Transport and Communications, 2017; Vol. I.
ISSN: 1339-5130
DOI: 10.26552/tac.C.2017.1.3

Temperature of the brakes and the Braking Force

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Abstract The kinetic energy of the braking vehicle is changed into heat and the resulting heat increases the temperature of each part of brakes. The changed temperature affects the coefficient of friction between the brake lining and brake drum of brake disc. Unless the brakes are actuated hydraulically there is the warning brake pads and brake fluid. Object of examination in this article is the impact of repetitive braking to change of these parameters and the impact of time to change the boiling point of the brake fluid.

Keywords: Brakes, the increase of temperature, the change of braking performance, brake fluid, the boiling point of the brake fluid

JEL R41

1. Introduction

The accident rate is one of the unintended effects of road transport. If we compare the different causes of accidents, the speed of driving is one of the most dangerous mistakes of drivers. Based on the statistics of the police [1] of Slovak Republic can be stated, that the Slovak republic had an accident, whose cause was the speed, the rate of the total number of 13.67 %, but he ration of the number killed was up 28.96 %. When it forms the column of vehicles on the road, the driver at the high speed must repeatedly brake from high speed to the speed of column and accelerated again. During this activity it occurs in the vehicle's brakes to transform the vehicle kinetic energy into heat, which causes the increase in temperature of the brake parts. In hydraulic brakes there is the raising the temperature of the brake fluid. We wanted find out in describing experiment just these thermal changes of individual parts. The aim was to determine the boiling point of the brake fluid at the time and the impact of absorbed moisture on it, because the brake fluid is strongly hygroscopic. We performed the measurement on passenger vehicle KIA cee'd 1.6 CRDi. When the vehicle was occupied by two persons the front axle was laden the mass m1 = 852 kg and rear axle m2 = 614 kg. Therefore the distance the center of gravity from the front axle was 1.11m. The measurement of temperature was performed on the brake disc of the front axle, brake caliper and piping with brake fluid at the place of connection to the calipers.

2. Change of the temperature of the brake components

As a test case we took the situation in overtaking the line of the traffic. The driver has to reduce the driving speed from 120 km/h to 60 km/h and accelerate again to its original speed. The purpose was to repeat this cycle several times. In order to perform the measurement of temperature at selected points we practised the measurement on laboratories on roller tester. It was necessary under braking converted the same amount of energy into heat as by driving on the road. It is more loaded during the braking the wheels of the front axle, so we focused on the change of temperature of the front axle. [2, 3]

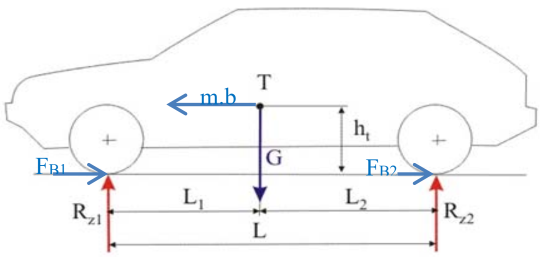

Figure 1. Reaction R_{Z1} Finding

To detect the change of temperature of the selected components of the front brake, it is necessary to determine what rate of kinetic energy the vehicle was converted into heat by the brakes of the front axle.

We suppose the driver draw the braking force that causes deceleration of 3 m/s^2. When the wheelbase of vehicle is L= 2.95 m and the known position the centre of gravity we can determine by calculation the load of the single wheel of the front axle during the braking to value m_l= 485kg, as is shown in Figure 1.

To achieve the deceleration of 3 m/s^2 then must act on the wheel the braking force F'_{B1} = 1 455N. This value of braking force must be set even if the measurement is performed on the roller brake tester.

Now it is necessary to determine the time of braking during the test on the roller brake tester. We will be average out the amount of kinetic energy which must be in the brakes of the one front wheel to turn on heat. This amount of energy is marked as ΔE_k. This energy is equal to the difference between the kinetic energy of the weight on this wheel at the speed of 120 km/h and 60 km/h. It is possible to write the following equality:

$$\Delta E_K = E_{K120} - E_{K60} \quad (1)$$

or,

$$\Delta E_K = \frac{m_1^{,} \cdot V_1^2}{2} - \frac{m_1^{,} \cdot V_2^2}{2} \quad (2)$$

Where,

m_1 = 485 kg - it is the weight on the one front wheel during the deceleration of the vehicle 3 m/s,

V_1- 120 km/h - it is the initial speed of braking test,

V_2 - it is the final speed of braking test,

ΔE_k - it is the difference of kinetic energies at the beginning and end of the braking test,

$E_{k\ 120}$ - it is the kinetic energy at the beginning of the brake test,

$E_{k\ 60}$ - it is the kinetic energy at the end of the braking test.

Using the information from the previous text, the change of kinetic energy of the vehicle is:

$$\Delta E_K = \left(\frac{485}{2}\right) \cdot \left(\left(\frac{120}{3,6}\right)^2 - \left(\frac{60}{3,6}\right)^2\right) \quad (3)$$

ΔE_{k} = 200 833 J

It must be transformed in the brake of one front wheel in to energy 200 833 J into heat. Thus, it was determined the amount of brake force and amount of energy that should be transformed into the heat. As it is a compensation of the real driving situation it is necessary define the time of living the braking force to operate. We determine it based on the track over which must apply the load to do the work 200 833J.

$$s = \frac{\Delta E_K}{F_{B1}^{,}} = \frac{200833}{1455} = 138.03\ m \quad (4)$$

The braking force should apply on the track 138.03 meters. When the roller speed of roller brake tester is V = 4.8 km/h, the time of measurement must be:

F'_{B1} = 1 455 N

F'_{B1} - It is the amount of braking force.

t - It is the time of activity the braking force [s],

V - It is the peripheral speed the roller of the roller brake tester [km/h],

s – It is the track on which must act the braking force $F_{B1}^{,}$ to carry out the work $\Delta E_K = 200833\,J$.

Braking force must be applied for a period of 103.5 seconds to carry out its work.

To be able to find out the change of braking force it must be ensured the equal actuating force. It will be used during braking the load cell to determine the actuating force to draw the desired braking force. For each repeated measurement will be used the same actuating force as was found out at the first measurement. After each measurement it will be detected the surface temperature of the brake disc of the front brake, the surface temperature of the brake caliper, temperature of pipe the brake fluid at the connection to the brake caliper and it will be read off the braking force at the perimeter of the wheel. [4]

2. The boiling point of the brake fluid

During a dynamic driving tends to increase the temperature of the brake components. Therefore, is the issue of brake fluid boiling point very important. The brake fluid is a highly hygroscopic substance which absorbs moisture from the surroundings and affects its boiling point. During the experiment was the brake fluid placed in the bowl, which has within the cap outlet with diameter 1 mm, figure 2, medium bowl. Thus, stored liquid was exposed to the activity of surrounding (heat, light, change of moisture) for seven months. After this time was reviewed its boiling point by the means of device Bosh BFT 100, figure 3.

Figure 2. Braking fluid

Figure 3. Device for measuring the boiling point of brake fluid

The brake fluid is a highly hygroscopic substance and its boiling point varies with the amount of absorbed moisture. What effect has the moisture on its boiling point has been verified by adding the distilled water. Into 100ml of brake fluid was gradually added one ml of distilled water, this substance was mixed perfectly and then was measured the boiling point. For comparison was measured the boiling point of the new liquid. [3]

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3. Measurements

Is was used to measure the vehicle Kia cee´d 1.6 CVVT and the following measuring devices:

- The roller brake tester Motex 75 19 (Figure 4). It is a diagnostic device that allows to measure and continuously monitor the braking forces at the periphery of individual wheels of one axle. The peripheral speed of the brake cylinders of roller brake tester is 4.8 km/h-1.

Figure 4. Roller Brake Tester Motex 75 19

- Pedometer Corrsys Datron is used to measure the force exerted on the brake pedal. It consists of a sensor, which is attached to the brake pedal (Figure 5), cable and evaluation device. The amount of control force is displayed on the digital display.

Figure 5. Pedometer Corrsys Datron

- Contact thermometer Greisinger GTH 122 (Figure 6). Thermometer has two ranges of measuremet: from -65°C to +199.9°C and -65°C to +1 150°C. The resolution 0.1°C or 1°C, accuracy ± 0.2 % and operating temperature 0 to 45°C.

Figure 6. Contact Thermometer Greisinger GTH 1200

- Seconds counter

4. Measurements results

A) The change of temperature of the brake components

The results of the measurement and the measured values are summarized in the graph at the figure 7.

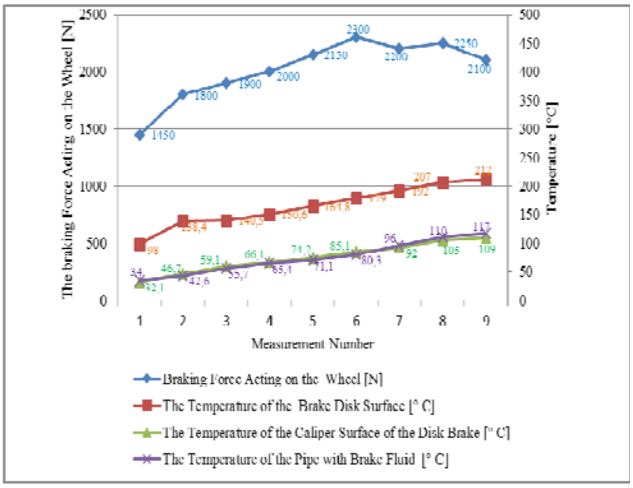

Figure 7. Changing of the braking force as a function of the temperature

In order to compare the change of amount of braking force on the peripheral of the wheel, at each measurement by using pedometer was inferred to the brake actuator the same operating force 350N. So was ensured that the change of amount of braking force has been caused as a result the change of friction properties of lining in changing its temperature. The friction of lining improves with increasing temperature. At the sixth braking cycle has been reached the temperature of brake disc 179°C. At this temperature was measured the maximum braking force of 2 300N. Next braking cycles caused an increase of temperature of the brake components but the inferred braking force has been lower and had a downward trend.

B) The change of the boiling point of brake fluid

Changes of the boiling point of the brake fluid are shown in Table 1.

Table 1. Changes of the boiling point of the brake fluid [°C]

	Changes of the boiling point of the brake fluid [°C]						
Status of the fluid	New	After 7 months	The added amount of distilled water into 100 ml of brake fluid				
			1 [ml]	2 [ml]	3 [ml]	4 [ml]	5 [ml]
Boiling point	267	162	216	202	186	155	138

5. Conclusions

The experiment verified the change of temperature of braking components in vehicle by repeated braking from high speed and the impact of the temperature to the amount of braking force. The second aim was to find out the change of the boiling point of braking fluid with the time and with the amount of absorbed moisture. That the result was comparable was used constant braking force authenticated by using pedometer. This was adjusted such that the vehicle has reached during the first braking deceleration of 3 m/s^2. From the comparison of the temperature is evident that the repeating braking can leads to the increase of temperature of the braking lining and also to increase in the braking. When the temperature of brake disc reaches the value 179°C it was recorded the decrease of braking force. This decrease lasted until the end of experiment. In terms of operation is important the boiling point of the brake fluid, because at the end of experiment was the temperature of pipe with brake fluid 117°C. During the measurement was verified that by repeated heavy braking of the vehicle and by omissions of braking fluid is realistically achieve the condition, that the temperature of braking fluid reaches the boiling point. In the time to achieve this is significantly reduced the performance of brake.

ACKNOWLEDGEMENTS

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