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STUDIES REGARDING THE REACTION METHOD TO WEAR BRAKING MECHANISM

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Abstract. *With the development of industry have made efforts to improve the performance of braking systems of motor vehicles on public roads. The choice of materials used for coupling brake system involved the development of new materials that meet safety requirements in circulation. During braking of any vehicle, due to the friction created between the disk and pad, temperature rise occurs with negative effects on the process of slowing down the vehicle. Mechanical and thermal stress being put on the brakes is very high. Due to overheating, brake discs and pads may warp or crack, and the material they are made may their change its structure. These defects give rise to vibrations and noise during braking, to reduce the coefficient of friction, reduce the effectiveness of the braking mechanism. This paper proposes a study regarding the thermal stresses effects of brake mechanism on the disc material of a car Dacia Logan. It proposes a theoretical model to calculate the temperature that occurred during the operation of the braking system and experimental analysis on the influence of temperature on the brake disc material.*

Keywords: *disc brake, temperature, hardness, operating conditions*

1. INTRODUCTION

The disc brake is a car body that is part of a complex mechanical brake system of a road vehicle. In the case of brake disc from the Logan braking system, subject of this study, braking occurs under the action of the master cylinder which increases the fluid pressure (brake fluid / glycol ether) inside of receptor cylinder. Pressure acting on the piston outward toward pushing to the brake pad and disc. Brake pads are machine parts that come in direct contact with the disc brake and by friction execute the braking (reduced travel speed or immobilization of the vehicle) [1]. Because the disc brake is a crucial component from the viewpoint of safety, materials used in brake system should be stable, abrasion resistant and have properties very good to wear under varying conditions of load, speed, temperature, environmental and durability [2,3,4].

In the literature are presented and analyzed different types of couplers materials [1,4,5,6], used to fabricate braking systems in particular disc brakes. From the literature study resulted that the material with the best properties is gray iron, because they have good tribological performance. It is known that gray cast iron is a material friction with very good quality / price ratio of cost. [7,8,20] The braking system of any road vehicle is a total change mechanism of various types of energy. When any car is moving at a certain speed we say that has a kinetic energy. When any car brakes, pads (or shoes) press on the disc (or drum) convert kinetic energy into thermal energy. Energy balance of the braking process indicates full conversion of kinetic energy into thermal energy [4]. The thermal stresses in the brake system may have undesirable consequences on:

- Material discs and pads where internal tensions may occur;
- Structural changes on the superheated material;
- Deformation or roundness disk-plate system;
- Premature wear of the disk-plate system.

All this contributes to the deterioration of the vehicle braking qualities. The effects of these changes on the system disk-plate manifests as vibration and noise during braking by reducing the braking coefficient, etc., in other words lead to decrease traffic safety. Due to these undesirable consequences, friction materials used in automotive braking systems, must have wear resistance and high mechanical strength, low thermal conductivity, lubrication components with a role of increasing seizure resistance. Due to the many factors that influence the brake system, the paper proposes a theoretical and experimental approach of this issue.

2. THEORETICAL MODEL TO ESTABLISHING TEMPERATURE OCCURRENCE ON THE FRICTION SURFACE BETWEEN DISK AND PLATE

Interaction method of different parameters in the friction process required to calculate the friction surface temperature of any friction couplings, simplifying assumptions specific to the work analyzed [9-14]:

- For this case subjected to analysis between disk and plate there is no lubricant, and the entire amount of heat generated by the friction between the two elements dissipates;
- The materials constituting the disk and pads are considered isotropic, and a thermal property does not change with temperature;
- Due to the relative movement between the disc and the pads, the temperature at a certain point changes with time;
- Distribution of temperature depends on the force (pressure exerted on the disc), surface topography (processing methods), properties of materials of friction coupling and the environment.

In the transmission process of the flow of strength and in the presence of the sliding movement, the phenomena occurring in the contact real area ,so that we can define a temperature "local" (flash) snapshots at local micro areas and an average temperature of nominal surface. [10,11,15,16].

The flow of heat generated in the contact surface roughness peaks are evaluated by relationship:

$$q = \mu p v = \mu \frac{F}{A_n} v \quad (1)$$

Where: μ - The friction coefficient of the surface;
p - Pressure exercised on the contact surface;
v - The relative speed between the surfaces;
F - The force exercised by the plate;
A_n - Nominal area of the plate.

In literature, the coefficient of friction between the material of the disc (which is analyzed for cast iron conditions) and pad material (which is ferodo) is estimated at $\alpha = 0{,}30...0{,}45$ [1,17]. In reality, in tribology terms, the coefficient has a constant value. It depends on the speed of movement of the elements, how to process the surface, etc.

Some part (α) of this heat flow diffuses into the disc and the rest ($1-\alpha$) diffuses into the plate so that the surface heats flux of:

- The disc will be:

$$q_1 = \alpha q \quad (2)$$

- Plate will be:

$$q_2 = (1-\alpha)q \quad (3)$$

After reaching the state of thermal equilibrium and linearizing first law of heat flow is obtained:

$$\alpha q \cong \lambda_1 \frac{(T_m - T_o)}{l_m} \quad (4)$$

Where: λ_1 - the thermal conductivity of the disc material;
T_m - The average temperature of the contact surface:

$$T_m = T_o + \frac{\alpha \mu F v \cdot l_m}{A_n \cdot \lambda_1} \quad (5)$$

T - The temperature of the disc clamping system ($T_o = 20^o C$);
l_m - Heat diffusion distance towards to the clamping mechanism of the disc.

Evaluation of partition coefficient of heat is based on the Jaeger assumption [16]. This ratio is dependent on the thermal characteristics of the materials and of the sliding speed. The speed is one of the factors that influence the brake, the speed is parameterized so is inserted an invariant Peclet, considered an indicator of operating parameters:

$$Pe = \frac{v \cdot r}{a_1} \quad (6)$$

Where: v It is the rotation speed of the disc
r It is the disk radius;
a_1 Thermal diffusivity of the material disc ($a = \lambda / \rho \cdot c$).

The properties of the material from they are made (the disc and the pads) are shown in Table 1.

Table 1. Materials characteristics of the braking system

Material Propertys	Measurement units/ symbol	Cast iron	Ferodo
Conductivity	[W/mK] - λ	445	0,08..0,21
Specific heat	[J/kg/K] - c	740	1000..1200
Density	[kg/m^3] - ρ	7640	383

In these conditions, the partition coefficient of heat it is:

$$\alpha = \begin{cases} \dfrac{\lambda_1}{\lambda_1 + \lambda_2} & Pe \le 0{,}1 \\ \dfrac{1}{1 + 0{,}795 \dfrac{\lambda_1}{\lambda_2} \left(\dfrac{a_1}{a_2} \right)^{1/2} \cdot Pe^{-1/2}} & Pe \ge 5 \end{cases} \quad (7)$$

For intermediate values of parameter Pe (0,1<Pe<5) it is recommended a linear interpolation.

The average temperature at the friction surface will be: s (0.1 <On <5).

$$\overline{T} = \frac{T_m - T_o}{\frac{a_1 H_o}{\lambda_1}} = 4 \alpha \mu \beta \frac{p}{H_o} Pe \quad (8)$$

Where: β parameter dependent on dimensional characteristics;
H_o The hardness of the disc material is (100…175HB).

In the figure 1 is represented variation of the average temperature function of working parameter Pe, for the three areas of the variation ($Pe1 < 0,1$; $0,1 \leq Pe2 \leq 5$; $Pe3 > 5$) at different loads.

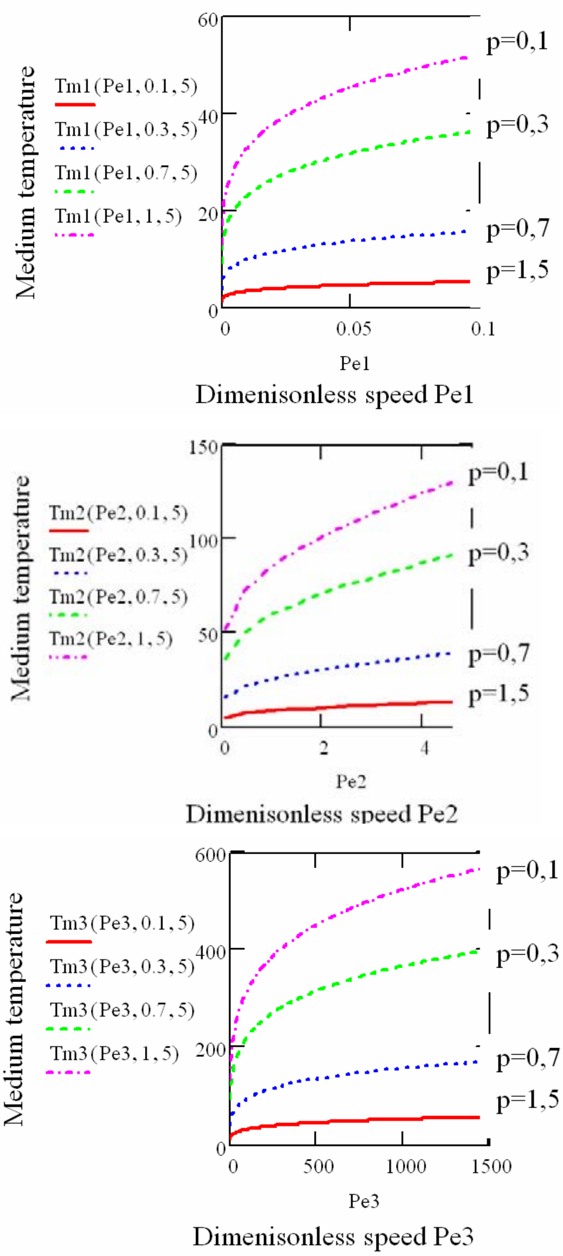


Figure 1. Medium temperature variation depending on the speed dimensionless (Pe1, Pe2, Pe3) at different loads

Analyzing evolution of temperature on the friction surface is evident that the temperature increase with its speed and the load (force push the plate on the disc).

3. MATERIALS AND ANALYSIS

Materials used for friction couple in tribological terms are made from cast iron with lamellar graphite Fc150 for the disk and ferodo for the breaking plate. The selected material for structural analysis has the following composition: 3,3-3,5% C, 2,0-2,4% Si, 0,5-0,8% Mn, <0,2P <0,15P. Figure 2a, b are given new and worn brake discs from a Dacia Logan autovehicle, selected for the study.

a) Used discs

b) New disc

Figure 2. Brake discs used for study

3.1. Macrostructural analysis

By macrostructural analysis of old cast iron brake discs recovered, can be seen on the surface defects occurring on the disc. Figure 3 indicates detachment of material and corrosion.

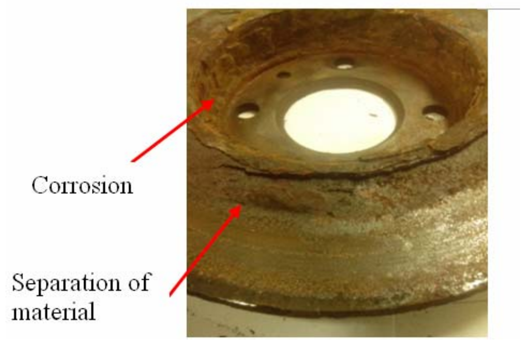


Figure 3. Macrostructural appearance of the used break disk

In Figure 4 shows a disc irregular worn with blue spots on the lateral surface of the disc, spots appeared after thermal heating. Surface analysis of the used disk was realised at runtime 143 936 Km.

In Figure 5 can be seen bumps on the outer surface that can describe a circle about 204 millimeters. These irregularities occur due to deformation of the material under the pressure it exerts the plate and are visible both on the left and the right disc. These irregularities occur due of material deformations under the pressure it exerts the plate and are visible both on the left and the right of the disc.

Figure 4. Irregular worn disc with blue spots

Figure 5. Irregular worn-traces on disk left by brake plate

3.2 Temperature monitoring in different sectors on the disk surface during braking

To determine the temperature developed after friction from the disk surface during braking, the car was suspended in the front left and was simulated a braking. This experiment was repeated 4 times under identical conditions. In the Table 2 are presented averages of these measurements. The disk was divided into four diameters with 10mm distances between them and the temperature was measured on the disc surface with a machine called TROTEC - BP25. The device reads the surface temperature of the material using two laser beams, each measuring was announced by an audible alarm and the response time is 150 ms. The measuring range of the device it is between 50°C to 260°C with accuracy between -50°-20°C, measurement error is ± 1 / 1,5°C, Laser class 11 with a laser power between 630/670 nm.

Table 2. Measured values of the temperature at different diameters on the disc brake

Temp. (oC)	Braking time (min)	D1= 158mm	D2= 178mm	D3= 198mm	D4 = 218mm
T_0		41,5°C	41,5°C	41,5°C	41,5°C
T_1	1 min	132°C	146°C	135°C	78,5°C
T2	3 min	147°C	154°C	153°C	130°C

This analysis was achieved in the following conditions: air temperature = 38°C, engine speed 2000 rot / min and after braking 1800rot / min, wheel speed = 465rot / min.

From the Table 2 can be seen that with increasing the breaking time grow and surface temperatures of the disk, especially in the contact area with the brake pads (corresponding to the diameter D2).

3.3. Microstructural analysis

For microscopic examination of a metalographic sample it was necessary previous preparation for the metal surface to be analyzed. Cutting the samples were made by mechanical cutting using a rotating disk-cooled with cooling emulsion based on water and then has been polished, polishing and chemical attack with NITAL (2% nitric acid + ethanol). Microstructural characterization of metallic samples was made with optical microscope MC6. Figure 6 presents the microstructural image of the sample taken from the new brake disc with a 250X magnification and figure 6.b is presented microstructure sample taken from the old disc brake at the same scale of magnification. The used material reveals the presence of a gray cast iron with lamellar graphite, graphite fine slides uniformly distributed in ferrite-pearlite mass base.

a) New brake disk

b) Old break disk

Figure 6. Samples microstructure, 250x

A perlitic basic mass with fine graphite and homogeneous spread shows the 100 time higher wear resistance than a grey iron with ferrite based and graphite heterogeneous spread [18,19,20].

Comparing the two images we can say that no structural changes occurred on used discs therefore temperatures were not so high to cause structural changes in the disk material.

3.4. Rockwell hardness analysis

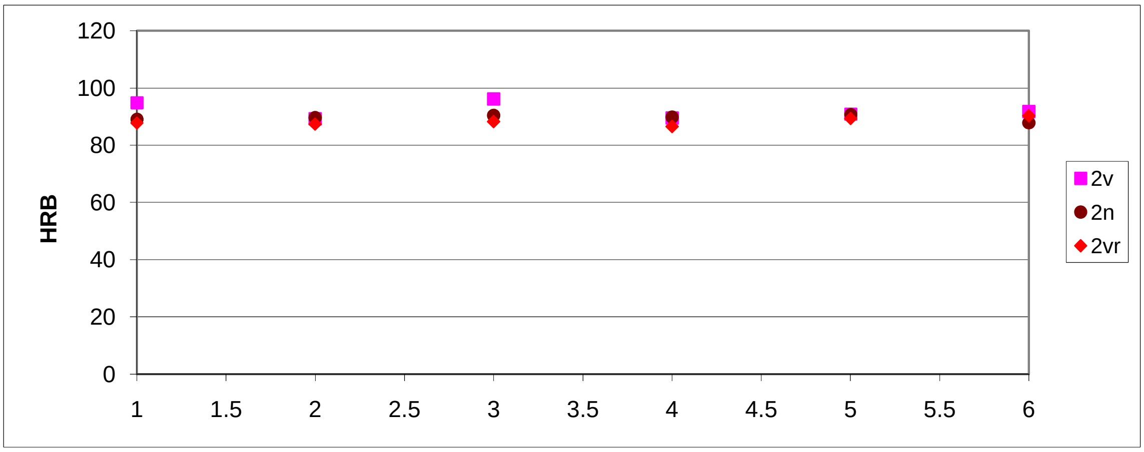
In order to analyze the hardness of the samples were divided into four diameter with 10 mm distance from each other, and on these diameters was measured the hardness of 6 points. There have been five such measurements and in Table 3 are listed their average values. Hardness tests were made on a Rockwell hardness tester NAMICON. Indenter was a steel ball, the contact force is 980N (100kg).

Figures 7.a, b is shown the proper hardness variations for diameters positions 2 and 3 identified as the area of contact between the brake disc and pad. For used disk were performed hardness measurements both sides (2V) and the reverse (2vr). For the new disc were measured hardness only one- sided (2n).

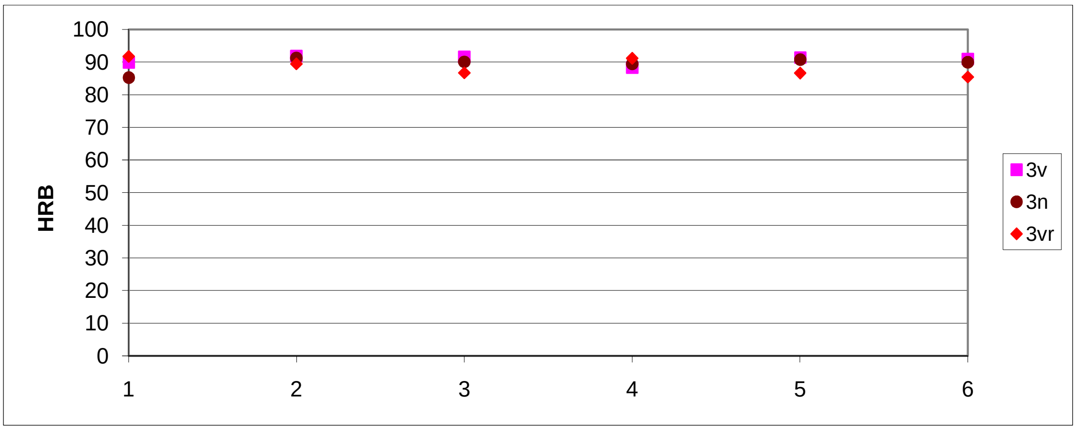
Is found that the harness values not show significant changes. It can be concluded that the temperature during the operation of the braking system does not influence material strength.

Table 3. Rockwell hardness values measured on new and used brake discs

Disk		Diameter	Diameter position					
			a	b	c	d	e	f
Used	Face 1 (2v)	1	81,4	86,8	80,1	88,8	86,3	86,5
		2	94,9	89,2	96,1	89,5	90,9	91,7
		3	89,8	91,9	91,5	88,3	91,4	91
		4	87	86,5	84,1	87	89,5	84,7
	Face 2 (2vr)	1	87	90,2	87,8	88,9	89,8	90,6
		2	87,8	87,4	88,2	86,5	89,3	90,3
		3	91,7	89,4	86,7	91,1	86,6	85,4
		4	91,5	90,6	88,3	85,5	85,7	83,4
New	Face 1 (2n)	1	82,1	88	87,9	89,5	89,1	87,3
		2	89	89,6	90,4	89,8	90,8	87,9
		3	85,2	91,2	90,1	89,4	90,7	89,9
		4	91,9	92,4	90,8	91,9	92,8	93,3



a zone 2 new and old disk



a zone 3 new and old disk

Figure 7. Measured values of hardness

4. CONCLUSIONS

It is noteworthy correlation between the theoretical model for setting the temperature at low and medium speed with experimentally results. Small temperature differences between the theoretical model and experimentally measured values, is because the theoretical model considers that the friction occurs on surfaces in contact with peak asperities. Theoretical temperature under these conditions is greater than the average temperature measured on the surface, bench trial.

In terms of tribological condition, on friction surface because of dimensional differences between nominal and real contact area is considered that:
- For high contact pressures, the real contact area is almost equal with the nominal area and the heat transfer is considered one-dimensional;
- For small contact pressures, the contact is performed on a finite number of rough edge of nominal surface and the heat transfer occurs from the rough edge to the whole body;

The disc brakes has not presented traces of thermal wear demonstrated by corelations of hardness and microscopic analysis. The predominant wear was corrosion accompanied by adhesion and abrasion wear, as confirmed in macro analysis.

By correlating structural analysis (micro and macro) and hardness we can see only changes in surface appearance and not in material hardness. Any differences between the measured temperature and hardness are insignificant, they fall into the error of measurement.

For older car, the wear is more pronounced on the outside diameter of the disk, may be due to plan -parallel misalignment of the plate with the brake disk when is running.

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