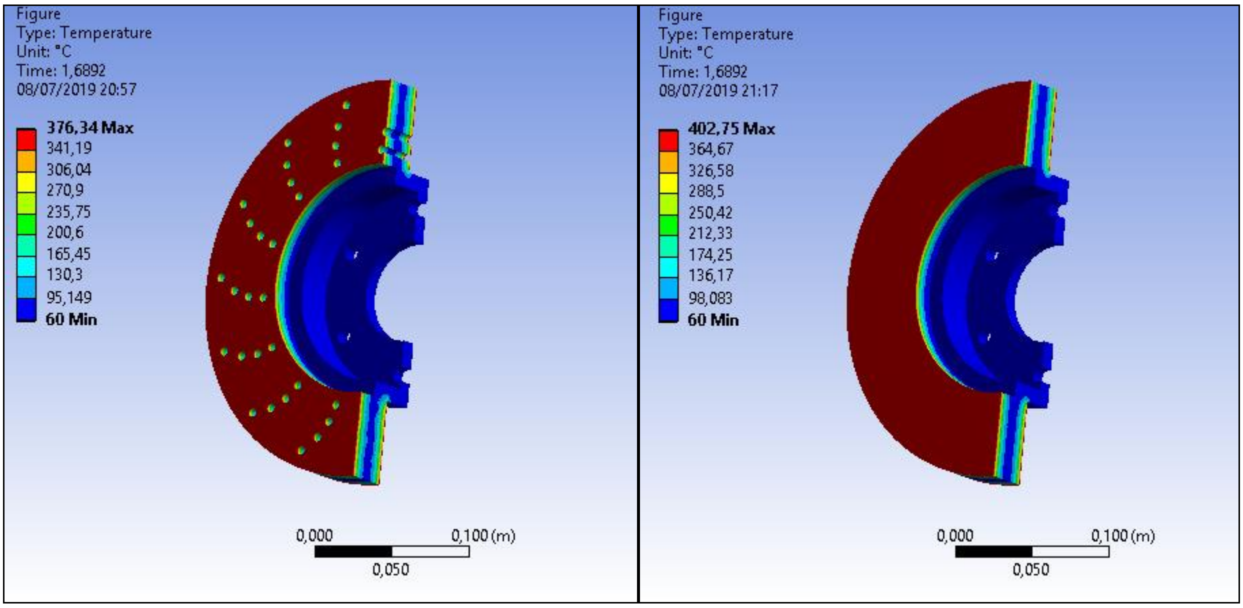

Figure 3. Temperature distribution in the discs

Figure 4 shows the same results of temperature graphically. At time 0 s to instant 2.60 s there is a rapid temperature increase due to braking, and at the instant 2.60 s the disks had the highest temperatures being 402.75 ° C on the solid disk and 376,34 ° C on the drilled disc. After the maximum temperature has been reached a decay up to 1.92 s, from this moment until the end of the simulation the temperature slowly decreased.

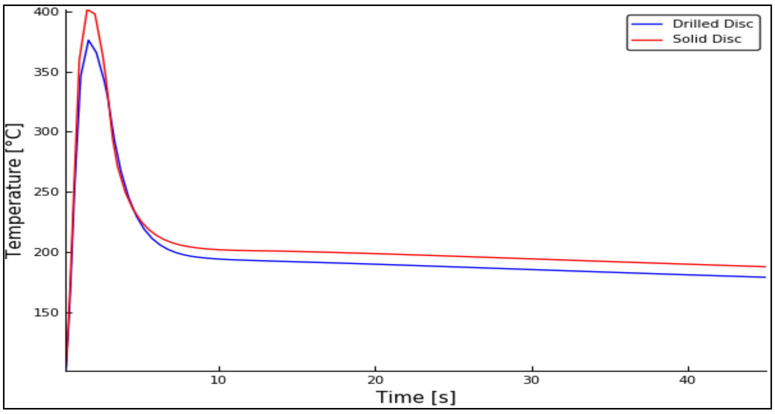

Figure 4. Temperature variation of the disks

From the temperature profile of the discs it is found that, the solid brake disc has the most elevated temperature compared to the drilled disc. The solid disk has the largest contact area, a better heat propagation is achieved by conduction according to the Fourier law and that is why its reach a higher temperature. Through the comparative analysis is this paper, it is possible to observe that the drilled disc presents a better dissipation of heat in relation to the solid disc.

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