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EXPERIMENTAL INSTALLATION USE IN TESTING OF COMPOSITE MATERIALS FOR BRAKING SYSTEM COMPONENTS

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ABSTRACT: This paper presents an experimental installation use in testing of new composite material brake pads for braking system of automotives. The pieces chosen for this experimental installation, come from a vehicle Suzuki Baleno, year of manufacture 1998, out of the use, equipped with spark-ignition engine with 4 cylinders in line, with the power of 63 kW and the maximum torque 103 Nm. Besides these components, it was necessary an electric motor, a reducing gear and a variable speed controller, a transmission through belts and a the resistance structure, some of this elements are purchased and others realized.
Keywords: disc brake, brake pads, new composite materials, testing, experimental installation

1. INTRODUCTION

The disc brake is a device for slowing or stopping the rotation of a wheel. This is usually made of cast iron or composite materials and is connected to the wheel and/or the axle. To stop the wheel, friction material in the form of brake pads (mounted on a device called a brake caliper) is forced mechanically, hydraulically, pneumatically or electromagnetically against both sides of the disc. Friction causes the disc and attached wheel to slow or stop. Most modern cars have disc brakes on the front wheels, and some have disc brakes on all four wheels. This is the part of the brake system that does the actual work of stopping the car. In today is growing automotive market the competition for better performance vehicle in growing enormously. The racing fans involved will surely know the importance of a good brake system not only for safety, but also for staying competitive. The brakes designed for the purpose of racing need to have very high braking efficiency, [1].

A disc brake assembly consists of a: cast-iron disc that rotates with the wheel, a caliper assembly attached to the steering knuckle and disc pads, friction materials that are mounted to the caliper assembly.

When hydraulic pressure is applied to the caliper piston, it forces the inside pad to contact the disc. As pressure increases the caliper moves to the right and causes the outside pad to contact the disc. Braking force is generated by friction between the disc pads as they are squeezed against the disc rotor. The friction surface is constantly exposed to the air, ensuring good heat dissipation, minimizing brake fade. It also allows for self-cleaning as dust and water are thrown off, reducing friction differences.

Generally, the disc rotor is made of gray cast iron, and is either solid or ventilated. The ventilated type disc rotor consists of a wider disc with cooling fins cast through the middle to ensure good cooling. Proper cooling prevents fading and ensures longer pad life, [2].

Different brake design applications require different kinds of friction materials. Several considerations are weighed in development of brake pads; the coefficient of friction must remain constant over a wide range of temperatures, the brake pads must not wear out rapidly or should they wear the disc rotors, should withstand the highest temperatures without fading and it should be able to do all this without any noise. Therefore, the material should maximize the good points and minimize the negative points, [3].

Brake pads material is very important for safe and consistent working of a vehicle braking system. Brake pads used to be made primarily of asbestos because of its heat absorbing properties and quiet operation. However, due to health risks, asbestos have been outlawed, so new materials are now being use. Brake pads wear out with use and must be replaced periodically. There are many types and qualities of pads available. The differences have to do with brake life and noise. On the other side, all pad material begins to disintegrate at the friction surface due to high heat generation process between the rotor and pad. Due to non uniform pressure distribution between the pad and rotor, pad surface temperature will be non uniform and the areas of higher temperature will have low friction level than that of the lower temperatures. An exact analytical value of coefficient of friction between rotor and brake pads is difficult to set. SAE J661 procedure is used to determine the friction coefficient for hot and cold surfaces. Disc brake pads should have certain amount of porosity to minimize the effect of water on coefficient of friction, [4].

The most important characteristics of brake pads are friction coefficient, wear rate, thermal conductivity and strength and durability. Materials like aluminum boron carbide are found to be best suited for automobile brake pad application. It has high toughness and thermal conductivity relative to other ceramics with better thermal shock absorbing capacity, [3].

Under this point of view, brake pads are designed for friction stability, durability and minimization of noise and vibration. Friction stability means that the brake pad`s friction coefficient remains high under hot, cold, wet and dry conditions at various speeds. Automotive engineers use a variety of materials to maximize performance in all areas, often combining five to twenty different material ingredients to form complex composite friction materials, [2].

Researchers are constantly testing new materials for braking performance, often in response potential upcoming regulation.

The purpose of this work is the design and manufacture of an experimental installation for testing of new composite materials intended for the completion of the brake pads of the composition of hydraulic braking systems. The basics of this installation come from a Suzuki Baleno car, manufacturing in 1998, out of use, with spark-ignition engine, with 4 cylinders in line with the power of 63 kW and a maximum torque of 103 Nm. The experimental installation is located in the laboratory of "Calculation and Construction of road vehicles" in the Faculty of Engineering of Hunedoara.

2. STUDY OF THE PROBLEM

The marks selected for the realization of the experimental installation, comes from the composition of a motor vehicle Suzuki Baleno, manufactured 1998, some of them in a degraded state, both because of time and due to the exploitation of the vehicle a long period of time. Thus, it has been necessary to reconditioning worn parts after they have been removed from the vehicle.

The main steps in the realization of the installation experimental have been:

- removal operation on the vehicle Suzuki Baleno, removed from use, the components necessary in the structure of the installation;
- cleaning, washing, degreasing parts;
- analysis of the removed parts of the status of their technical;
- reconditioning parts;
- constructive analysis components;
- painting all elements in order to assembly;
- manufacture of non-standard marks from the component stand;
- purchase of the elements of the stand;
- the achievement of the structure of the resistance will support the elements of the stand;
- painting of the structure of resistance;
- assembly and clamp work-pieces elements from the component stand on the structure of resistance;
- general fitting of the stand;
- the achievement of finishes and adjustments.

In order to achive the experimental facilities, it has been removing the elements of the entire vehicle Suzuki Baleno. Subassemblies necessary for the achievement of the stands have been:

- overall brake disc-the calliper-planetary shaft-shock absorber of oscillation
- Components of the braking system: the vacuum pump-pipe-master cylinder - servo mechanism.

In addition to these components, the stand was necessary to achieve an electric motor, a speed reducer, a belt drive, a variable speed drive and a structure of resistance. Also, for the evaluation of the pressures on the vacuum pump and the refrigerant fluid pressure of work, in the braking circuit have purchased two pressure gauges. The following are a few sequences that took place on removal of the components from the front axle of the vehicle, Figure 1.

Figure 1. Removing certain components necessary for the realization of the stand of the entire vehicle Suzuki Baleno

The removed parts are subject to cleaning operations, washing, degreasing, drying and then painting.

After degreasing all parts are subject to the control and sorting. The control of the parts was carried out visual, after which it passed to the sorting them into reusable parts and parts reconditionable. As a result of the analysis of the marks removed it was noted that the only part to be subjected to the operation of reconditioning is the brake disc.

Figure 2. The cleaning of the parts with the bristles disc

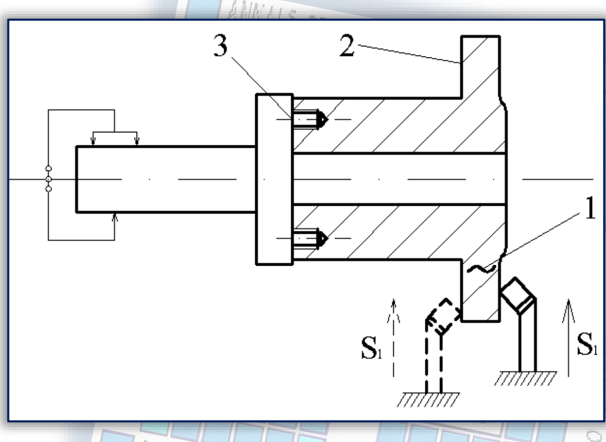

Figure 3. The faults of the brake disc and the method of reconditioning. 1- fissures and cracks; 2- the wear on the friction with the seal of the brake pad;3- Damage to the holes of the attaching screws;

Reconditioning the disc contains the following specific work, Figure 3:

- » holes are damaged reconditions by charging and thread cutting at nominal dimension or increase;
- » the surfaces of the friction plates reconditions by turning and resurfacing.

In order to achieve the experimental, it was need an electric motor of the direct current with the bristles which has a power of 1.5 kW and an engine speed of 800 rpm, Figure 4. For installation transmission, after the electric motor, was placed a cylindrical-auger reducing gear with a single stage with gearing ratio 13, Figure 5. In order to change the rotative speed we got a speed controller which allows adjusting the engine speed from 200 rpm, Figure 6.

Figure 4. Electric motor with brushes

Figure 5. Cylindrical-auger reducing gear with a single stage

Figure 6. Speed controller

In order to achieve vacuum in the brake system it has purchased a vacuum pump, type 14 AG 08, which is a diaphragm pump with the operating system mechanically with scored pulley: power belt 10X750 Li with maximum pressure 77.2 KPa and maximum speed 5,000 rpm.

Next there was the painting of the parts of the composition of the installation. As the parts of the composition of the stand are relatively low and have the dimensions and areas does not very large, has adopted the procedure for manual painting with a brush and by spraying. Figure 7 shows the parts needed for the completion of the stand, at the end of the spraying operation.

Figure 7. The parts necessary for the realization of the stand at the end of the spraying operation

In order to achieve the transmission electric motor-reduction gearing-brake disc, it was necessary to achieve a transmission through the trapezoidal belt. In this regard it have been achieved two pulleys with an outer diameter of 95 mm, these being positioned on the axel shaft of the assembly steering knuckle-pivot-disc brake with an outer diameter of 22 mm. In Figure 8 is a pulley design sketch, performed according to ISO SR 254; 1996. Also, in order to achieve the mechanical transmission has been necessary to carry out two couplings, the one who makes the connection between the electric motor and the reduction gear, with a diameter of 117 mm, and the other, which makes the connection between the output shaft of the reduction gear and planetary drive shaft with a diameter of 56 mm, Figure 9.

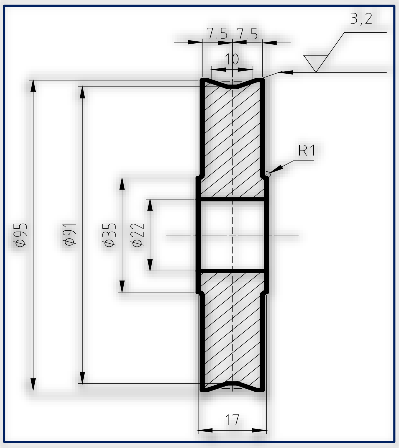

Figure 8. Constructive diagram of sheave from the mechanical transmission of the experimental installation

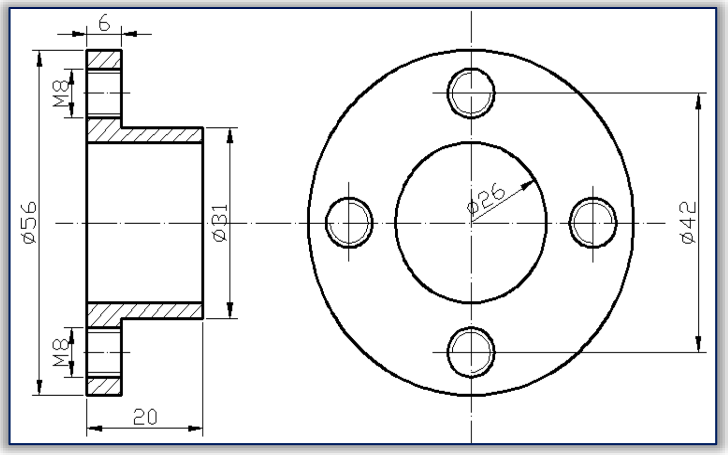

Figure 9. Constructive diagram of a coupling part which makes the connection between the writer and the planetary drive shaft

Figure 10 presents the sequence of the time to achieve a coupling part with a diameter of 56 mm. To support elements stand was accomplished a structure of resistance of square profile 40 x 40 mm and 30 x 30 mm. Diagram of the design of the structure of resistance is presented in Figure 11 and in Figure 12 is presented the resistance structure of the experimental installation.

Figure 10. During construction of coupling part

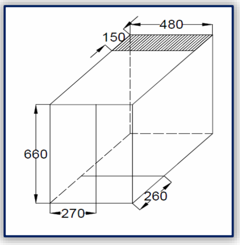

Figure 11. Diagram of the structure of resistance

Figure 12. The resistance structure of the experimental installation

Next, it has passed to the achievement of the assembly of the elements in the experimental installation assembly. In Figure 13 is shows the components of the installation prepared with a view to the completion of the assembly operations.

Figure 13. The components of the stand prepared for assembly operations

At the beginning of the mounting operation has been positioned on the resistance structure then the pedal bridge, the servo vacuum and the master cylinder, after which the buffer has been mounted. Followed by the fitting of the brake disc, of the calliper and the assambly motor-reducing gear. Figure 14 shows the sequence of operations during the assembly of the stand.

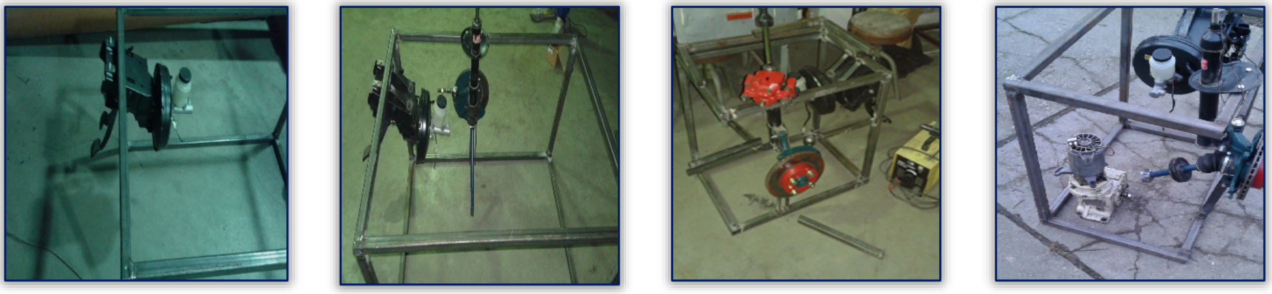

Figure 14. Sequences during operation of the stand assembly

The kinematic scheme of the stand it shows in Figure 15 and Figure 16 shows the general assembly of the stand which will be in the laboratory of "Calculation and Construction of Road Vehicles" in the Faculty of Engineering of Hunedoara. Table 1 shows the kinematic sizes corresponding to the stand.

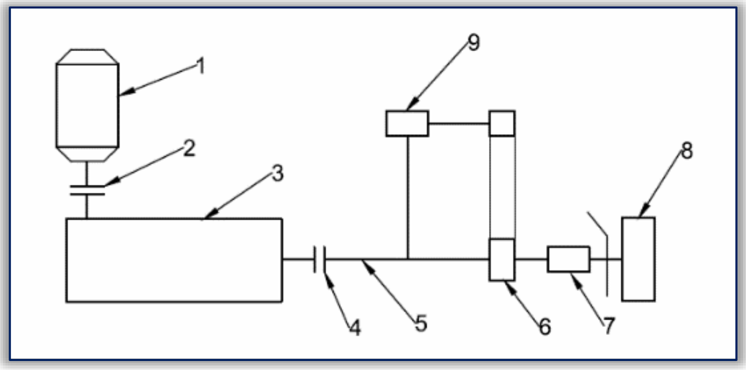

Figure15. Kinematic diagram of the stand teaching for the study of hydraulic braking components
1- electrical motor; 2,4- gearing//coupling; 3- reducing gear; 5- planetary shaft; 6- transmission through belts// pulley gear; 7- assembly steering knuckle –pivot; brake disc;

Figure 16. The general assembly of experimental installation for testing composite materials

Table 1

Electrical motor power P_1 [kW]	Rotation speed of the electric motor n_1 [rot/min]	Power transmitted to the planetary shaft P_2 [kW]	The engine speed of planetary shaft n_1 [rot/min	Power transmitted to the whole disc caliper P_2 [kW]
1,5	800	1,47	61,53	1,39

In Figure 17 is presents the main geometric dimensions of the section of the belt from the experimental installation, according to STAS 1164/1-91, and the values obtained from the calculations are presented in table 2. Diagram of the calculation of the geometric characteristics of the transmission is shown in Figure 18, and the values obtained are shown in table 3.

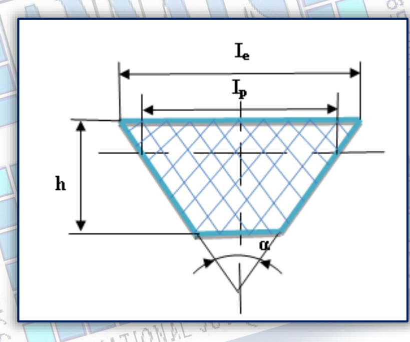

Figure 17. The geometric dimensions of the section belt from the instalation

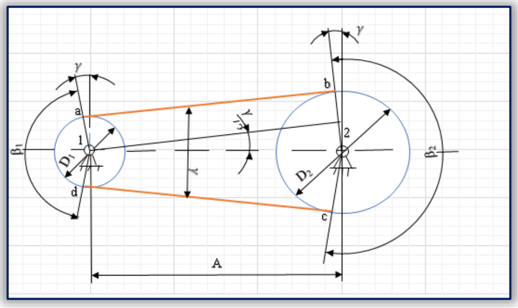

Figure 18. Diagram of the calculation of the geometric characteristics of the belt transmission, [1]

Table 2

Type of the belt	Primitive width of the belt i_p [mm]	Belt length L [mm]	Belt height [mm]	Distance from the upper edge of the strap at the primitive fiber b [mm]
SPZ	10	750	8±0,4	2

Table 3

Diam. of the drive wheel D_{d1} [mm]	Wheel diameter led D_{d2} [mm]	Angle of the branches belt y[°]	Distance between the axis [mm]	Number of transmission wheels [no.]
95	130	8,36˚	240	2

The forces acting in the belts in rest position, during transmission operation are shown in Figure 19, and the values of these forces are shown in Table 4. Loading the transmission shafts is illustrated in Table 5.

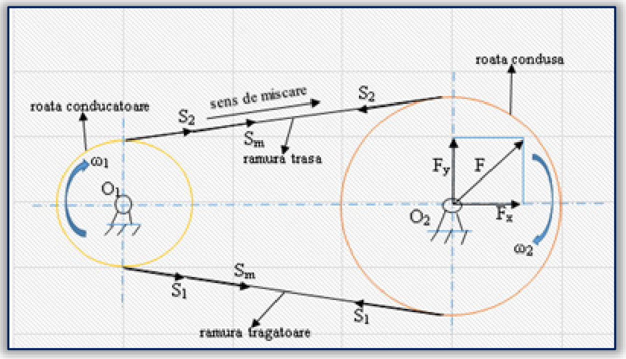

Figure19. Diagram of the actuation of the forces of the belt, [3]
S_0- initial elastic force; F_{tu}- Useful force necessary for the transmission of power;
S_1- elastic force from acting branch; S_2- tensile strength of the branch held

Table 4

Periphery force [N]	Elastic force of belt [N]	Useful force necessary to transmit power [N]	The elastic force from acting branch [N]	The tensile force of the branch held [N]
3283,5	4925,2	3611,85	5574,81	42,99

Table 5

Structure after the direction of centers F_x [N]	Structure after the normal direction to the line of centers F_y [N]	Radial load resulted $F = \sqrt{F_x^2 + F_y^2}$ [N]
5602,85	-409,48	5617,7

3. ANALYSIS, DISCUSSIONS, APPROACHES, INTERPRETATIONS

In the braking systems of motor vehicles, the brake has a great importance for their operation in the best possible conditions. The experimental installation allows repeated braking for testing composite materials for brake pads. For this purpose we will establish the different recipes of composite material from which will be carried out the brake pads. In this way it was made a mold for prepare the mixture of composite material obtained with metallurgical powder, Figure 20. The disc-sample is presented in Figure 21. From the resulted disk will be achieved the brake pad, with the form of Figure 22, which will be fitted in the experimental assembly and will be subject of repeated braking tests.

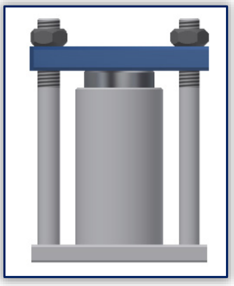

Figure 20. Mold for making samples

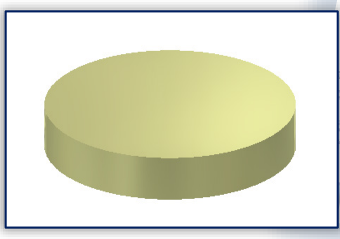

Figure 21. The disc sample

Figure 22. The brake pad made of composite material under test in the experimental installation

At repeated stops, when their number is large, it establishes a balance between the heat generated and heat escaping, leading to the saturation temperature of the disc, given by [3]:

$$\tau_s = \frac{\tau_0 + \Delta\tau}{b \cdot t_0} \ [^oC] \qquad (1)$$

where: τ_0 - the ambient temperature; $\Delta\tau$ = the temperature increase due to the braking; b= coefficient characterizing the cooling conditions of the brakes, b= 0.001-0.004 [s^{-1}]; t_o= interval between two successive braking.

The procedure for the experimental determination includes the following steps:

» Establishing the braking time;
» Starting the stand and carried out 10 repeated braking, measuring the temperature at each braking with a thermography room, Flir Thermo about Quick View, which allows to capture the temperature in the work area at a certain distance; captured images can provide information about the evolution of the temperature of the contact area between the brake pad and the brake disc, and could determine the increase of temperature between two successive braking;
» Centralizing the results in table 6;
» Determining the temperature of the saturation of the disc at the beginning, respectively at the end of the 10 repeated braking;
» The temperature of permissible saturation is $\tau_s \leq 300^0 C$;

Table 6

Measurements													Sizes calculated	
Ambient temperature τ_0 [ºC]	Interval between two braking t_o [s]	b [s^{-1}]	The temperature rise due to braking $\Delta\tau$ [ºC]										Temperature of saturation [ºC]	
			1	2	3	4	5	6	7	8	9	10	$\tau_{s initial}$	$\tau_{s final}$

4. CONCLUSIONS

The experimental installation carrying out experimental research on the behavior of some new composite materials, for braking systems and can be used as teaching purposes for students, in order to improve the knowledge of hydraulic brake systems, both structural design and functional.

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