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TEMPERATURE ANALYSIS DEPENDENCE IN THE VICINITY OF THE BRAKE DISK

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Abstract: *The paper demonstrates the friction nodes statistical analysis of road tractor brakes as well as the temperatures analysis of selected wheel breaking systems. The measurement system consists of six temperature sensors mounted in the vicinity of the friction nodes and seventh to measure the ambient temperature. The output signals of the sensors are transmitted to a digital temperature meter based on ATmega 64 microcontroller. The measurement results were recorded on the SD memory card. The digital temperature sensors of the 1-wire interface manual DS18B20 of Dallas Semiconductor were used to measure the temperature. Moreover, the paper presents the research regarding the wheel temperature dependency of the outside temperature. Based on the multiple regression coefficients of approximations made equation describing the temperature increase as a function of the braking force and the distance from the blade point.*

Keywords: Statistical analysis, Road tractor brakes, Brake temperature, Multiple regression.

1. Introduction

The breaking system of a truck is an especially important system for road safety and operation of a vehicle. The intensive experiments and theoretical analysis of the system have been conducted in the Control Division of the Faculty of Mechanical Engineering at UTP University of Science and Technology in Bydgoszcz (Perczyński et al., 2016). It has been assumed that the temperature at the selected point of a wheel brake is a measure of correct operation of the system under operational conditions.

Operation of braking systems in motor vehicles shows occurrence of abnormal operating conditions. The abnormality is defined as e.g. wheel blocking, braking force difference on the axis over 30 %, inadequate braking force of the wheel in relation to mass of examined system and, in extreme cases, lack of braking force. Higher speed of vehicles as well as reducing the size of braking friction pair (disc-brake pad) require the use of higher pressure of friction parts on the disc and affect the growth of thermal load of the braking system. Increased requirements for braking systems force not only the periodic monitoring of the state of the friction, but also constant monitoring of the condition of the braking system, together with the control system and actuators.

To diagnose the friction pair of the braking system, various measurements are carried out which provide information about its condition in direct or indirect way. The direct methods refer mainly to wear and tear of the friction pair by using micrometric tests and devices. The other group of direct methods consists of these applied in non-destructive examination (penetration and magnetic particle testing), which are used to control and measure the length of thermal cracking on the braking disc.

The indirect methods, used to estimate the technical condition of the braking system, consist of measurements of braking distance, tightness or pressure of the braking system. These methods provide information about condition of the system without its disassembly. Unfortunately, the measurements of

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braking distance cannot provide full information about the condition of a specific wheel friction system, but only total score of braking system operation.

During the braking process, kinetic energy of the motor vehicle is converted into heat in the braking system (braking disc – brake pad or brake drum and friction lining). It seems that this diagnostic signal can give useful information about the state of the analysed system. Establishment of optimal place and way how to measure temperature of the friction pair can be a method which allows determination of the emergency status of the braking system.

2. Measuring position

The realization of the target temperature measurement and its surroundings were made to built test bench shown in Fig. 1.

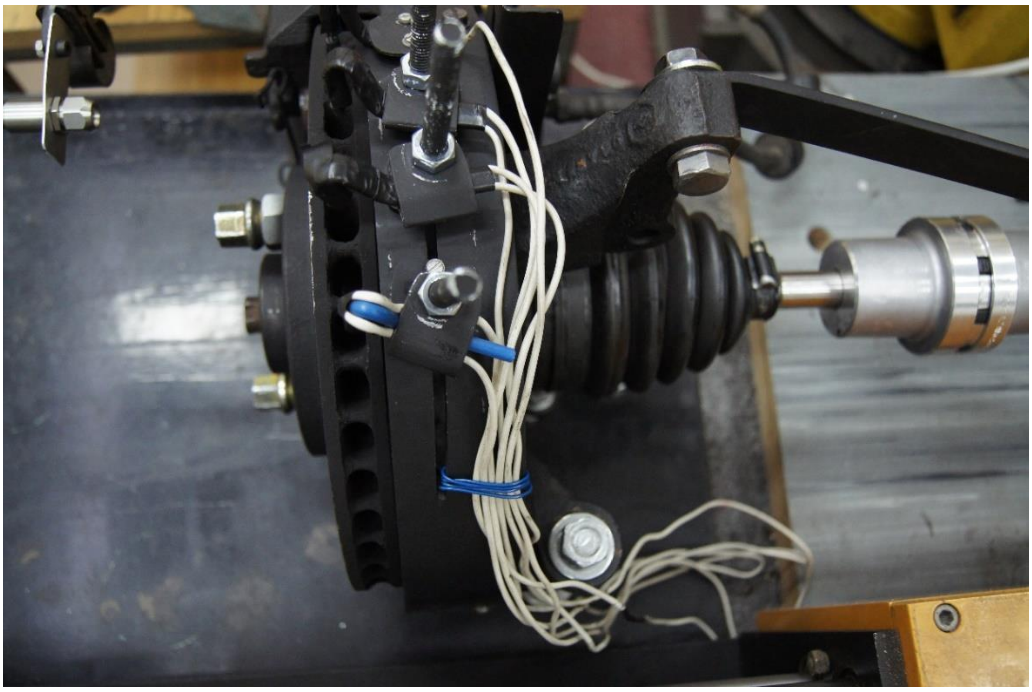

Fig. 1: Measuring position.

In order to record temperature measurement system was built based on a microcontroller ATmega 64 and the digital temperature sensors of the 1-wire interface manual DS18B20 of Dallas Semiconductor. Temperature measurements were made in four points disposed on the circumference of the disk using DS18B20 sensors. The temperature of the disk was measured using a pyrometer OPTCT3MLSF. Furthermore, in order to determine the braking force, the measurements of the fluid pressure in the brake system.

3. Mathematical model

The dependence of temperature changes in the disk and four points distant from the disk 5 mm, 10 mm, 15 mm, and 20 mm described by means of the function $F(t)$ of the form:

$$F(t) = \begin{cases} A(1-\exp(-\lambda_1 t)) & \text{for} \quad t \in [0, t_1], \\ B\exp(-\lambda_2 t) & \text{for} \quad t \in (t_1, t_2), \end{cases} \tag{1}$$

where:

$A, B, \lambda_1, \lambda_2$ are fixed coefficients, t_1– the time braking the end, t_2 – the moment of completion of temperature measurement.

Sample values of the parameters $A, B, \lambda_1, \lambda_2$ with the selected pressure values given in Tab. 1. In addition, in the last row of the table contains the standard error for the approximation of the empirical data by using the tool according to Eq. (1).

Tab. 1: The values of parameters $A, B, \lambda_1, \lambda_2$ and standard error approximations.

0.25 MPa	Disk	5 mm	10 mm	15 mm	20 mm
A	412.10	61.28	53.91	50.33	40.23
λ_1	0.00242	0.00429	0.00400	0.00344	0.00363
B	3051.00	314.33	251.32	193.80	163.43
λ_2	0.01499	0.01053	0.01022	0.00975	0.00985
Std	4.30	0.36	0.29	0.27	0.20
0.23 MPa	Disk	5 mm	10 mm	15 mm	20 mm
A	750.65	132.41	82.56	78.24	72.30
λ_1	0.0014	0.0019	0.0031	0.0027	0.0024
B	1545.99	242.74	231.92	186.31	152.36
λ_2	0.0143	0.0113	0.0112	0.0108	0.0105
Std	5.19	0.79	0.83	0.78	0.66
0.21 MPa	Disk	5 mm	10 mm	15 mm	20 mm
A	468.83	628.45	628.63	628.63	204.38
λ_1	0.00313	0.00047	0.00046	0.00039	0.00079
B	927.12	146.41	146.41	127.74	113.27
λ_2	0.01894	0.01420	0.01420	0.01463	0.01169
Std	4.60	0.80	0.81	0.62	0.54
0.19 MPa	Disk	5 mm	10 mm	15 mm	20 mm
A	887.70	628.96	34.60	628.72	25.50
λ_1	0.00091	0.00029	0.00704	0.00025	0.00653
B	540.67	78.47	84.00	73.39	62.51
λ_2	0.01639	0.01138	0.01206	0.01216	0.01238
Std	3.19	0.58	0.41	0.53	0.36

Graphs of the function $F(t)$ for the case where measurements are performed directly on the face and at a distance *d = 10 mm* of the disc and the pressure of the brake fluid 0.21 MPa shown in Fig. 2. On the presented figure τ is a constant delay of transport between the disk and the heated temperature sensor.

The dependence of the maximum temperature increase $\Delta T_{\max}(x, y)$ with distance measuring the temperature of the disc and the brake pressure is described by the equation (Draper et al., 1998 and Morrisom, 1990):

$$\Delta T_{max}(x, y) = ax + by + cx^2 + dy^2 + exy + f \qquad (2)$$

where: x – pressure [MPa], y – the distance between the sensor and disk face [mm].

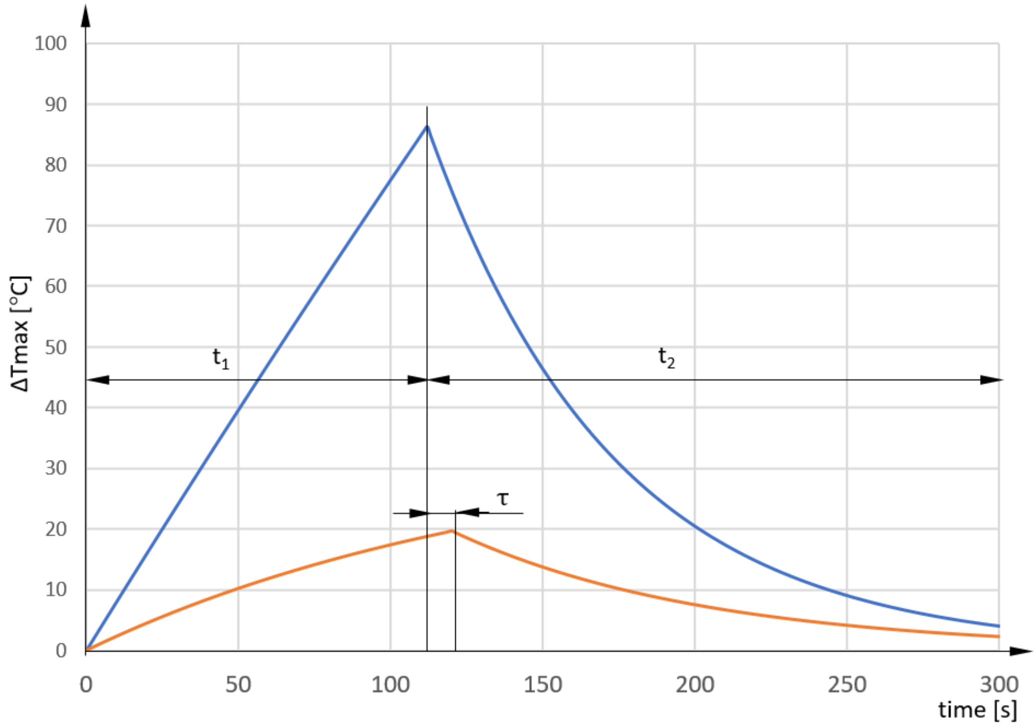

Fig. 1: Relationship between the growth temperature of the target and at a distance d = 10 mm *as a function of time of measurement. The pressure of the brake fluid 0.21* MPa.

For the measurement point on the disk takes up a distance equal to 0.

Using the methods of multivariate approximation made the parameters of the Eq. (2). The values of the coefficients of Eq. (2) are as follows:

$$\begin{aligned} a &= 133.186, & b &= -9.68766, \\ c &= -2.96375, & d &= 0.609143, \\ e &= -0.3466, & f &= -1328.98. \end{aligned} \qquad (3)$$

The calculated value of the coefficient of multiple correlation to empirical data and the adopted model is $R = 0.93$. The study analyzed the level of significance of the equation gives the value $p - value < 0.00001$.

4. Conclusions

Eq. (2) gives the possibility of the temperature increase maximum calculating for different values of pressure and distance than used to determine Eq. (2) parameters. Based on the value of the temperature increase recorded, Eq. (2) makes possible to calculate of the braking force values on the wheels of the same axle. This information is essential for analysing the efficiency state of the braking system. The last possibility is important in practice, so further research is presented in this work will be continued in the direction of seeking "good" according to the binding temperature increase of the target, the distance measuring point and the value of the braking force.

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