Monitoring of disk brakes vs drum brakes using infrared thermography

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Abstract – **In this article we will examine the principle of operation and characteristics of infrared thermographs; Their applications in the monitoring of braking systems. We will make experimental measurements of the temperature distribution in the braking systems at rest and at different loads. We will analyse the obtained results.**

Keywords – **Brakes, Emissivity, Thermography, Vehicles.**

I. INTRODUCTION

The number of cars in these days is increasing worldwide every year. And with the number of cars, the number of accidents increases as well, as a result of which more people die and even more become disabled. Not good technical conditions and operation of vehicles is one of the main causes of many accidents. Accidents resulting from damage to various vehicle systems have the most serious consequences.

The most important system responsible for vehicle safety is the braking system. The design of the cars is constantly improving, but the presence of the braking system remains unchanged, which helps to stop the car when needed, which saves the lives of pedestrians, drivers and passengers, as well as other road users. Repair of the brake system is necessary for all vehicles, however, it is necessary to diagnose the technical condition of the brake system every few thousand kilometers, this is necessary to reduce the likelihood of damage to the brakes of the car. [1-2]

The aim of the paper is to increase the efficiency of diagnosing the car's braking system through the use of thermographic systems. It is through them that we will show how effective the braking system of the studied car is.

II. THEORY

Infrared thermography captures infrared heat, which allows the determination of the surface temperature of a body. Any object with a temperature above absolute zero (0 K or -273.15 °C) emits energy - electromagnetic heat depending on its temperature. [3]

Brake disc temperature is one of the critical variables in vehicles. In fact, temperature directly affects braking efficiency. This effect becomes very important at excessive temperatures, which are due to repeated or continuous contacts between pads and discs. This phenomenon is called "fading". It is clear that braking performance has a strong role to play in the quality and safety of vehicle control. The loss of stopping power logically implies an increase in the probability of accidents and traffic accidents. Thus, it is essential to monitor this temperature. This is especially true when the vehicle has to enter mountain tunnels, for example, where accidents are a possible source of fire. [4-6]

III. THERMOGRAPHIC IMAGES OF THE STUDIED CAR, CALCULATIONS AND DATA

The paper is to make the practical measurements of the set task. In order to do so, we used FLIR E40 thermal camera, HPA brake stand, Car QQ Cherry (on Fig.1), Software - FLIR Tools +.

Fig. 1. The vehicle we used to make the practical measurements and it was mounted on the HPA car stand.

Turning to the practical part, we will consider several cases. Since the car is equipped with disc brakes at the front and drum brakes at the rear, we will observe the temperature difference between the two cases - the front and rear wheels. In this way we will judge in which of the wheels the braking efficiency is higher, and also to note whether the heating is higher with the disc brakes or the drum brake and how long it takes to reach a certain temperature. [7]

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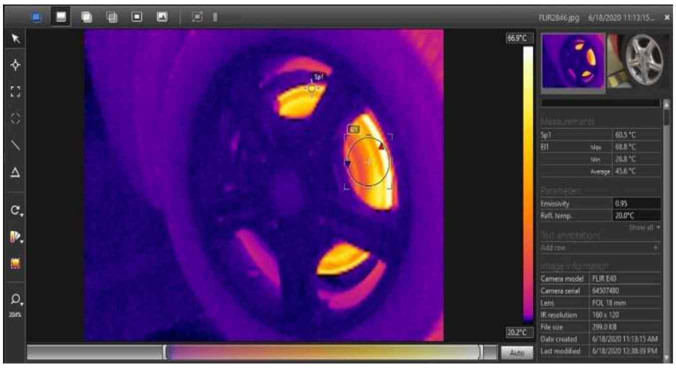

Fig.2 Thermographic image of the experimental setup. Moment 7 of 7 of the LEFT front disk brake.

In the following experiment we will present the temperature change under load of the front disc brakes. We will observe the temperature at a certain point Sp (point of interest) which can be seen on the Figures above:

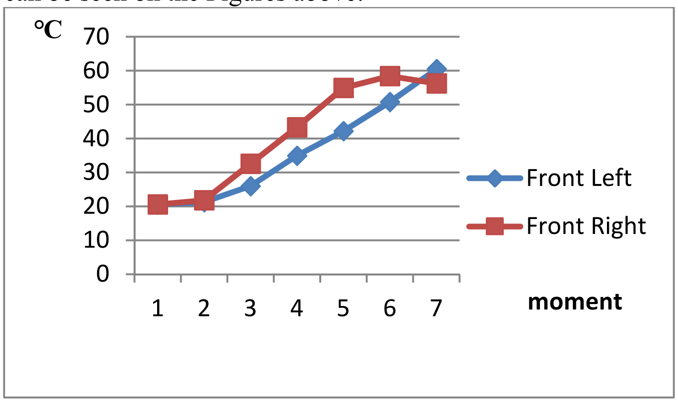

Fig.3. Along the abscissa axis are plotted the seven moments for the images, in which the pictures were taken at every 10 seconds, and along the ordinate axis are the degrees Celsius.

The images were taken in period of 10 seconds. The difference in temperature between the left and right disc brakes is due to the fact that the same load cannot be provided on both disc brakes at a time, but the results are approximately the same. [8]

In the graph we notice that the temperature values of the front right disc brake are higher than those of the front left. This can be due to both the unequal load and the difference in wear between the two brakes. [9-12]

From the acquired data we can calculate the average values.

The average temperature of the left brake disc is 32.38 °C and that of the right 37.89 °C. This is over 5 degrees difference between the temperatures of the two brake discs. As the temperature of the left brake disc is lower, we can note that it is more efficient than the right one.

We will again present the temperature change under load of the front disc brakes, but this time we will observe the temperature in El (circle of interest). This is the arithmetic mean of the temperatures in the whole circle. Here we will include the averages of the circle of interest [13-15].

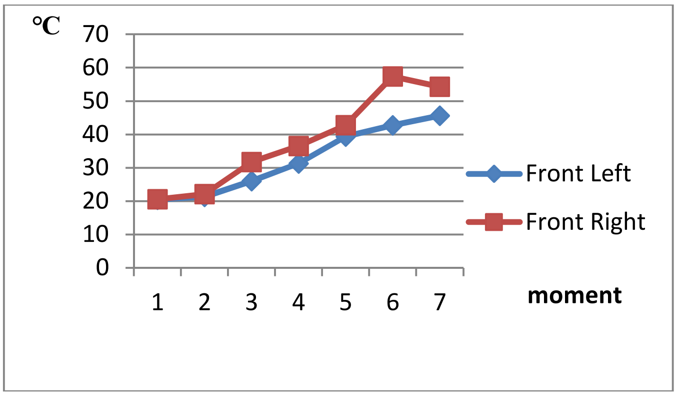

Fig.4. Along the abscissa axis are plotted the seven moments for the images, in which the pictures were taken at every 10 seconds, and along the ordinate axis are the degrees Celsius.

Those for the right brake disc are slightly higher than those for the left. We can see that in Fig.4 with the Graph for Front Left and Right brakes.

Now we will present the temperature change under load of the front brake discs, and again we will observe the temperatures in El (the circle of interest), but this time we will subtract the min and max values in the circle of interest.

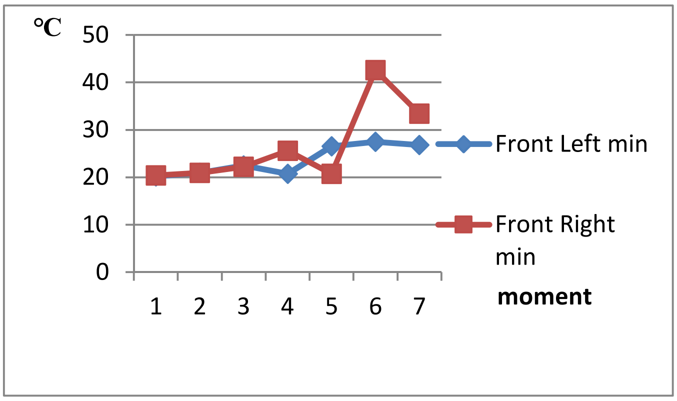

Fig.5. Graphic representation of the minimums from the front wheels

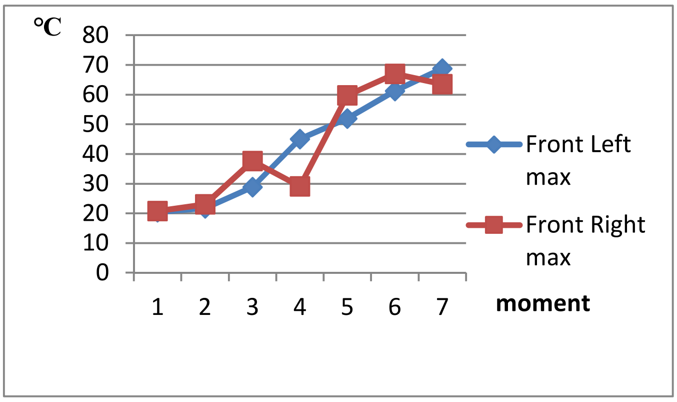

Fig.6. Graphic representation of the maximums from the front wheels

In both graphs from Fig.5. and Fig.6. we notice approximately the same values with minimal deviations which can be seen in the Graphs.

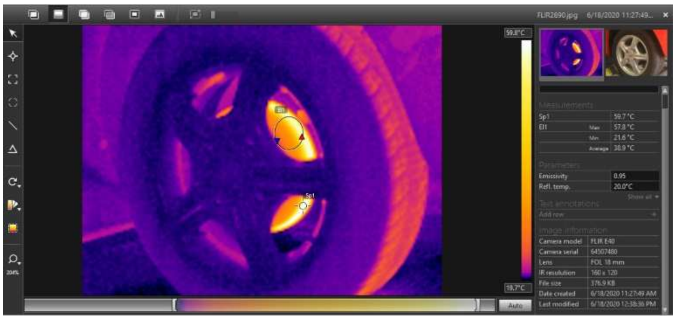

Fig.7 Thermographic image of the experimental setup. Moment 7 of 7 of the LEFT rear drum brake.

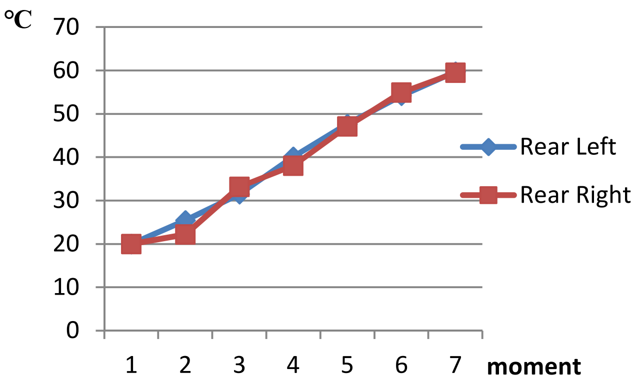

Fig.8. Along the abscissa axis are plotted the seven moments for the images, in which the pictures were taken at every 10 seconds, and along the ordinate axis are the degrees Celsius.

In the graph from Fig.8. we notice that the values of the temperature of the rear drum brakes are approximately the same with minimal differences.
The average value of all 7 points of interest Sp; c_1, c_2, c_3, c_4, c_5, c_6, c_7 are the values of Sp in every moment of all 7 ones of the LEFT rear drum brake is $z_{1av} = 30{,}2$°C .
The average value of all 7 points of interest Sp; d_1, d_2, d_3, d_4, d_5, d_6, d_7 are the values of Sp in every moment of all 7 ones of the RIGHT rear drum brake is $z_{2av} = 30{,}33$°C .
Here the difference between the average temperatures of the rear drum brakes is very small - only 0.13 °C. Therefore, we can say that the two drum brakes have almost equal efficiency. Still, if we have to be precise and specific, the rear left drum brake is a bit more efficient than the right one.
$z_{12av} = 30{,}27$°C is the average between z_{1av} and z_{2av}.

In Fig.9. which refers to the minimum values in the circle of interest El, we notice approximately the same values for the temperature of the drum brakes. The largest difference is observed in the sixth moment of the measurement. This may be due to the inaccurate measurement moment. Because the measurements are made approximately every 10 seconds.

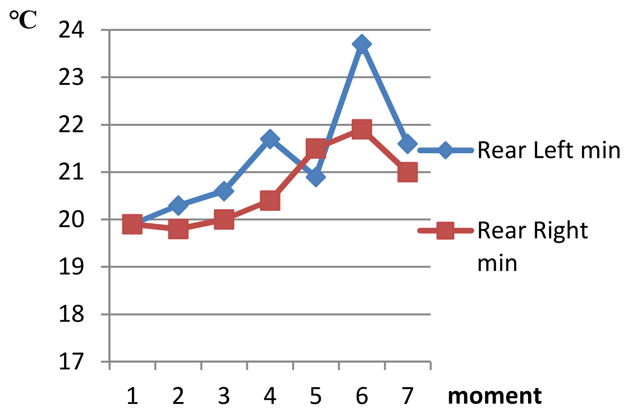

Fig.9. Graphic representation of the minimums from the rear wheels

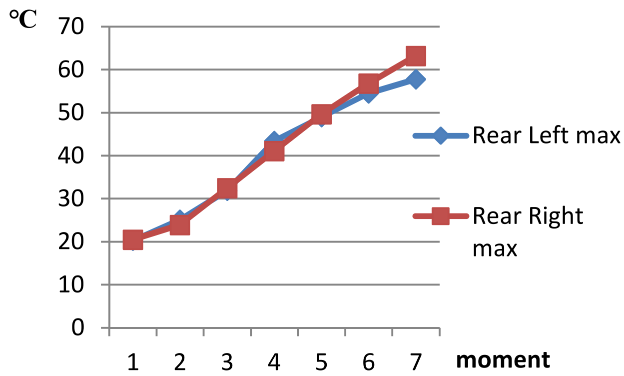

Fig.10. Graphic representation of the maximums from the rear wheels

In the Fig.10 which refers to the maximum values in the circle of interest El, we notice approximately the same values at absolutely all times.

To statistically compare the change in data between the front and rear wheels, we will use a correlation function. The correlation coefficient gives us information about how strongly two variables are interconnected.

After processing the results, the correlation coefficient for the front wheels is 0.975, for the rear wheels is 0.982 and compared to the front and rear wheels is 0.954.

For graphical representation of the behavior of the individual wheels with increasing temperature we will use Linear least squares method, which shows that three of the wheels have a similar behavior, while the front right wheel has a large deviation in the last measurements, shown in Fig. 11.

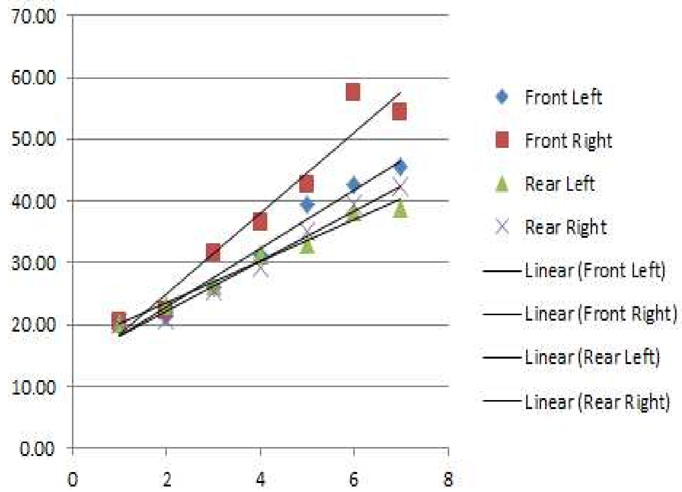

Fig.11. Graphic representation of the linear least squares of the four wheels.

IV. Conclusion

On the thermographic images it can be seen that the heating of the brake disc is almost uniform everywhere and the brake system of the car is completely working. We can conclude that the car has a good braking system. After measurements, software processing of the thermographic images and data observations, we found that the drum brakes, which were on the rear wheels of the car we used for the study, were more efficient than the front brake discs. This is not really the case, because in addition to the temperature we get from friction, another factor is the time it takes for the disk brakes or drum brakes to cool. The drum brakes need a lot more time to cool down, just because the pads are located inside the drums, unlike the disk brakes – as they are uncovered. That is what allows them to cool down faster and it makes them more efficient. As mentioned earlier, we can conclude thanks to infrared thermographic images, that the braking system is in good condition. In conclusion, it can be said that such a monitoring system could be used both in the production of brake systems for cars and in checking the integrity of the car in order to promptly eliminate problems in the braking system.

Acknowledgement

We would like to express our sincere gratitude to the Faculty of Telecommunications and the Faculty of Transport at the Technical University of Sofia for providing the laboratory base.

The scientific research and the results obtained are part of a contract №202ПД0014-07 for a research project to help doctoral students: "Using optical methods to collect and transmit audio signals" of the Technical University of Sofia, Research Sector.

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