University of Banja Luka
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DEMI 2021

15th International Conference on Accomplishments in Mechanical and Industrial Engineering

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Banja Luka, 28 - 29 May 2021

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DEMI 2021

Banja Luka, May 2021

15th INTERNATIONAL CONFERENCE ON ACCOMPLISHMENTS IN MECHANICAL AND INDUSTRIAL ENGINEERING

DEMI 2021

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CONTENT

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Experimental determination of thermal stresses disk brakes in depending from the braking pressure and vehicle speed

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Abstract *The goal is that during the process of braking stopping distance as short as possible, which is one of the important parameters of braking. During the braking process itself, a certain heat is generated on the brake disc and brake pads, which depends on the speed of movement that the vehicle had at the time of the brakes, as well as from the realized pressure in the brake installation. The purpose of this work is to find optimal braking parameters, in order to generate as less heat as possible on the disc brakes. The paper presents experimental research on a test rig BRAKE DYNO 2020, for a simulated vehicle speed of 100 km/h when the braking pressure of 2.8 MPa and 5 MPa. It is concluded that higher temperatures occur in the case when the braking pressure is 2.8 MPa, because it takes more time to stop. The results of this research can be applied in practice, in defining braking pressure.*

Keywords *braking parameters, heat, experimental research, BRAKE DYNO 2020*

1. INTRODUCTION

During the exploitation from vehicle is expecting to achieve the fastest possible desired speed, as well as to slow down or to stop for shortest possible time, all depending from road conditions. Because of this reason, the system that is the most exposed to the stresses, is the braking system. The braking system should do three basic tasks and that:

- Emergency braking – characteristic for critical situations;
- Easy long-term braking – vehicle movement on long downhills, and
- Easy short-term braking – characteristic for city situations.

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During the braking process, the entire kinetic energy transforms into the heat energy, on disc brakes. The heat energy generates in the contact between the braking disc and braking pads, as the consequence of the friction appearing. The tendency is, that the friction coefficient during the braking process be as great is possible, in order to provide as shortest possible stopping distance. However, the undesirable consequence of friction is the heat generation in the braking system.
With the temperature increment, the friction coefficient value falls [1]. However, this happens, when the temperature value on the contact surfaces passes value of 250 □. In the case, when the temperature on the contact

surface of the braking disc is 150 □, the friction coefficient is biggest [2]. Important parameters from which depends, the amount of heat that generates on the contact surfaces are coefficient of heat transfer, heat flux, specific heat and heat dissipation into the environment [3].
Braking pads, during the braking process acting on the braking disc with determined force. Due this, it comes to the deformations of elements, which are in contact, which further causes the appearance of wear on the same elements. On the wear size, as well as on the size of contact temperatures are influencing loads that appear in observed moment [4], where are separating three different wear types and that:

- Slight wear;
- Moderate wear, and
- Hard wear

In more researches, the same conclusions have been obtained, that is that the temperature that was generated on the contact surfaces is not uniform [5, 6]. Because of this it comes to greater wear of contact elements. When the sliding speed is high, the temperatures that are generating on the contact surfaces are very high, which can cause the disturbances in the material [7]. The shape of hot surfaces that appearing during the braking process (Figure 1), can be separated on five types [8]:

1. Asperity – the heating appears on discrete points on the contact surface of the braking disc, are short-term character.
2. Gradients on hot bands – its appearing one long contact track, with interruptions.
3. Hot bands – are consequence of reduced contact between the braking disc and braking pads, can be present more bands.
4. Macroscopic hot spots – are representing hot spots that are deployed on the contact surface of the braking disc. Due such generated temperature on the braking disc, it can come to the braking disc twisting.
5. Regional hot spots – on the contact surfaces are appearing lower temperatures that are characteristic for nonhomogeneous cooling

By observing all five heating types, Figure 1, the greatest damages of the braking disc are appearing in the cases 2., 3. and 4. types of heating.
The aim of the paper is the investigation of the influence of the braking pressure on the size of the generated temperature on the braking disc and braking pads, all with reason to find optimal braking parameters.

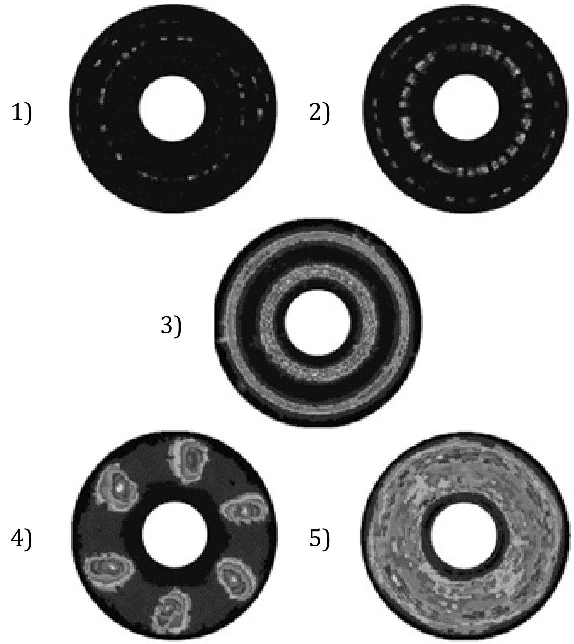

Fig. 1. Types of braking disc surface heating: 1) asperity, 2) gradients on hot bands, 3) hot bands, 4) macroscopic hot spots, and 5) regional hot spots [8]

2. THE TEST RIG WITH APPLIED DEVICES/SENSORS FOR MEASUREMENT

The experimental investigation for this paper was performed on the test rig BRAKE DYNO 2020, on the Faculty of Engineering University of Kragujevac. The scheme of the test rig for investigation of the disc brake thermal stresses can be seen on the Figure 2.
The test rig control is performing by application of the PC (11), from which command signals are sent through A/D converter 6353, to the actuators. By command signals is performing the activation of the electric motor (29) start. Also the same electric motor is controlled by by AC drive (13), which also receives command signal from the PC. At the end, the signal for the activation and deactivation of the electromagnetic clutch (2), also is also sent form the PC. The activation of the brake caliper (27), is performing by braking cylinder (12), which activates by application of the pneumatic installation (9), Figure 3. The air supply for pneumatic installation is from compressor (10), which can provide maximal pressure 10 bar. The electromagnetic clutch is on one side in

rigid connection with electric motor and on other side, with the flywheel mass shaft (5). The flywheel mass is on the both side with two bearings placed on the carrying construction (22) of the test rig. While the position of the electric motor is defined by vertical adjusters (23) in order to achieve axis adjustment between the shaft of the electric motor, and shaft of the flywheel mass. On the other side of the flywheel mass shaft is mounted braking disc (6). Where the braking calliper is in rigid connection with the calliper carrying plate (28), which is with other side relying on a force sensor (19).

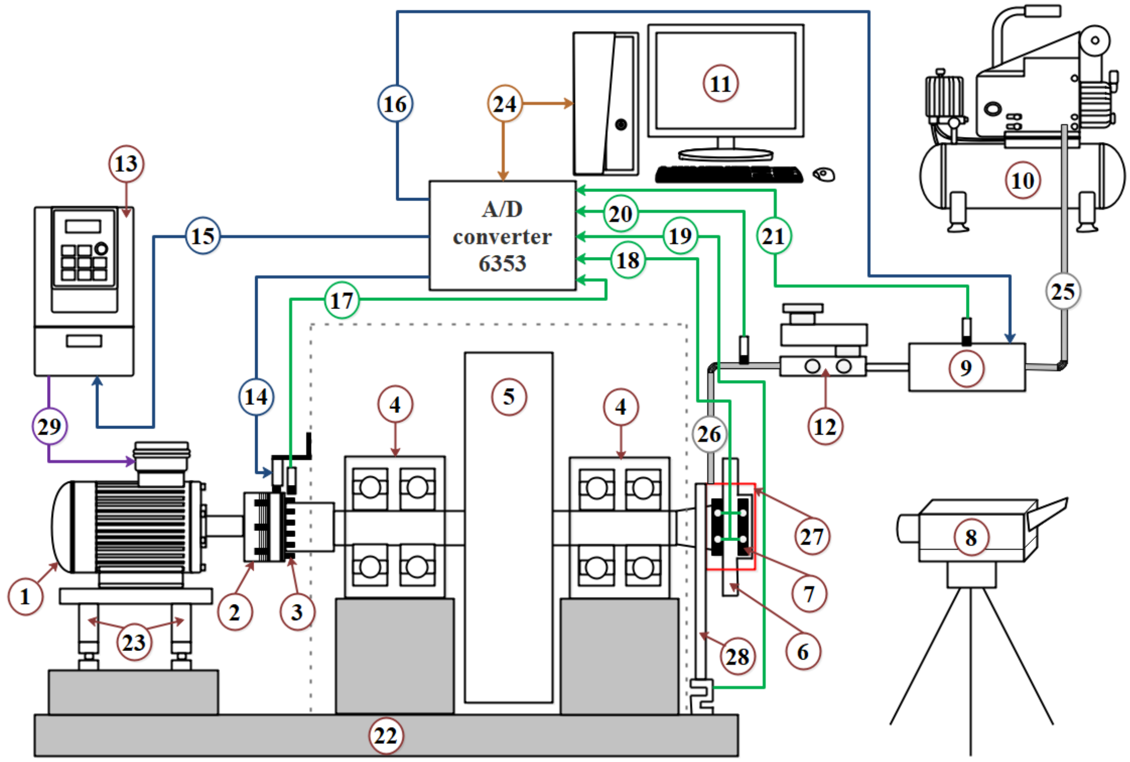

Fig. 2. The scheme of the test rig

Also, by A/D converter 6353 are collecting the measured signals from mounted sensors, which are mounted on the test rig. On the test rig, during the experimental work, are measured next parameters:

- The angular speed of the flywheel mass/braking disc (14).
- The pressure in the pneumatic installation (Figure 2 – position 21, Figure 3 – position 7).
- The pressure in the braking installation (20).
- Braking torque (19).
- Temperature in the braking pads (18).

While the temperature on the contact surfaces of the braking disc is measured by application of thermal imager TESTO 868 (8). Inside each braking pad are located two temperature probes at 2 mm depth, from the contact surface. One is located on the entering side of the braking pad and the other on the exiting side of the braking pad

Pneumatic installation (Figure 3) consists from air conditioning group (1 and 2), 5/2 electromagnetic valve (3), with which is performing activation of the pneumatic cylinder (8). The air pressure is controlling by pressure regulator (4), while by flow control valves (5 and 6) are controlled activation and deactivation speed of the pneumatic installation.

The test rig for the investigation of the disc brake thermal stresses BRAKE DYNO 2020, is shown on the Figures 4 and 5. The Figure 4 represent the 3D model of the test rig that was created in the CATIA software package, while Figure 5 illustrates the realized test rig.

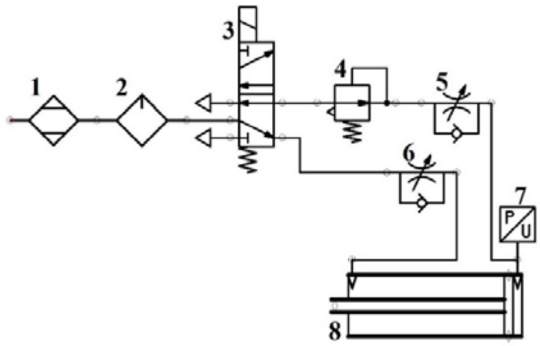

Fig. 3. The pneumatic installation for the braking system activation

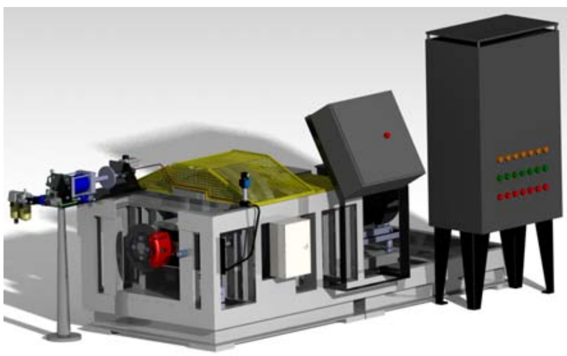

Fig. 4. 3D model of test rig BRAKE DYNO 2020

Fig. 5. The appearance of test rig BRAKE DYNO 2020

3. TESTING PROCEDURE

How the aim is to determine how the size of the braking pressure influences on the value of the generated temperature on the disc brake, is was defined testing procedure, Figure 6. First step is to define the testing conditions such are value of the braking pressure, the vehicle quarter mass (the test rig simulates one quarter of the vehicle) and desired vehicle speed. After that are defining values which are observing during the investigation process – output parameters. The output parameters are the temperatures on braking pads and on the braking disc, deceleration, friction coefficient, the pressure changes during the stopping period and braking torque.

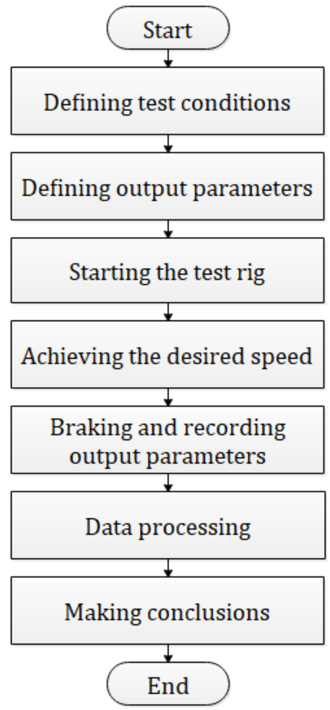

Fig. 6. Testing procedure

Next step after defining input and output parameters is the test rig starting, and after achieving the desired speed, the simulated vehicle is stopping and during the braking process are recorded the input and output parameters. After that, the measured data is processing and showing by charts, from where are coming conclusions, about thermal stresses that occurred during the braking process. While the temperature obtained by application of the thermal imager, are showing in the shape of thermal images.

4. RESULTS AND DISCUSSION

In this chapter are shown the obtained results by experimental work, according to the defined testing procedure on the test rig BRAKE DYNO 2020.

In the moment of achieving the maximal speed, the brake activates and it starts the stopping process of the simulated vehicle. According to the defined braking conditions, at the moment when starts the braking process, the electromagnetic clutch deactivates and separates the electric motor from the flywheel mass. The maximal braking pressure in both cases was achieved after 1 s, Figures 7 and 8, and it stays almost constant during entire braking process.

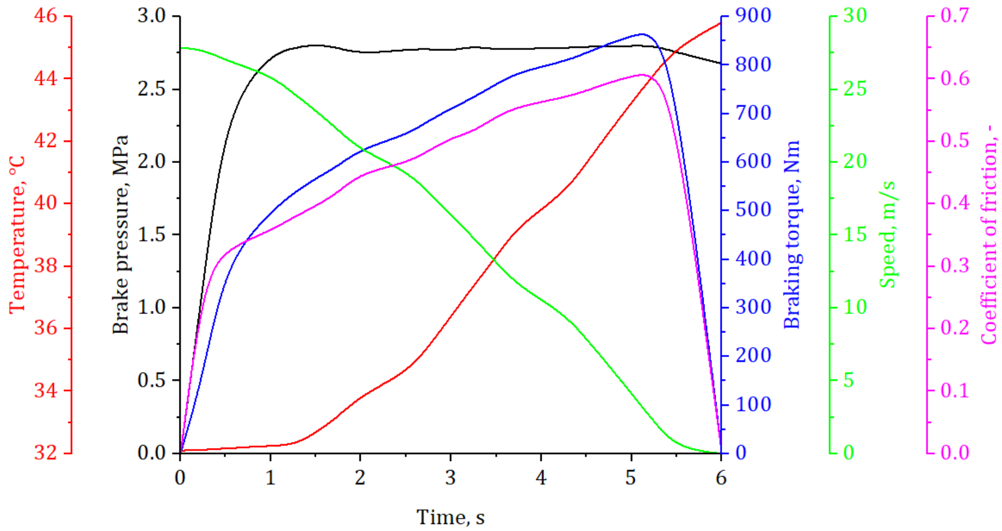

Fig. 7. Changes of braking pressure, temperature, braking torque, speed and friction coefficient in the function of time, when the maximum pressure in braking installation is 2.8 MPa

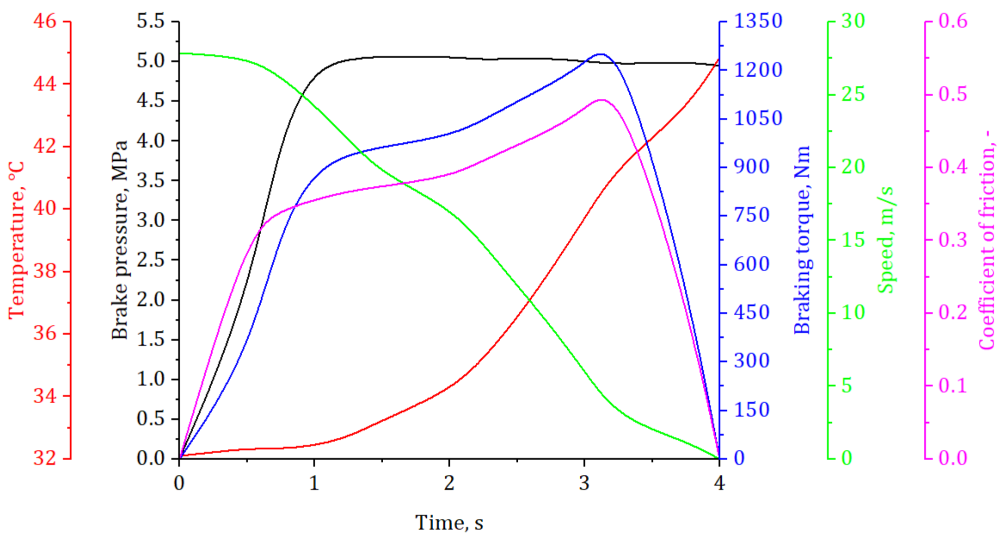

Fig. 8. Changes of braking pressure, temperature, braking torque, speed and friction coefficient in the function of time, when the maximum pressure in braking installation is 5 MPa

Maximal values of braking torque and friction coefficient are appearing when the speed of the simulated vehicle falls under 3 m/s. The temperature that was observed, is the temperature on the external braking pad, on the side that first enters in contact with the braking disc, from reason, because on it are appearing highest values. In the first period, while vehicle speed don't falls under 20 m/s, the temperature changes are insignificant, more accurately its grown for 1.5 □. After the speed falls under the 20 m/s, the temperature change is significantly greater. In the case when is defined 5 MPa braking pressure, the temperature it's grown for 9.7 □. While in the case when the braking pressure is 2.8 MPa, it has grown for 11.22 □. The reason for higher temperature in the case when the maximal braking pressure is 2.8 MPa, is because the braking time is longer, Figures 7 and 8.

The thermographic representation of the braking disc and braking pads is shown on Figures 9 and 10. Different from braking pads, greater temperatures are appearing on the braking disc. Which is very good, because only the braking disc can dissipate heat into the environment, because during the braking process, the greatest part of the braking disc rotates free in space, where on it acts only the air. How the testing was performed in stationary conditions, without air that flows around disc, the heat dissipates only because the temperature difference of the braking disc and air. Higher values of temperature on the braking disc are consequence of higher pressure in the braking installation, which is proven and in earlier researches [9, 10].

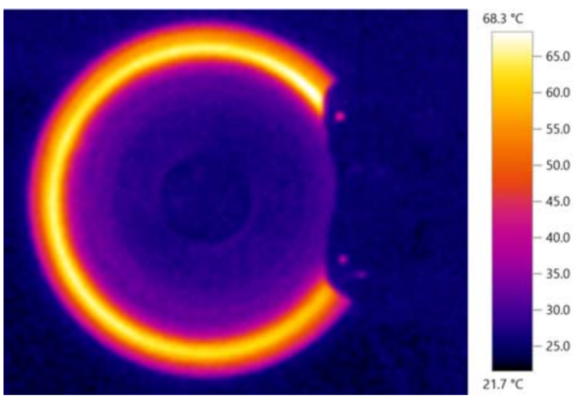

Fig. 9. The thermographic representation of the braking disc for braking pressure 2.8 MPa

the braking disc for braking pressure 5 MPa

During the braking process, when the braking pressure is 2.8 MPa, on the braking disc can be noticed hot band on the entire contact surface of the braking disc. This is not good from the aspect of the gratest damages appearing of the braking disc, which further have shorter life as the consequence [8].

However in the case when the braking pressure is 5 MPa, on the contact surface of the braking disc, can be noticed two hot bands. Which also is not good from the aspect of greatest damages appearing of the braking disc.

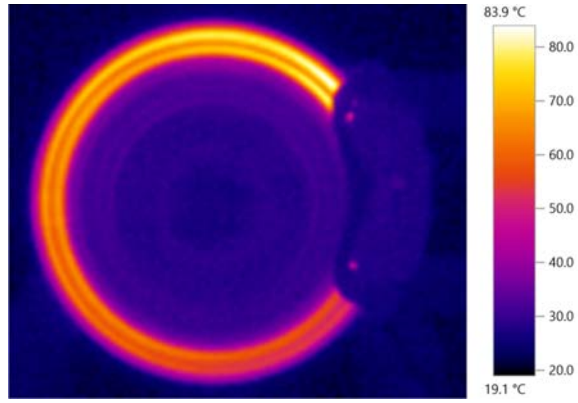

Fig. 10. The thermographic representation of

On the braking disc can be noticed that the contact surface heats more than hub, which further can cause appearance of the uneven temperature expansion, which further can led to the appearance of deformations, and at the end to breaking.

5. CONCLUSION

The stopping process is fallowed with appearance of temperatures generation on the braking disc and braking pads. Which further as consequence have appearance of deformations and damages. The braking pressure is very important parameter how from the aspect of traffic participants safety, where the tendency is that the stopping distance be as less as possible in the case of some critical situation, so and from the aspect of disc brake stresses. How the final temperature that was generated on braking pads is different only for 1.52 □, the pressure in the braking installation can be 5 MPa.

Future research should include analysis of braking disc and braking pads made from alternative materials, and to investigate their influence how in normal conditions of exploitation, so in the extreme exploitation conditions.

ACKNOWLEDGEMENT

This paper was realized within the framework of the project “The research of vehicle safety as part of a cybernetic system: Driver-Vehicle-Environment”, ref. no. TR35041, funded by the Ministry of Education, Science and Technological Development of the Republic of Serbia.

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ISBN 978-99938-39-92-7