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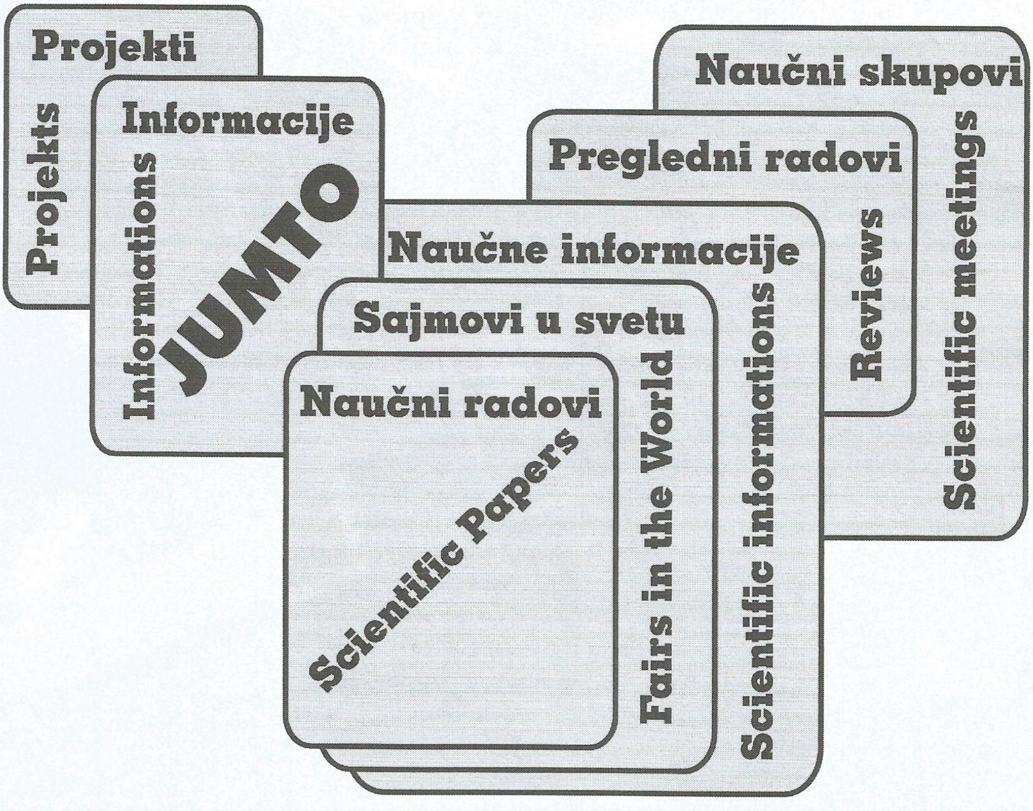

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Scientific paper

PROJEKTOVANJE KOMORE ZA SAKUPLJANJE I MERENJE ČESTICA NASTALIH HABANJEM KOČNICE NA INERCIJALNOM DINAMOMETRU

DESIGN OF CHAMBER FOR COLLECTION AND MEASUREMENT OF PARTICLES FORMED BY BRAKE WEAR ON AN INERTIAL BRAKE DYNAMOMETER

Vasiljević S.[1], Glišović J.[2], Stojanović N.[3], Grujić I.[4]

REZIME

Sakupljanje i merenje koncentracije čestica koje nastaju habanjem kočnica, u zavisnosti od metodologije koja se primenjuje, može predstavljati veliki izazov. Postoji niz različitih izvora čestica koje ne nastaju sagorevanjem u motoru SUS, pa ih je potrebno razdvojiti i meriti samo čestice koje nastaju habanjem elemenata frikcionih parova kočnice. U slučaju inercijalnog kočnog dinamometra najčešće se koristi komora u kojoj se nalazi kočnica i na taj način se omogućava da se sakupljaju i mere samo čestice koje nastaju habanjem kočnih pločica i diska. U ovom radu je prikazana i predstavljena konstrukcija komore inercijalnog kočnog dinamometra koji se nalazi i koristi na Fakultetu inženjerskih nauka u Kragujevcu. Komora je konstruisana na osnovu zahteva planiranih ispitivanja i konstruktivnih rešenja koja su primenjena na inercijalnim kočnim dinamometrima u različitim istraživanjima autora širom sveta.

Ključne reči: Komora, inercijalni kočni dinamometar, čestice, merenje.

SUMMARY

Collecting and measuring the concentration of particulate matter formed by brake wear, depending on the methodology used, can be a major challenge. There are a number of different sources of particles that are formed not by combustion in the IC engine, so it is necessary to separate and measure only the particles that are formed by the wear of the elements of the brake friction pairs. In the case of an inertial brake dynamometer, the chamber in which the brake is located is most often used, and in this way, it is possible to collect and measure only

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the particles created by the wear of the brake pads and disc. This paper presents and presents the chamber construction of an inertial brake dynamometer located and used at the Faculty of Engineering University of Kragujevac. The chamber is constructed based on requirements of planned tests and constructions applied to inertial brake dynamometers in various studies of authors around the world.

Key words: Chamber, inertial brake dynamometer, particles, measurement.

INTRODUCTION

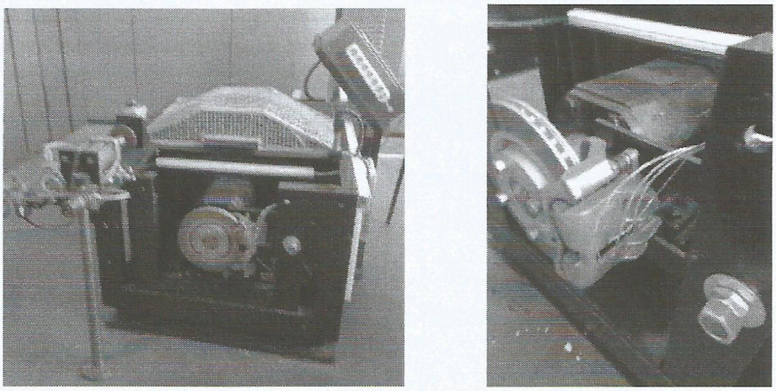
Inertial brake dynamometers are devices used in laboratory conditions, with the aim of simulating the operation of the brake on the vehicle. In relation to real vehicle and real driving conditions, this method can most closely simulate the vehicle braking cycles. The reason for this is the fact that real brakes are used on brake inertial dynamometers, i.e. the entire braking system used on motor vehicles is also applied to brake inertial dynamometers. The construction of inertial brake dynamometers is such that they mainly consist of several basic elements that enable proper operation and simulation of a real vehicle and braking process [1]. The whole system is mainly controlled via a computer control unit. An electric motor is started via a computer unit (ECU), through which the parameters of the rotating speed of the electric motor are set. The electric motor drives the flywheel which transmits the torque to the moving part of the brake (rotor). On the other hand, the braking process is also controlled via a computer unit via a hydraulic or pneumatic mechanism by increasing the pressure in the brake system, i.e. the brake is activated, which stops the rotor (brake disc). The kinetic energy of the vehicle simulated in relation to the vehicle is achieved by applying a flywheel mass, e.g. according to the relation shown in Grujić et al. [2].

The application of an inertial brake dynamometer is suitable for simulating and analyzing the processes that occur during braking under different braking conditions. In the case of measuring particles caused by brake wear on the dynamometer, it is necessary to install additional devices that collect particles or that prevents the collection of particles from the environment. Often, as in this research, the inertial brake dynamometer is fitted with a chamber that is hermetically sealed and from which the device for measuring and analyzing particles draws air in which there are only particles formed during the wear of the brakes. There are different constructions of the chamber in which the brake is located, which is intended for measuring particles, and a detailed review and analysis of such chambers are shown in [3].

Having in mind the previous fact, the aim of this paper is to present the chamber for collecting and a measuring installation for measuring the particles created by the brake wear. The chamber shown in the paper was upgraded the inertial brake dynamometer (Brake Dyno 2020) developed at the Faculty of Engineering, University of Kragujevac. The chamber presented in the paper is based on the experiences and research of other authors who have been conducted research in the field of brake wear and particle formation.

INERTIAL BRAKE DYNAMOMETER ON WHICH THE CHAMBER WAS UPGRADED

The inertial brake dynamometer developed at the Faculty of Engineering, University of Kragujevac is called Brake Dyno 2020. The stages of development of this inertial brake dynamometer are described in detail in [4]. Figure 1 shows the appearance of this brake dynamometer. Brake Dyno 2020 was developed with the aim of testing brake thermal stresses, but with its upgrade, it is possible to measure the formation of particles that occur during braking, i.e. when the rotor (disc) of the brake and brake pads wears.



a) *b)*

Fig. 1. Brake Dyno 2020, a) dynamometer, b) closer view of the brake on Brake Dyno 2020

A simplified diagram of the Brake Dyno 2020 is shown in Figure 1, where the basic elements of this inertial dynamometer are shown. Through the computer unit, the electric motor is given input data for the simulation of the movement of the quarter vehicle. By applying equation [2] which is integrated into the dynamometer starting software, by entering the load and the desired speed to be simulated, the software calculates the speed of the flywheel mass and starts it via an electric motor. Also, the application of the ECU determines the braking parameters of the brake, such as the pressure with which you want to brake. The ECU receives and stores certain data is measured using the sensors and that the ECU stores as output. In this way, data such as braking torque, simulated speed, brake pressure, brake pad temperature … are recorded.

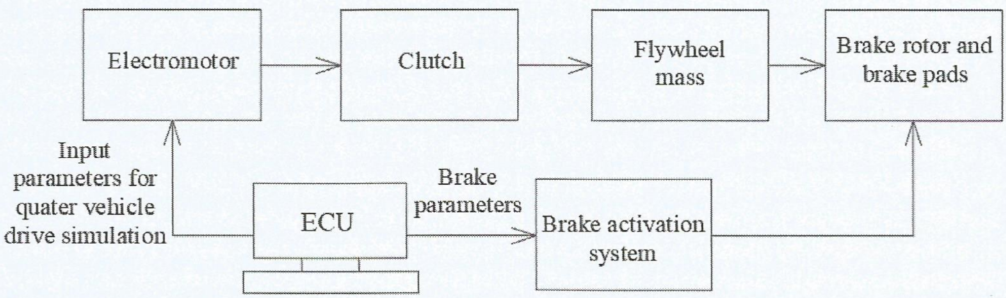
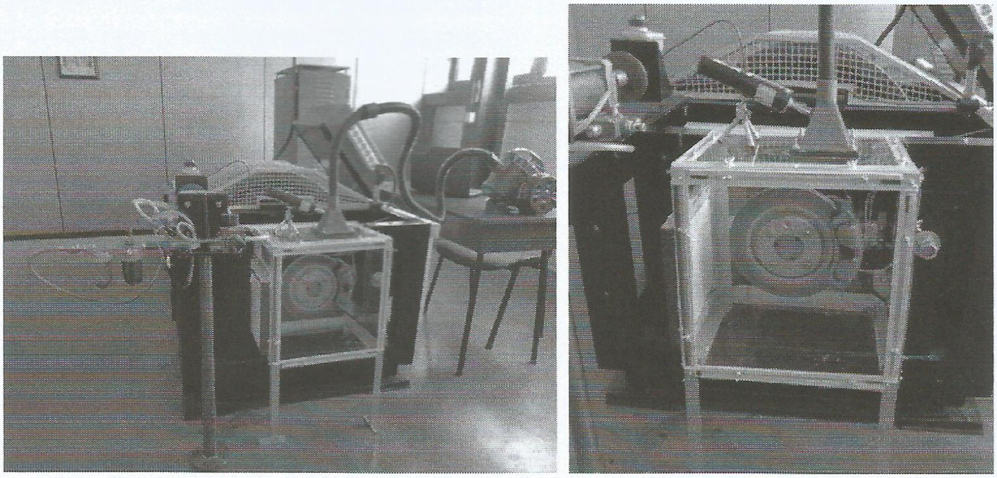


Fig. 2. Simplified scheme of Brake Dyno 2020

Chamber on Brake Dyno 2020

As it was emphasized in the previous part of the paper, in order to measure the particles generated by brake wear, it is necessary to make certain corrections on the dynamometer, i.e. to upgrade the dynamometer. Figure 3 shows the chamber and the installation that will be used to measure the concentration of wear particles. As shown, the disc brake is located inside a chamber that is hermetically sealed. In the further work, the construction of the chamber and the measuring installation will be explained and described in detail.



a) b)
Fig. 3. Chamber and measuring installation on Brake Dyno 2020, a) view of the complete chamber and measuring installation on the brake inertial dynamometer, b) closer view of the chamber and brake inside the chamber

Schematic representation of the chamber and measuring installation is shown in Figure 4. The construction and design of the chamber are shown in the next section. It is important to explain that the chamber is closed with Plexiglass on all sides, except in the parts through which air passes inside the chamber and when air is extracted from the chamber with the particles being measured. Before the air enters the chamber, it is purified through an HEPA filter, which aims to keep all particles from the environment, i.e. outside the chamber and thus clean or purified air enters the chamber. This eliminates the possibility of measuring particles that are not the product of brake wear. The resulting particles are measured using the Trotec PC220 [5]. Despite the fact that the device has its own air extraction pump, there is an additional device that helps the extraction particles by reducing the pressure, so the particle measuring device itself extracts the air, so there is a complete particle measurement. This extraction of particles and air from the chamber can lead to the creation of a vacuum, and for that very reason, there is a filter and a part of the chamber from which air enters the chamber, and it is purified through a filter: Thus, as much air as is extracted from the chamber, as much air is drawn into the chamber through the filter. Another role of the device for additional air extraction is the role of cleaning the chamber in case some side of the chamber opens and air enters the environment, thus the device draws dirty air with particles from the chamber and pulls the air to be cleaned through the filter. In this way,

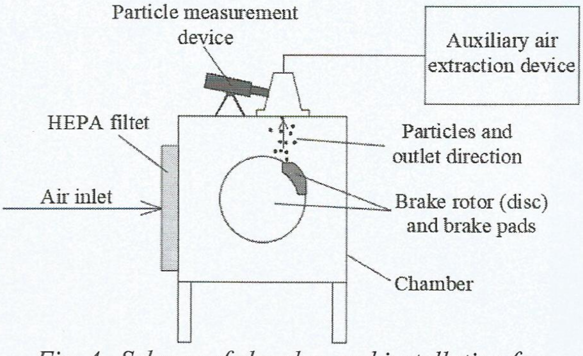


Fig. 4. Scheme of chamber and installation for measuring particles on Brake Dyno 2020

clean air remains in the chamber and only particles formed by brake wear are measured during the measurement.

Extraction of air and particles from the chamber is done from the upper side of the chamber. The reason for this solution is the particle release mechanism given in [6]. The position of the particle-measuring device is shown in Figure 5, as well as the construction of the adapter by which the device is connected to the chamber.

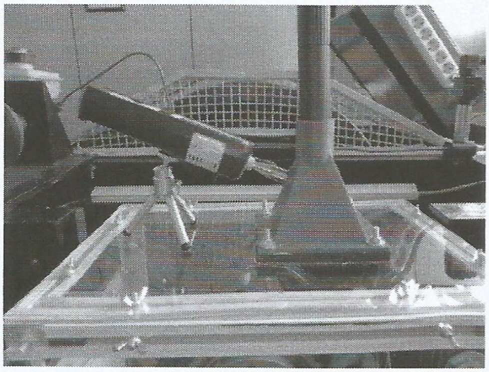


Fig. 5. Position of the particle-measuring device

CHAMBER CONSTRUCTION

The construction of the chamber in which the brake of the inertial brake dynamometer is located is shown in Figure 6. The construction is made of aluminum L profiles, so that it is formed of several profiles that are interconnected by screws. The structure rests partly on the floor of the laboratory where the inertial brake dynamometer is located, while, on the other hand, it relies partly on the inertial dynamometer.

The chamber is closed on all sides with Plexiglas, but some geometrically more complicated sides could not be made from one part of Plexiglas. Thus, some sides are made of two parts, as shown in Figure 7.

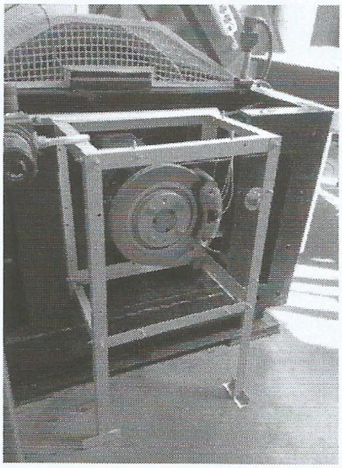


Fig. 6. Construction (supporting part) of the chamber

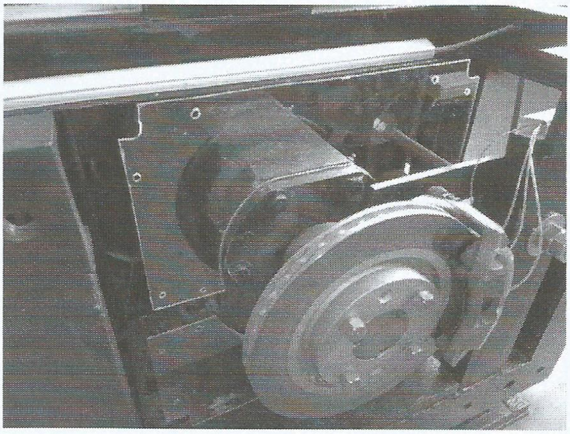
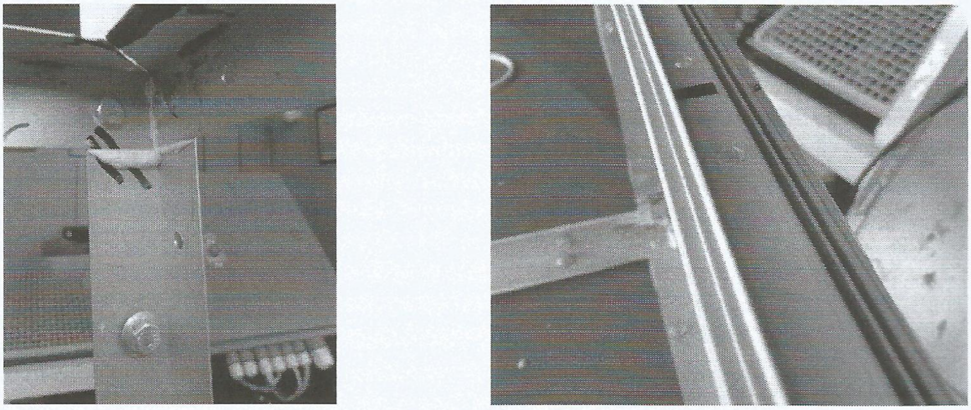


Fig. 7. Example of Plexiglass corresponding to the shape of a dynamometer

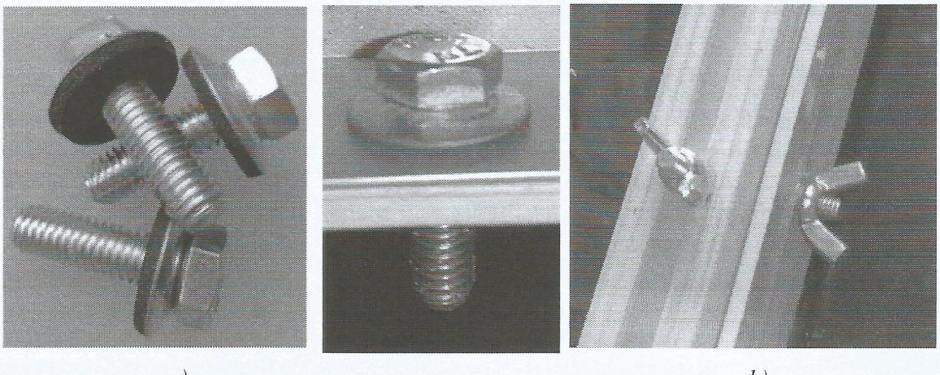
To ensure the hermetic closure of the chamber, it is insulated so that air from the outside environment cannot enter any part. Thus, in the parts of the chamber that are interconnected and non-separable, the sealing is achieved by applying a silicone mixture, as shown in Figure 8a. The parts that are in contact with the Plexiglass and the base structure are lined with sealing-tape, so that any gap between the Plexiglass and the chamber structure is eliminated. An example of a sealing strip is shown in Figure 8b, where it can be seen that two rows of rubber sealing-strips are placed on the structure in order to ensure sealing on both sides of the holes through which the screw passes.



a) *b)*

Fig. 8. Methods of sealing the gaps on the chamber structure, a) sealing with silicone compound, b) sealing using rubber sealing-tapes

In order to ensure complete hermetic closure of the chamber and to prevent any possible entry of particles and air from the environment inside the chamber, complete sealing of the screw holes is also provided. Thus, the screws that connect the elements that are often detached from the base chamber (when the chamber is cleaned for the next test) have sealing washers, which are shown in Figure 9a, where the installation method is also shown. On the other hand, the way of attaching and clamping the Plexiglass to the chamber is done by wing nuts, which rest on the rubber sealing-tape with tightening. An example is shown in Figure 9b.



a) *b)*

Fig. 9. The method of sealing the space between the screws and the structure

CONCLUSION

The inertial brake dynamometer is used for the purpose of testing disc brakes in laboratory conditions, and under the input parameters set by the researcher via a computer control unit. This paper presents the upgrade of the brake dynamometer in order to measure the particles formed by the wear of the brakes. In this case, the chamber is placed on the dynamometer so that the entire brake of a real vehicle is inside it. The chamber is hermetically sealed so that the entry of particles from the outside environment is prevented. When the particles are drawn in, air is also drawn in from the chamber, but air from the outside must certainly enter, so when the air is drawn in, it passes through a filter that purifies the air from particles, so completely clean air enters the chamber. The solution presented in the paper is based on the experiences of other authors presented in their research. This construction is very convenient considering the efficiency of the chamber itself. The following variants of the chamber could be aimed at improving the construction in terms of simplifying the assembly and disassembly of the chamber from the inertial brake dynamometer.

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