

Laboratory testing of brake pads made of organic materials intended for small and medium vehicles

C Pinca-Bretotean¹, A Josan¹ and C Birtok-Băneasă¹

¹University Politehnica Timișoara, Faculty of Engineering Hunedoara, Revoluției 5, 331128 Hunedoara, Romania

E-mail: camelia.bretotean@fih.upt.ro

Abstract. The brake pads are an important component in the braking system of vehicles. Materials used for brake pads should have high durability, stabile and reliable frictional and wear properties under varying conditions of load, velocity, temperature and environment. In this regard, has been produced an organic frictional material with coconut fibre, friction modifiers, abrasive materials and solid lubricant using powder metallurgy. In this paper are presented the experimental determinations carried out under laboratory conditions for testing the friction material developed. In this sense will be analysed density, porosity, hardness, mechanical properties, the evolution of the friction coefficient and the temperature field in the contact area between the disc and the brake pad on an own design installation. The results performed in the laboratory give a better image about the performance of the developed friction material recipes designed to make the brake pads for small and medium vehicles.

1. Introduction

The braking system constitutes an integral part of an automotive. Failure of the automotive brake system can lead to accidents, property damage or even death of an individual [1]. This is the reason why special attention is paid to the design and manufacture of braking systems components. The most important components of the brake system are discs and brake pads. Brake discs have a direct effect on the life of the brake pads. At the moment, great care is given to improving the behaviour of the brake discs in running order. Brake pads are designed for friction stability, durability, minimization of noise and vibration [2]. The ideal brake friction material should have constant friction coefficient under various operating conditions such as applied loads, temperature, speeds, mode of braking in dry or wet conditions. Besides, it should also have various desirable properties such as resistance to heat, porosity in water and oil, low wear rate and high thermal stability and does not damage the brake disc [3]. However, it is practically impossible to have all these desired properties. Some of these properties have to be compromised in order to achieve some other requirements [1]. The type of brake pads depends on the material from which they are made [4]. The range of materials used in the manufacture of brake pads are from asbestos to organic and metallic formulas [1]. For lightweight and low-performance vehicles, specialists recommend organic brake pads. Over the time, the most used fibres for making brake pads were asbestos fibres [5]. They have high mechanical properties, temperature resistance and highly friction coefficient (0.8 values). Studies have shown that asbestos fibres have harmful effects on the environment as well as on human health [1], [5], [6]. For this reason, it has been decided worldwide to prohibit this reinforcing fibre in the friction materials for making the brake pads. The papers [1-4], [7], [9] lists several materials that can replace asbestos, but none has the same



properties as this one, but it offers some features with similar performance. The current trend in the field of vehicles is to use composite materials with natural fibres, which offer many economic and ecological benefits [1-3], [7]. Each friction material has advantages and disadvantages in terms of use under certain environmental conditions, wear and noise [7]. In this sense, new organic friction material for brake pad applications were prepared with friction modifiers, abrasive material, organic fibres and solid lubricant using powder metallurgy technique [6], [10]. The development and validation of friction material involve a significant amount of laboratory experiments and on the road. In this paper are presented the experimental determinations carried out under laboratory conditions for testing an organic frictional material, meant to make brake pads for small and medium vehicles.

In the paper will be analysed density, porosity, hardness, mechanical properties, the evolution of the friction coefficient and the temperature in the contact area between disc and brake pad on an own design installation [8]. The results of brake tests performed in laboratory give a better image about the performance of the developed friction material recipe designed for brake pads applications.

2. Sintering technology

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 [1-5]. In order to achieve the properties required for brake pads, most of the friction materials are not composed of single elements or compounds, but rather are composed of many materials [9]. Therefore, it is of fundamental importance to analyse the implication of new technologies and materials developments that may be applied for brake systems [6].

In this paper, the materials used for produced the friction material are aluminium, graphite, zirconium oxide, silicon carbide, titanium oxide, hexametyltetramine, phenolic resin and coconut fibre [6], [10]. The coconut fibre was used as a filler material in this investigation [7]. Table 1 shows the chemical composition of friction material produced in laboratory.

Table 1. Chemical composition of friction material.

Aluminium (%)	Graphite (%)	Zirconi oxide (%)	Silicon carbide (%)	Titanium oxide (%)	Phenolic resin (%)	Hexametyl- tetramine (%)	Coconut fibre (%)
15	5	2	11	11	40	6	10

The components presented in Table 1 were milled, sorted by grading, weighed, compacted and then subjected to the sintering process. After homogenization, the mixture of raw materials was introduced into a mold which allows to making disc samples with 100 mm diameter. The mold-sample assembly is pressed on a hydraulic press with a force of 5 KN. The sintering process took place into an oven with power of 3.6 kW and maximum heating temperature of 1200°C. Parameters of the sintering process are presented in Table 2.

Table 2. Parameters of sintering process.

Heating temperature (°C)	Heating time (min)	Time in oven (min)	Cooling			
			In oven		In air	
			Temperature (°C)	Time (min)	Temperature (°C)	Time (min)
180	15	45	100	240	25	600

The sample obtained has satisfactory shape, structure and hardness and did not raise any problem in extracting it from the mold. This can be used for sampling specimens for testing the physico-mechanical characteristics of the friction material produced. The results are presented in Table 3.

Table 3. Physico-mechanical characteristics of organic friction material.

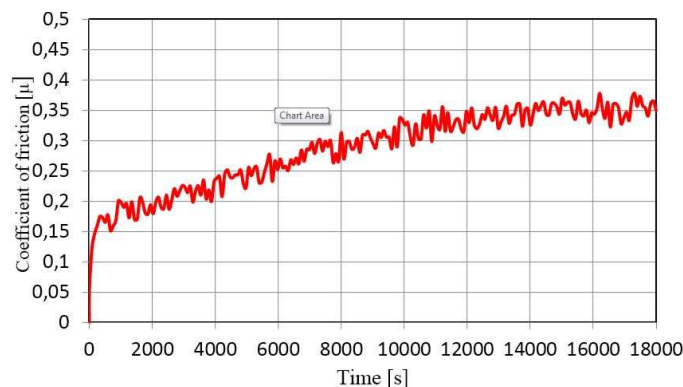
Density (g cm ⁻³)	Porosity in oil (%)	Hardness HRS	Breaking force (N)	Compressive strength (N mm ⁻²)
1,35	0,16	61	15766	38,7788

3. Determinations of friction and wear characteristics

Friction and wear characteristics play an important role in deciding which new formulations developed are suitable for the brake system designed for a particular vehicle. These depend on a number of factors such as: pressure, speed, interface temperature, the composition of the friction material, the duration and length of the friction path, the density of the friction material, the modulus of elasticity, the type, design and geometry of the friction mechanism [11]. The friction coefficient are depend not only on the material composition, but also on the environment of the braking system and the duty cycles which the brakes are subjected [5]. In this paper the determination of the friction coefficient was performed on a TR-20 test equipment, whose principle of operation is based on the "pin-on-disc" method. The pin equipment is a steel ball with 6 mm diameter and the experimentation regime is dry friction. In experiments the friction material was made of parallelepiped shape with dimensions 45x45x50mm. Each test was performed at a radius of 25 mm from the symmetry axis of the equipment. Test parameters use in experiment are presented in Table 4. In the same table are presented the values of the friction coefficient and the wear of the sample at the end of the experiments. It is mentioned that three test specimens were tested and the results presented in Table 4 and represent the arithmetic mean of them. The evolution of friction coefficient is shown in Figure 1.

Table 4. Values of test parameters, friction and wear characteristics.

Test parameters use in experiment				Friction and wear characteristics		
Speed (rpm)	Testing time (min)	Force (N)	Test distance (m)	Diameter of the wear line (mm)	Friction coefficient	Wear (g)
150	300	20	2200	15	0,45	0,06

**Figure 1.** The evolution of friction coefficient.

At the beginning of the tests, the friction coefficient varies as a result of the discontinuous contact between the steel ball and the composite material sample. This is due to the irregularity of the frontal surface of the specimen. After 2000 seconds, the friction coefficient reached to 0.25. In the period from 2000 seconds to 10000 seconds, there is an increase in friction coefficient, exceeding to 0.35. The friction coefficient has high fluctuations around the value 0.35. Around this value the coefficient of friction stabilizes until the end of the experiments. Studies shown that friction coefficient fluctuate between 0.3 and 0.5, so the value obtained confirm the technical literature [5].

4. Laboratory tests

For laboratory testing of organic composite materials used for brake pad applications, an experimental installation was developed and it was presented in the Figure 2 [8]. The results obtained allow the evaluation of the behaviour of organic friction material. The installation consists of the following components: electric motor with power of 2.2 kW and speed of 2950 rpm, gearbox, belt drive, vacuum pump with membrane, planetary shaft, hub, pivot, brake disk. Vacuum pump training is carried out by a trapezoidal belt transmission. The drive belt was fixed to the planetary shaft by a non-demountable mounting and the driven belt is fixed to the vacuum pump mechanism by a removable mounting with screws. Two couplings have been made for the mechanical transmission, one connecting the electric motor to the reducer and other linking the output shaft between the gearbox and the planetary shaft. The speed variation allows the speed to be changed from 0 to 200 rpm [8].

The principle of experimental determinations implies ten successive brakes and measuring the temperature at each one with a Flir Termo CAM Quick View. The thermal image capture the temperature in the work area from a certain distance. The captured images provide information about the temperature evolution from the contact area between the pad and the brake disk. It will be observed that the temperature after the ten successive brakes should be less than 300⁰ C. In the test, were made brake pads from the friction material produced in the laboratory. These pads were mounted in the experimental installation. The dimensions of the brake disc used in the experimental installation are shown in Figure 3. Figure 4 shows the metal support and the composite material sample. The experiment also analyse the evolution of the thermal field in the contact area of the friction couplers (cast iron-organic friction material). Table 5 shows the temperatures in the contact area at each brake and in Figure 5 are presented the thermal field in the contact area of some brakes done in laboratory experiment.

Temperature has the largest effect on wear and friction behaviour. Increased temperature affects the mechanical properties as well as acting to more rapidly form oxidation layers, thus greatly reducing contact [10]. The temperature in the contact area increases rapidly in the first part of the test. It can observe that the most of the heat dissipates in the brake pads. In Figure 5 it can be observed that the temperature dissipated in the brake disk is lower than the dissipation temperature in the brake pads. If the temperature in the contact area is lower, the degradation of the organic components in the composite materials is less. When dismantling the plate from the experimental plant assembly, it was observed that during the braking the disc-plate contact was approximately 80%, this confirms ECE R90 norms, Figure 6.



Figure 2. The general assembly of experimental installation [8].

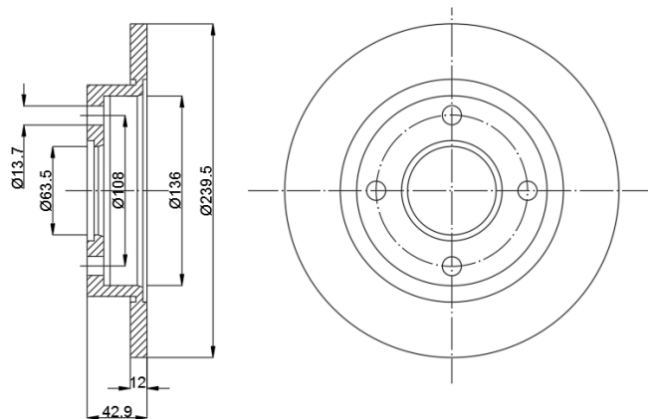


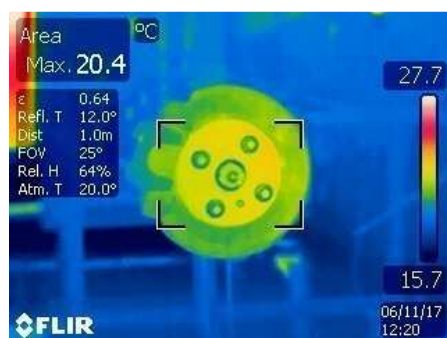
Figure 3. Dimensions of brake disc used in the experimental installation.



Figure 4. Metal support and the composite material sample.

Table 5. Temperature values in contact area at braking.

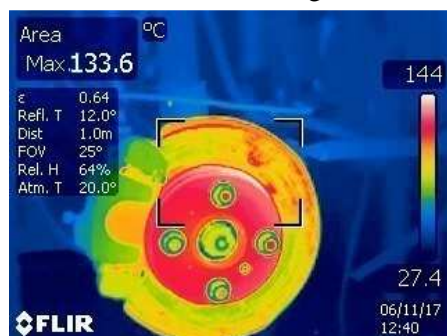
Initial temperature τ_0 [°C]	Pedal force [N]	Temperature due to braking $\Delta\tau$ [°C]									
		1	2	3	4	5	6	7	8	9	10
15	120	18	20,4	36,6	62,7	77,8	133,6	149	245	255	206



Second braking



Fifth braking



Sixth braking



Tenth braking

Figure 5. Evolution of thermal field in contact area.

In the paper will be assessing the degree of degradation of the friction material subjected to wear. This can be done by knowing the evolution of superficial layer parameters by physical investigation methods. For superficial layer analysis was used SEM with an EDS type Inspect S system. Figures 7 and 8 show the SEM images of the worn and unmarked area at a magnitude of 500.



Figure 6. Plate disc contact surface during the experiments.

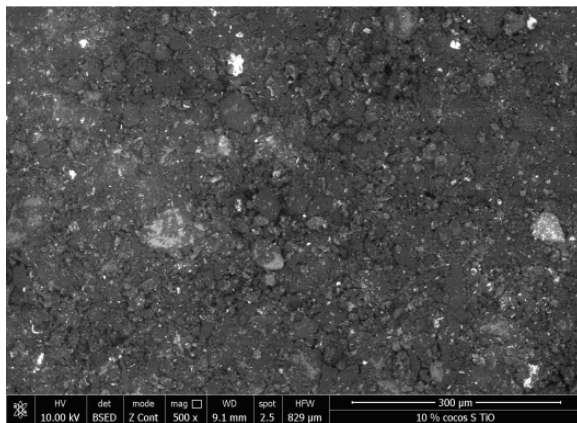


Figure 7. Unmatched area x 500.

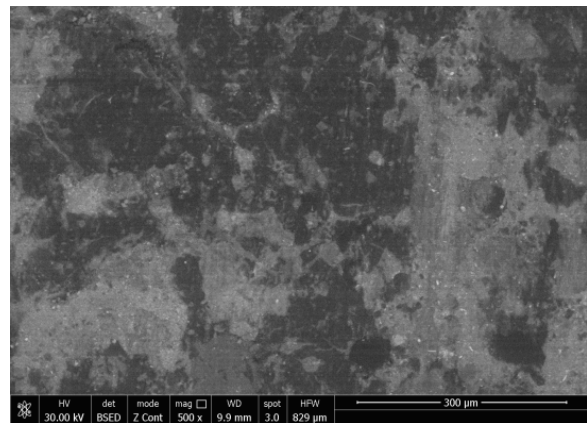


Figure 8. Worn area x 500.

The SEM images show the wear traces obtained on the brake pad surfaces at the end of the experiments. There is a slight discovery of the metal parts in the sample mass. It can be noted gaps in the mass of the composite as a result of rapid cooling of the non-metallic mass in contact with the metallic mass. Abrasive wear by peeling can be noticed due to the removal of wear particles that keep the metal particles in the uncover sample structure.

5. Conclusions

Each recipe of newly produced composite material must be subjected to a series of tests to evaluate the physico-mechanical and tribological properties. The development and validation of a friction material involve a significant amount of testings in laboratory. Knowledge of wear parameters, temperature in the contact area of the friction couplers, as well as the evolution of the coefficient of friction, allows to appreciate the durability of the composite materials.

Based on the results obtained in this paper the following conclusions can be made:

- the composite material tested in laboratory has low density, low porosity, high hardness properties and high compressive strength, that make them useful in automotive industry;
- the structural integrity of the composite materials produced ensures superior physical and mechanical characteristics the friction coefficient stabilises after a certain time;
- the factors influence the achievement of superior physical and mechanical characteristics for the composite materials produced are the type of components chosen in the recipes, the optimization of the proportion of the components and the parameters of the sintering technology the value of friction coefficient has stabilized at 0.35 and the friction material can be used for small and medium vehicles, which is in accordance with technical literature;
- the temperature in the contact area increases rapidly in the first part of the test and the most of the heat dissipates in the brake pads;

- during the brakings, the contact between disc and brake pad were approximately 80%, this confirms ECE R90 norms;
- from the SEM study it can be see that microstructures of friction material unmatched, showed the homogeneous distribution and this composite modelling appropriate percentage between matrix and reinforcement volume;
- the SEM images for worn area show the wear traces obtained on the brake pad surface at the end of the experiments;
- natural coconut fibre can be used as filler material for brake pads application for small and medium vehicles;
- the inconvenience of the organic friction material produced is the cost of coconut walnut, which is an exotic fruit.

References

- [1] Vijay R, Jees J M, Saibalaji M A and Thiagarajan V 2013 Optimization of Tribological Properties of Nonasbestos Brake Pad Material by Using Steel Wool, *Advances in Tribology* **2013** 165859-1–165859-1
- [2] Park J H, Chung J O and Kim H R 2010 Friction Characteristics of Brake Pads with Aramid Fiber and Acrylic Fiber, *Industrial Lubrication and Tribology* **62**(2) 91-98
- [3] Leman Z, Sapuan S M, Saifol S M, Maleque A M and Ahmad MM 2008 Moisture Absorption Behavior of Sugar Palm Fibre Reinforced Epoxy Composites, *International Journal of Materials and Design* **29**(8) 1666-1670
- [4] Amaguchi Y and Ahodas J 1991 Non-asbestos, Non-Metallic and Non-Glass Brake Pad Composite, *Automotive Engineering* **99** 12
- [5] Blau P J 2001 *Compositions, Functions and Testing of Friction Brake Materials and Their Additives*, Research DE-AC05-00OR22725, Oak Ridge
- [6] Crăciun A L and Pinca-Bretotean C 2016 Advanced Materials with Natural Fibred Reinforced Aluminium Composite for Automotive Brake Disc, *IOP Conference Series: Materials Science and Engineering* **163** 012014
- [7] Maleque M A, Atiqua A, Talib R J and Zahurin H 2012 New Natural Fibre Reinforced Aluminium Composite for Automotive Brake Pad, *International Journal of Mechanical Engineering* **7**(2) 166-170
- [8] Crăciun A L, Hepuț T and Pinca-Bretotean C 2016 Experimental Installation Use in Testing of Composite Materials for Braking System Components, *International Journal of Engineering* **14**(3) 243-250
- [9] Liew N 2009 On the Dry and Wet Sliding Performance of Potentially New Friction Brake Pad Materials for Automotive Industry, *Wear* **266**(2) 275-287
- [10] Crăciun A L, Pinca-Bretotean C, Birtok-Băneasă C and Josan A 2016 Composite Materials for Friction and Braking Application, *IOP Conference Series: Materials Science and Engineering*, **200** 012009
- [11] Todorovic J 1987 *Modelling of the Tribological Properties of Friction Materials Used in Motor Vehicle Brakes*, Institution of MechE, London, UK, pp. 911-916