ANNALS OF THE UNIVERSITY OF ORADEA
Fascicle of Management and Technological Engineering
ISSUE #2, AUGUST 2015, http://www.imtuoradea.ro/auo.fmte/

STUDY REGARDING THE CAR BRAKE DISC TEMPERATURE VARIATION DURING THE LENGTHY BRAKING

George DRAGOMIR[1], Rares PANCU[2], Tudor Adrian MITRAN[3], Liviu GEORGESCU[5]
[1] University of Oradea, e-mail georgedragomir@yahoo.com
[2] University of Oradea, e-mail rpancu@uoradea.ro
[2] University of Oradea, e-mail tudor_mitran@yahoo.com
[5] University Polytechnica of Bucharest, e-mail liviuadriangeorgescu@gmail.com

***Abstract*—** When a car descends a slope with a great length, the thermal stresses resulting at contact between the brake discs and brake pads, there is possible to exceed the maximal limits of the materials resistance, resulting the rapid wear, decreasing performance of braking or the loss control of movement and the road accidents are producing.

The study refers to establishment the dependence between the braking intensity and time when the temperature achieve a maximum limit on surface of the car brake disc which descends a slope with constant speed so that the material is not affected or the brake pads.

***Keywords*—** brake disc, thermal stress, temperature.

I. Introduction

During the displacements with a car there are situations where the road descends on a long-distance with a different slopes and for maintain a constant speed of movement it is necessary braking the wheels.

In these cases, the most part from potential energy resulting through descent it turns into heat energy at the contact between brake discs and brake pads.

The thermal stresses results, exceed the maximal limits incurred by the disc material or of brake pad and are producing a rapid wear of the theirs, the appearance of axial beatings, noises and vibrations, the braking performance decrease or even destruction and production of road accidents [1], [2].

Knowledge of the thermal stresses and other stresses (vibration, etc.) they may be used to estimate their condition, respectively to planning the maintenance activities [3], [4].

For their prevention it is important to know the dependence of displacement regime, the roads characteristics and the time when the maximum temperature limit is achieved and is borne by the material into a particular area on the disc surface [5].

Whereas during the movement, the temperature from the brake disc surface is difficult to measure, it is necessary a method to estimate the acceptable precision based on parameters measured simply to warn the driver in real time about the dangerous thermal regime from functioning of the braking system [6].

The study aimed at identifying the surface from the brake disc where are the thermal stress and establish an analytical relations to determine the time in which temperature is reached of 200 (°C) at a point in the area, according to brake fluid pressure from the hydraulic circuit who operate the brake.

After each experiment was check the lateral run-out from the brake disc that was produced by unhomogeneousness of the thermal stresses, for check their technical condition.

II. Experimental Methods

The experimental study was accomplished on a stand equipped with heat engine, transmission, wheel hub, hydraulic braking system with a brake disc with a diameter of 247 (mm), represented in Fig. 1, [3].

Fig. 1. The experimental stand and infrared camera

For the determination of temperatures from brake disc surface has been used the FLIR SC 640 infrared placed on a tripod at a distance of 1 (m) and the software Flir R&D software version 3.3 for analyzing the infrared movie realized by a thermal camera.

The speed rotation of the brake disc was remained constant at an equivalent value with the movement speed of 40 (km/h), controlled with a board speedometer of the stand.

The liquid pressure from brake disc actuation circuit was controlled with a pressure gauge with glycerin, represented in Fig. 2.

Fig. 2. The speedometer and the stand manometer

The pressure modification from brake disc actuation circuit was achieved with a brake main cylinder controlled by a mechanism with screw – nut, which ensures an adjusting precision for the pressure value and maintaining it constant throughout the measurement cycle.

The lateral run-out measurement from brake disc before and after each measurement cycle was performed with a Dial Indicator accurate to 0.01 (mm), represented in Fig. 3.

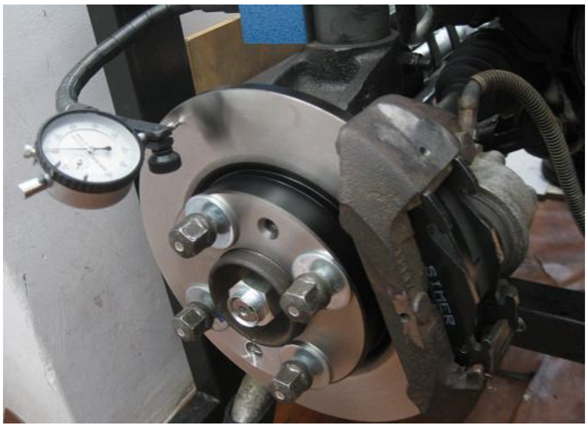

Fig. 3. Check brake disc lateral run-out with a Dial Indicator

The experiments were performed in several similar cycles. At the beginning of each cycle, the brake disc temperature was equal to the atmospheric temperature and with the dial indicators was checked the brake disc lateral run-out the fall within the limits prescribed by the manufacturer accurate to 0-0.08 (mm), so that is suitable for testing.

With the infrared camera and a panel Lambert reflective type radiator was determined the reflected temperature and the emissivity of the disc material.

The heating result by the other components from the stand and the air from the room, where the experiments were performed due to operation of motor and heating generation from the braking process has produced a modification to reflected temperature values and the emissivity of the disc material [7], [8]. For this reasons the determination of the reflected temperature and emissivity it was repeated at the beginning of each experiment.

For the emissivity the measured values has in the interval (0.48;0.49) and the reflected temperature value has been in the interval (18.9;21.2) (^{o}C).

In the first cycle of the experiment was acted the brake main cylinder until to the 1 pressure (MPa), and after the coupling of transmission, the engine speed was established at the value who corresponding to movement speed of 40 (km/h).

With the thermal camera was measured the temperature distribution on the brake disc surface, and was identified the area were the thermal stress was higher and the temperature variations recorded starting with the brake from the beginning until in that area were the disc was heated to 200 (^{o}C), which is considered the maximum limit supported by the brake pad gasket material.

At the end of cycle was checked the brake disc lateral run-out to notice the irreversible permanent deformation due to braking and if they exceed the limits allowed by the manufacturer.

In the subsequent cycles the intensity of the brake was modified by increasing fluid pressure in the brake circuit to values of: 1.25 (MPa), 1.50 (MPa), 1.75 (MPa), 2.00 (MPa), 2.25 (MPa), 2.50 (MPa), 2.75 (MPa), 3.0 (MPa), this simulates descents on roads with steep slopes. The rest of the parameters remain constant.

It was observed that the point of the brake disc surface where temperatures get to the highest value is located at the exit from contact area with the brake disc within a radius close to the medium radius of friction surface, represented in Fig. 4 .

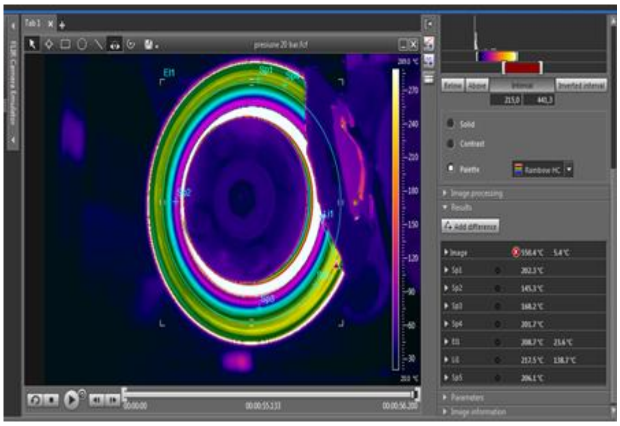

Fig. 4. The picture of disc brakes heated

After each cycle was found that the deformation of the disc do not was above limits which make him in inappropriately, the brake disc lateral run-out are located in 0.03-0.05 (mm) interval, below the maximum allowed by the manufacturer.

The temperatures variation from the point where the thermal stress was higher depending on the time interval recorded starting with the brake from the beginning until in that area were the disc was heated at the maximal value realized in 9 cycles of experiments is represented in Fig. 5, where T - the temperature of the brake disc.

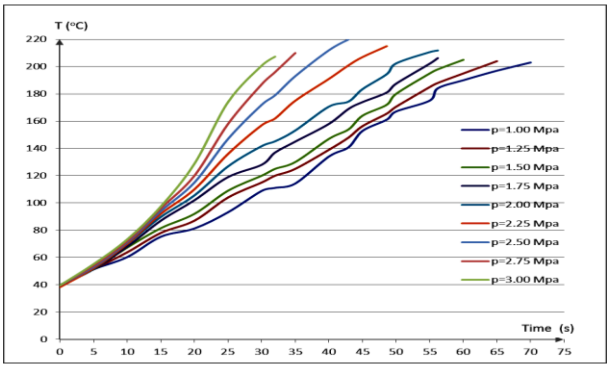

Fig. 5. The variation of the most solicited point temperature on the brake disc surface

III. RESULTS

From the analysis of the experimental data was observed that the heating of the brake disc does not increase uniformly with increasing braking intensity, and time after which achieve a safe limit temperature of operation, decreases with increasing pressure from their operating system.

TABLE I
THE TIME VALUE TO WHICH ACHIEVE THE LIMIT TEMPERATURE ON BRAKE DISC SURFACE

Braking liquid pressure (MPa)	The time experimentally determined (s)	The time analytically determined (s)	The error %
1.00	67.40	66.967	0.64%
1.25	62.70	63.035	0.53%
1.50	57.10	58.356	2.20%
1.75	54.10	53.198	1.67%
2.00	48.70	47.830	1.79%
2.25	42.60	42.519	0.19%
2.50	36.80	37.534	1.99%
2.75	32.80	33.143	1.05%
3.00	30.00	29.614	1.29%

Based on graphical representations from figure 5, for each value of liquid pressure from the actuation circuit of the braking system , denoted with the P letter, it was determinates the time values of the most solicited point temperature on the brake disc surface which has heated to 200 (^{o}C). These values have shown in Table I, where p - liquid pressure from the circuit of the braking system.

Based on experimental data recorded by statistical processing using regression procedure were determined analytical relationships that modulation this variation.

The graph obtained based on experimental data and the analytical relationship is represented in Fig. 6.

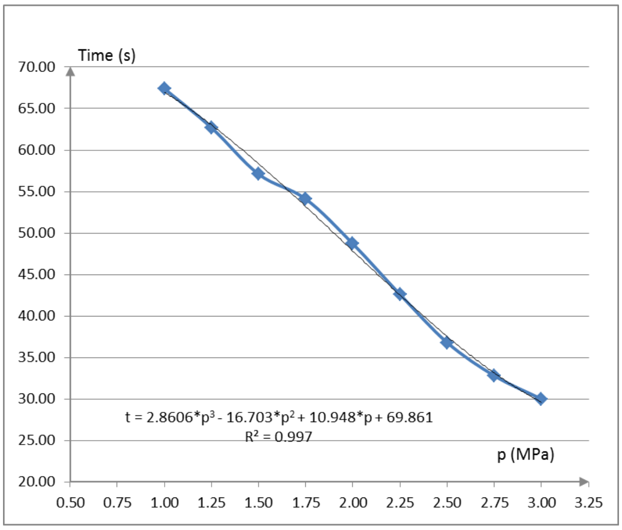

Fig. 6. The time variation which achieve the limit temperature on brake disc surface

The relationship obtained is a polynomial function of the third degree (1), where t – the time measured in seconds

$$\mathbf{t = 2.8606*p^3-16.703*p^2 +10.948*p+69.861} \qquad (1)$$

In this case the coefficient of determination R^2 established using regression procedure in Excel programme is: R^2= 0.997.

TABLE II
COMPARISON BETWEEN THE TIME VALUES WHICH ACHIEVE THE LIMIT TEMPERATURE ON BRAKE DISC SURFACE

Braking liquid pressure (MPa)	The time which achieve the limit temperature (s)
1.00	67.40
1.25	62.70
1.50	57.10
1.75	54.10
2.00	48.70
2.25	42.60
2.50	36.80
2.75	32.80
3.00	30.00

To validate the above relationships, we compared the values determined analytically with those determined experimentally, and the results obtained with the related errors are shown in Table II.

We observe that the differences between the analytical results do not exceed by more than 3% of the values obtained experimentally.

Considering that the experiments were done at a constant speed of 40 (km/h), to determine the distance in meters that can be traveled by car from on a descent slope by actuating the brake disc. The results obtained are shown in Table III.

TABLE III
LIMITED DISTANCE TRAVELED AT A DESCENT SLOPE

Braking liquid pressure (MPa)	Distance traveled until the limit temperature is achieved on brake disc (m)
1.00	749
1.25	697
1.50	634
1.75	601
2.00	541
2.25	473
2.50	409
2.75	364
3.00	333

IV. CONCLUSION

It be observed that with the increasing of the intensity of braking, the thermal stress is increasing rapidly, in the time in which point where is a thermal stress, the heat decreases with increasing fluid pressure in the brake circuit system by a polynomial function of the third degree shown in the previous chapter.

The automobile can descend slopes of 300 (m) with maintain a constant of speed 40 (km/h),by actioning the brake pedal which corresponding a liquid pressure from the brake circuit of 3 (MPa). In the case of shareholders slight at the brake pedal when the pressure is corresponding with a value of 1.00 (MPa), this distance increases to 750 (m).

Because the speed and liquid pressure from the braking system circuit . are parameters that can be easily measured on board the vehicle, manufacturers can deploy an equipment that to warn the driver about the limit of temperature at which the brake discs it works safely.

While the driver will learn how to combine a service brake with the motor brake, for a safe displacement, depending on the length of the slope and the displacement speed.

ACKNOWLEDGMENT

This research was in part undertaken through the Programme Partnerships in Priority Domains- PN II, developed with the support of MEN-UEFISCDI, Project no. 337/2014.

REFERENCES

[1] A. Belhocine, M. Bouchetara, "Thermal–Mechanical Coupled Analysis of a Brake Disk Rotor",*Journal of Failure Analysis and Prevention*, Volume 13, Issue 2, 2013, pp 1167-1179.
[2] H. Beles, N. Chioreanu, T. Mitran, "Researches Regarding The Development Of A Mathematical Model To Optimize The Operation Of The Anti-Lock Braking System", *Annals of the Oradea University Fascicle of Management and Technological Engineering*, ISSUE #2, 2014, pp. 11-16.
[3] M. Baban, C.F. Baban, C. Bungau, G. Dragomir, R.M. Pancu, "Using Fuzzy Logic for the Estimation of the Technical State of Automotive Disc Brakes", *International Journal of Computers, Communications & Control*, 2014, 9(5), pp. 531-538.
[4] M. Baban, C.F. Baban, F.S Blaga, "Maintenance planning of cold plastic deformation tools using fuzzy logic", *Eksploatacja i Niezawodnosc-Maintenance and Reliability*, 2010, 3, 21-26
[5] P. Hwang, X. Wu., "Investigation of temperature and thermal stress in ventilated disc brake based on 3D thermo-mechanical coupling model", *Journal of Mechanical Science and Technology*, vol. 24, no. 1, 2010, pp. 81-84,
[6] M. Nastasoiu, "Study on Increasing BrakingnPerformance and Efficiency of Four-Wheel-Drive Tractors Through Braking on All Wheels",*Annals of the Oradea University Fascicle of Management and Technological Engineering,* ISSUE #1, 2013 pp.229-232
[7] G. Dragomir, R. Pancu, C. Bungau, H. Beles, L. Georgescu, "Studies About Emissivity Variation Depending on the Temperature for Car Brake Disc", *Annals of the Oradea University Fascicle of Management and Technological Engineering*, ISSUE #1, 2014, 253-256 pg, ISSN 1583-0691
[8] G. Dragomir, R. Pancu, G. Husi, L. Georgescu, H. Beles, "Studies About Reflected Temperature Variation for the Car Brake Disc", *SMAT 2014 - 3rd International Congress Science And Management of Automotive and Transportation Engineering*, 2014, Craiova, Romania, 399-402 pg., ISBN 978-606-14-0865-8.