SERBIATRIB '23

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18th International Conference on Tribology

17 – 19 May 2023, Kragujevac, Serbia

PROCEEDINGS

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Serbian Tribology Society

University of Kragujevac
Faculty of Engineering

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EDITOR: Slobodan Mitrović

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Preface

The International Conference on Tribology – SERBIATRIB, is traditionally organized by the Serbian Tribology Society every two years, since 1989. The previous conferences were held in Kragujevac (1989, 1991, 1993, 1999, 2005, 2007, 2011, 2013, 2017, and 2019), Herceg Novi (1995), Kopaonik (1997), Belgrade (2001, 2003, 2009, 2015 and 2021). This year the 18th International Conference on Tribology – SERBIATRIB '23 also takes place on May 17-19, 2023 in Kragujevac.

This Conference is organized by the University of Kragujevac, Faculty of Engineering and the Serbian Tribology Society (STS). Organizing Scientific Conferences, STS plays a significant role in helping engineers and researchers to introduce in the fundamentals of tribology and to present their experience, solutions and research results.

The scope of the 18th International Conference on Tribology – SERBIATRIB '23 embraces the state of art and future trends in tribology research and application. The following two aspects of tribology practice require special attention. Firstly, the requirement for higher productivity of machinery means that machines must operate under higher loads and at higher speeds and temperatures, and that is why finding the right solutions for tribological processes is extremely important. Secondly, a good tribology knowledge can greatly contribute to the saving of material and energy.

The Conference program generally includes the following topics: fundamentals of friction and wear; tribological properties of solid materials; surface engineering and coating tribology; lubricants and lubrication; tribotesting and tribosystem monitoring; tribology in machine elements; tribology in manufacturing processes; tribology in transportation engineering; design and calculation of tribocontacts; sealing tribology; biotribology; nano and microtribology and other topics related to tribology.

All together 100 papers of authors from 30 countries (Algeria, Australia, Austria, Belarus, Bosnia and Herzegovina, Bulgaria, China, Croatia, France, Germany, Greece, Hungary, India, Iran, Iraq, Italy, Japan, Kuwait, Malaysia, Montenegro, Nigeria, Poland, Romania, Russia, Serbia, Slovenia, Switzerland, Turkey, Ukraine, United Kingdom) are published in the Proceedings.

All papers are classified into nine chapters:

- Plenary lectures (5)
- Fundamentals of friction and wear (11)
- Tribological properties of solid materials (15)
- Surface engineering and coating tribology (13)
- Lubricants and lubrication (10)
- Tribology in machine elements (7)
- Tribology in manufacturing processes (11)
- Tribology in transportation engineering (5)
- Design and calculation of tribocontacts (3)
- Biotribology (5)
- Other topics related to tribology (15)

It was a great pleasure for us to organize this Conference and we hope that the Conference, bringing together specialists, research scientists and industrial technologists, and Proceedings will stimulate new ideas and concepts, promoting further advances in the field of tribology. I would like to thank the Scientific and the Organizing Committee and all those who have helped in making the Conference better.

The Conference is financially supported by the Ministry of Science, Technological Development and Innovation, Republic of Serbia, TRC PRO, Rtec Instruments, Ansar-analitika Instrumenti, Lotrič Metrology and Coatings.

We wish to all participants a pleasant stay in Kragujevac and we are looking forward to seeing you all together at the 19th International Conference on Tribology – SERBIATRIB '25.

Kragujevac, May 2023

Editor
Slobodan Mitrović

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THE INFLUENCE OF THE TEMPERATURE OF DISC BRAKES ON THE VEHICLE STOPPING EFFICIENCY

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Abstract: *The vehicle exploitation is characterized by vehicle start from steady state, the acceleration – achievement of the desired speed, the constant movement, the deceleration – adjustment to the road and traffic conditions and vehicle stop. How the main focus of the paper is placed on the braking system, during the deceleration or stopping, the braking system is activated and it comes to the increment of the temperature of parts which are in contact (the brake disc and brake pads). Depending from the driving conditions and number of stops, the temperature of parts which are in contact will rise, while the coefficient of friction will change in each next braking cycle, as well as the time necessary for the vehicle to stop. The investigation was conducted in laboratory conditions on the test rig BRAKE DYNO 2020. With the increment of the number of cycles, the temperature rises, and the coefficient of friction rises as well, and after some temperature is passed, the coefficient of friction decreases. From where comes out the conclusion, that stopping time also changes, with the change of the temperature in the contact between the brake disc and brake pad, because of the change of the coefficient of friction.*

Keywords: *vehicle drive, braking system, coefficient of friction, test rig, efficiency.*

1. INTRODUCTION

All depending on the vehicle driving conditions, will be different and the vehicle braking regimes. During the drive on the long downhills, the driving process is characterized by many consecutive accelerations and braking processes. That is, in such vehicle exploitation conditions, the braking system works periodically. During the braking process, due to friction, comes to the heat of the brake disc and brake pads, while during acceleration and constant driving, it comes to their cooling [1]. The main problem in such exploitation conditions is because it comes to the overheating of the friction pair, from where was came out the idea for the research of consecutive processes of acceleration and braking.

During the braking process, comes to the increment of the temperature of the brake disc and brake pads. With each next braking process, when existing more consecutive braking processes, the temperature is higher and higher. While the cooling of the brake disc and brake pads happens during the acceleration [2]. This temperature changes influence on the change of the coefficient of friction. For such exploitation conditions, the brake disc and brake pads can't cool enough to return on the initial temperature.

On the contrary, the temperature of the brake disc and brake pads have higher and higher after each braking process. Which in one moment can cause the overheating of the brake disc and brake pads [3]. In the beginning, the coefficient of friction rises with the rise of the temperature, in order to achieve its maximal value in one moment. With a further temperature rise, the coefficient of friction starts to decrease. However, it can be said, that this process is characterized by stable braking, all until the moment for which these elements were made to give the best braking characteristics [4], but, if the values of the temperatures are higher than those which are prescribed on for the friction pair, it will come to the frictional instability and to the change of the properties of the material. Besides the listed problems, it should take into consideration the wear rate of the friction pair, which appears, and which depends on the contact temperature [5]. The reason for this, is that the products formed during the wear are very small, can enter into the human organism, and cause different health problems [6].

The aim of this paper is to investigate how the temperature change during the ten consecutive braking processes influence on the change of the coefficient of friction.

2. LABORATORY TEST RIG – BRAKE DYNO 2020

The experimental work was conducted in the Laboratory for motor vehicles at the Faculty of Engineering University of Kragujevac, and it was used the test rig – BRAKE DYNO 2020, which scheme is shown on Figure 1.

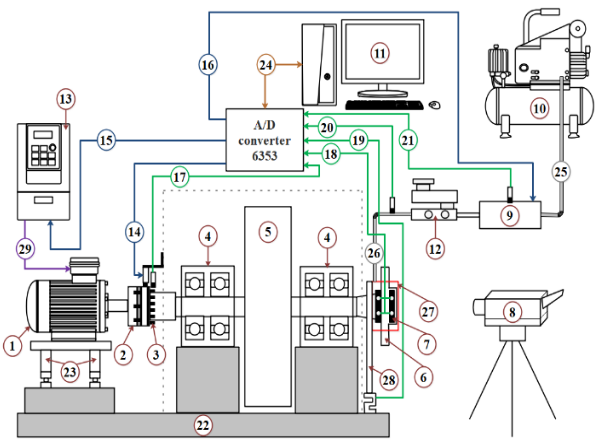

Figure 1. The scheme of the test rig

The test rig represents the dynamometer, which main purpose is to simulate the kinetic energy of the quarter of the vehicle. The test rig consists of many elements, however, the main parts can be divided into three groups: the drive group (1, 13, 2), the flywheel mass group (4, 5), and the braking system group (6, 7, 12, 9, 28, 10). The drive group, where the electric motor (1) and frequency regulator (13) are the main parts, serves to provide the adequate angular speed of the flywheel mass (5). Together with the flywheel mass group, it simulates the kinetic energy, which a quarter of the vehicle had at the beginning of the braking process. So the input parameters, for these two groups, during the measurement, are the vehicle speed and the mass of the quarter of the vehicle. The braking group serves to provide the braking at the exact moment (when the vehicle achieves desired speed). For this group, the input parameter is the braking pressure. During the measurement are followed next data: vehicle speed (14), braking pressure (20), brake pads temperature at four points (18), brake disc temperature (8), braking moment (19), braking time (11), and the pressure in pneumatic installation (21, 9) which serves to activate the hydraulic braking installation (12, 26).

3. THE PLAN OF THE EXPERIMENT

In order to determine, how it changes the coefficient of friction with each next stopping cycle, where the temperature of the brake disc and brake pads rises with each next braking, it was defined the plan of the experiment (Figure 2). The first step is defining of working parameters such are the braking pressure, the quarter of the vehicle mass, and the desired vehicle speed (Table 1). While the output values are those which cannot be defined, and that are the temperature of the brake disc, the temperature of brake pads, the coefficient of friction, the deceleration, the change of the braking pressure during the braking process (in the program is defining the maximal value of the braking pressure), and the braking moment.

After the input/working parameters are defined, the measurement can start. During the measurement, all data are collecting on the PC, which later are processing, show with diagrams, analysing, and compare with results obtained in other researches.

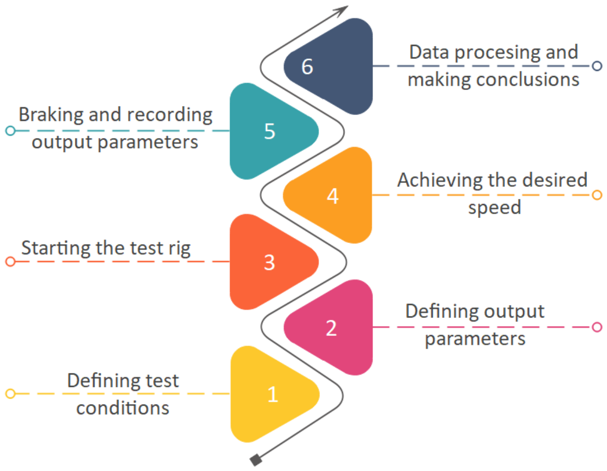

Figure 2. Testing procedure

Table 1. The values of input parameters

Input parameters		Values
Initial temperature, °C	Brake pads	25.5±0.5
	Brake disc	
Quarter of the vehicle mass, kg		300
Braking pressure, MPa		5
Vehicle speed, km/h		100
Number of cycles, -		10

The temperature of brake pads will be observed on the entering and exiting sides of each brake pad, Figure 3. While for the analysis will be taken the maximal value of the temperature which will appear, no matter the position where appeared.

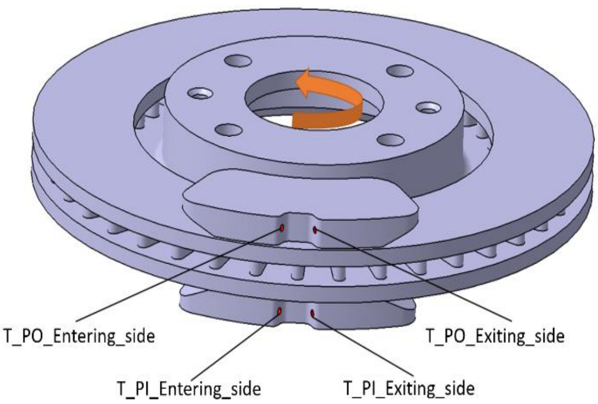

Figure 3. Temperature sensors mounting position in brake pads

4. RESULTS AND DISCUSSION

The brake pads temperature was measured at 2 mm depth from the contact between the brake disc and brake pads. So because of this, the measured temperature is lower than the actual temperature in contact between the brake disc and brake pads, which in contact can be higher for 40 °C to 70 °C [7]. The highest value of the coefficient of friction obtains during the 2nd braking cycle, when the measured temperature was around the 80 °C, Figure 4. According to the results from the research [7], it means that the temperature on the contact surface can be between 120 °C and 150 °C. This corresponds to the research [8], where it was found that the highest coefficient of friction obtains when the temperature on the contact surface of the brake disc is 150 °C.

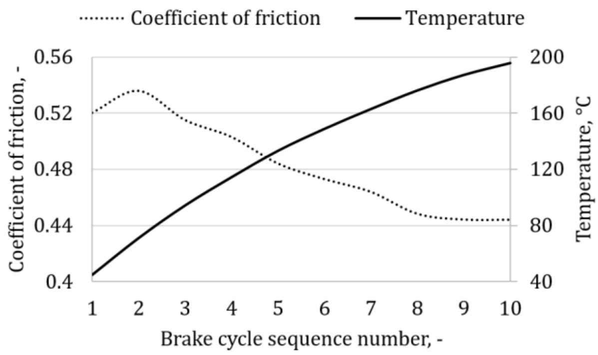

Figure 4. The change of the maximum value of the coefficient of friction and the maximum value of the temperature for each braking cycle

How is very important for the braking system to be very efficient, that is, to provide to the vehicle with the shortest possible stopping distance, together was analysed the change of the coefficient of friction, and stopping time. How the disc brake was correct, the stopping time was between 3.2 s and 4 s, all depending on the value of the coefficient of friction, Figure 5. The shortest stopping time was recorded for the case when the coefficient of friction was highest (2nd braking cycle), as well as for the cases when the temperature distribution equalized (braking cycles 8th, 9th and 10th). In the research [9], where were considered 20 consecutive braking cycles, can be found that from the 8th braking cycle until the 20th braking cycle, the stopping time was unchangeable. The stopping time obtained for braking cycles from 8th to 20th is not the shortest one, but is very close to it. From where comes out the conclusion, that in order for the braking system to be efficient, it has to achieve the "working temperature".

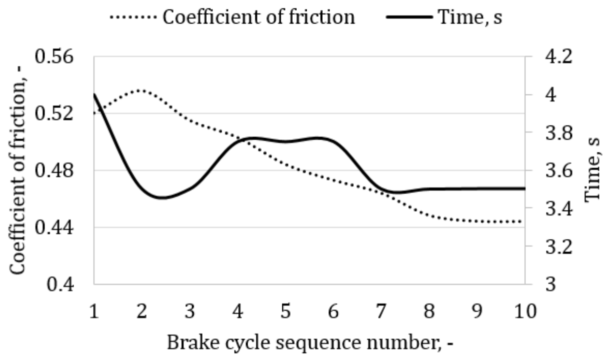

Figure 5. The change of the maximum value of the coefficient of friction and the minimum value of the stopping time for each braking cycle

The temperature of the brake disc was followed with the thermal camera. On Figures 6 and 7 are presented temperatures of the brake disc for the 1st braking cycle and for the 10th braking cycle. The red-hot, that is, the highest values of temperature appear in the shape of a ring. This type of heating is known as hot bands, and it is very undesirable from the aspect of brake disc damage. What is characteristic for this type of heating, is the changeable contact surface in the radial direction between the brake disc and brake pads [10]. Also, on the brake disc can appear and more consecutive rings, in the direction of sliding.

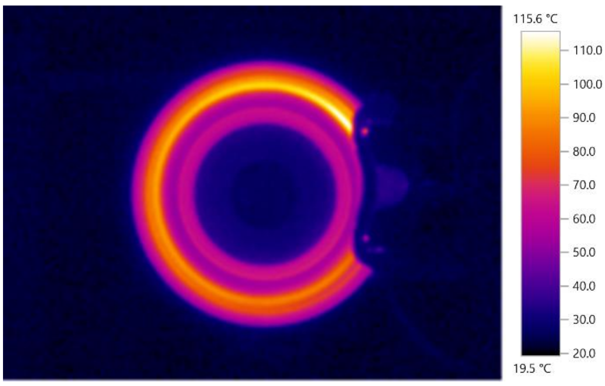

Figure 6. Thermographic representation of the brake disc for the 1st braking cycle

It can notice from Figure 7, that the temperature has raised for approximately 120 °C, on the back side of the brake pad, which further causes the heating of the brake fluid, which in the worst scenario can cause the decay of the brake pedal, and failure of the braking system function, that is, the braking will not be possible. Besides the heating of the brake fluid, heating has an influence and on the adjacent elements, that is, on their work, which are near the brake disc.

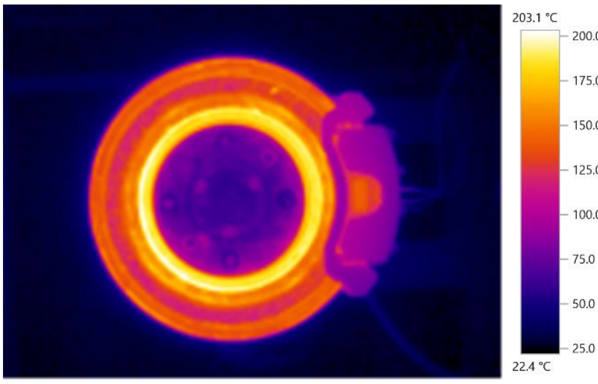

Figure 7. Thermographic representation of the brake disc for the 10th braking cycle

One more disadvantage, which is characteristic for the heating of the brake disc, is because the temperature of the brake disc hub, in large amount, differs from the temperature which appears on the contact surface of the brake disc. This further can have as the consequence uneven thermal expansion of the brake disc, and this further influence on the deformation of the brake disc. While in the worst case can cause crack of the brake disc.

5. CONCLUSION

The vehicle stop is followed by the heating of brakes, no matter if disc or drum brakes are used. The consequence of the heating of executive organs, in this case, dis brakes, has influence on the appearance of deformations, and in the worst case can come to damages, as well as to break. The coefficient of friction is a very important parameter, from the aspect of the vehicle stop, that is, from the aspect of stopping distance, as well as stopping time. On the basis of the conducted research in this paper, comes out the conclusion, is that the increment of the temperature changes the coefficient of friction, as well as the stopping time of the simulated vehicle. However, after more consecutive braking cycles, the values of the coefficient of friction and stopping time stay almost constant, no matter the temperature which still rises. On the basis of this comes out the conclusion, that the safety of the traffic participants will not be endangered, in the tested exploitation conditions.

Further investigations should cover the tests with brake discs and brake pads made from alternative materials, in order to investigate their behaviour for different exploitation conditions.

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