RESEARCH ON THE PRODUCTION OF COMPOSITE MATERIALS FOR BRAKE SHOES

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The European law enforces limitations for railway noise, both for new, as well as for reconditioned and restored rolling stock. Thus, the rolling stock needs to be equipped with silent brake shoes, which significantly reduce braking noise. Braking efficiency depends on the type of brakes used, thus, for brakes with brake shoes, the braking force depends on the speed of the rolling stock. The paper focuses on determining the evolution of the temperature in the contact area of composite materials in the study of brake wear, using the pin-on-disk method. The composite materials are used for manufacturing brake shoes intended for motor and towed rolling stock.

Keywords: cast iron, composite materials, brake shoes, thermal field, structure

1. Introduction

Brakes with brake shoes can be equipped with brake shoes made of cast iron or of composite materials. Cast iron brake shoes are mainly used for rolling stock, when the maximum speed does not go above 140 km/h, as they have some disadvantages like: relatively quick wear, reduced coefficient of friction, coefficient of friction which depends on speed, production of sparks at breaking and overheating of the brake shoe [1]. Composite material brake shoes are used to replace conventional cast iron brake shoes, which are considered noisy. These are efficient in reducing noise by 10dB, the equivalent of 50% of the noise made by cast iron brake shoes [2]. When manufacturing brake shoes for rolling stock, the most commonly used material is P10 phosphorous cast iron. This material has limited usage, as its coefficient of friction drops drastically during braking at high

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speeds, and its wear intensifies, due to jam tendency, as the temperature in the friction coupler rises [3]. K brake shoes are made of organic composite materials and have braking characteristics which are distinct from the ones found in traditional brake shoes. Post-equipping requires adjustments of the braking system, leading to additional costs of up to 10 000 euros/car. They are very efficient for noise reduction and they are usually considered cost-effective when it comes to new train cars [4-6]. LL brake shoes only require minor adjustments of the braking system. They are designed so as to have similar braking characteristics to those of cast iron brake shoes. They are made either of organic composite materials, or of hot-pressed metals, and ensure a noise reduction similar to K brake shoes. By replacing cast iron brake shoes with LL composite material brake shoes we get a noise reduction and an increased durability which is 1.5 times higher [4-6]. K brake shoes have a coefficient of friction which is 2.5 higher than that of cast iron brake shoes, but they require modifications of the braking system when mounted on existing cars, and are recommended to be used on newer vehicles [7]. LL brake shoes have a coefficient of friction similar to cast iron brake shoes, they do not require modifications of the braking system when mounted on existing cars, and are recommended to be used on older vehicles already in use [8]. Equipping the existing rail freight car park with silent braking systems, especially by replacing cast iron brake shoes with composite material brake shoes [9, 10], represents the most important and profitable step in reducing noise at the source. From a legislative point of view, the tendency of imposing noise emission limitations for rolling stock, as well as introducing financial mechanisms for promoting a more silent railway traffic, continues to increase at European level [11,12].

2. Experiments in the laboratory phase

Considering the advantages of composite materials when manufacturing brake shoes [13-21], and their bahavior in exploit when compared to cast iron brake shoes, we made experiments on obtaining composite materials for brake shoes intended for rolling stock. For testing the composite materials, some disk specimens have been elaborated, so as to comply with the characteristics of the equipment used for testing. Disk specimens made of P10 cast iron have also been elaborated in order to make the comparison with the classic material used for manufacturing brake shoes possible.

The specimens obtained (4 samples/recipe) were made out of composite materials according to the recipe presented in fig.1. The process of obtaining the composite material specimens was determined, as well as the parameters of the process and the order and way of adding the components in the experimental recipes. The resulting experimental samples made of composite materials are presented in fig.2. For comparison with the phosphorous cast iron, which is the classic material used for making brake shoes, there have been made P10 cast iron specimens. The cast iron was obtained in an induction oven and disk samples were then cast, as presented in fig.3. The chemical composition of the cast iron is presented in table 1.

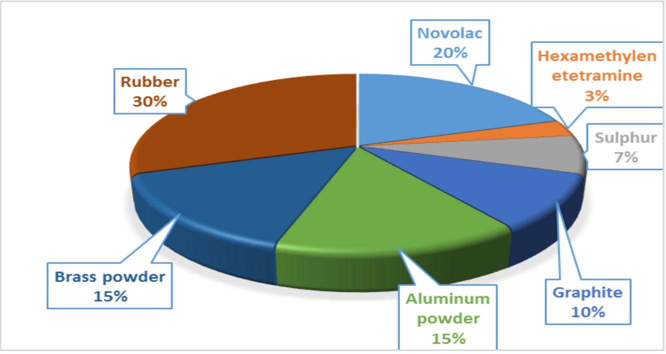


Fig.1. The composition of the recipe for the composite material disk sample

Fig.2. Experimental specimens made of composite material

Fig.3. Experimental specimens made of P10 cast iron

Table 1

The chemical composition of the cast iron

The chemical composition, %(wt)						
C	Si	Mn	P	S	Cr+Mo+Ti+W+V+Nb	1.72%S + 0.30% < %Mn < 1%
3.16	1.82	0.92	1.05	0.066	0.268	0.41% < 0.92% < 1%

The samples (cast iron, respectively composite material) were prepared for the study of wear using the pin-on-disk method (testing made on the laboratory stand presented in fig.4). The revolution speed *n* of the disk depends on the sliding speed and the work radius, and the time required for each test depends on the sliding speed.

Fig.4. Laboratory stand used for the study of wear using the pin-on-disk method

The aim was to determine the evolution of the thermal field in the contact area for the study of wear using the pin-on-disk method. Table 2 presents the calculus used to determine the trial parameters.

Table 2

The calculus used to determine the trial parameters

Average pressure [MPa]	Test time [min]	Sliding speed [m/s]	Angular velocity [rad/s]
$p = Fz / A$	$t = L/v$	$V = \omega R$	$\omega = \pi n / 30$

A – specimen area

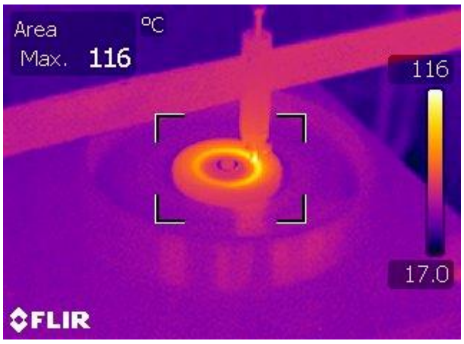
The thermal field was measured using a FLIR "Therma CAM Quick View" thermographic camera. The captured images offer information about the evolution of the temperature at the contact point between the pin and the disk, as well as the temperature of the contact trace.

3. Result and discussion

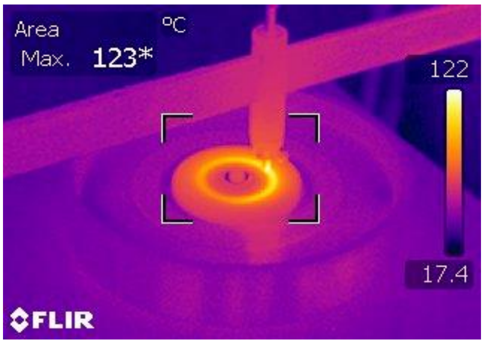
The evolution of the thermal field in the contact area for the study of wear using the pin-on-disk method was analysed.

Fig. 5 presents the images which show the evolution of the temperature at the contact point between the pin and the disk, as well as the temperature of the contact trace for the composite material sample.

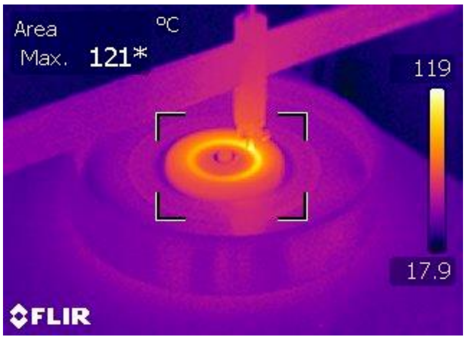
Fig. 6 presents the images which show the evolution of the temperature at the contact point between the pin and the disk, as well as the temperature of the contact trace for the phosporous cast iron disk sample.



The temperature distribution, L = 500m



The temperature distribution, L = 1000m



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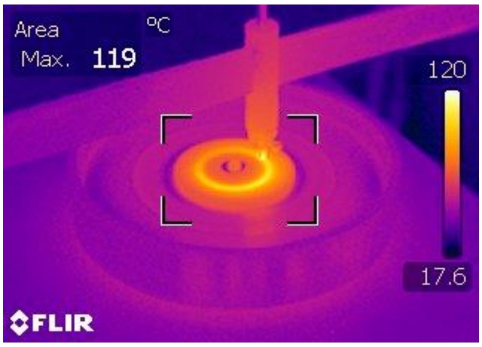
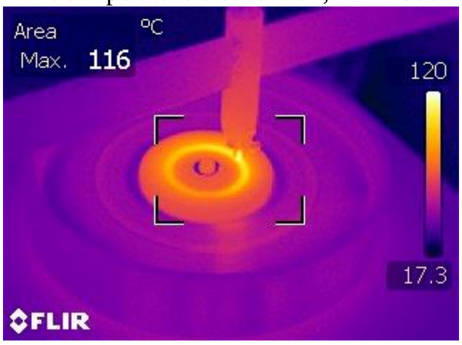
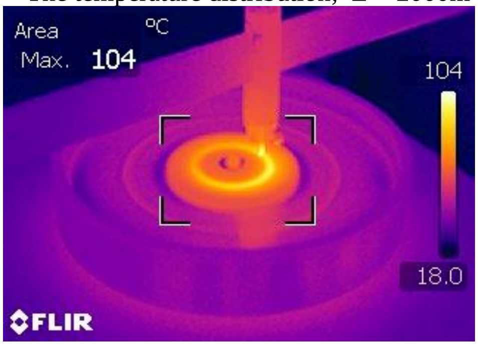


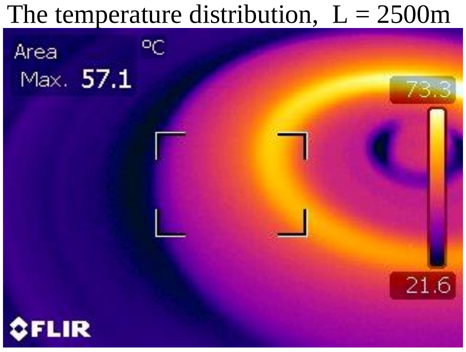
The temperature distribution, L = 2000m



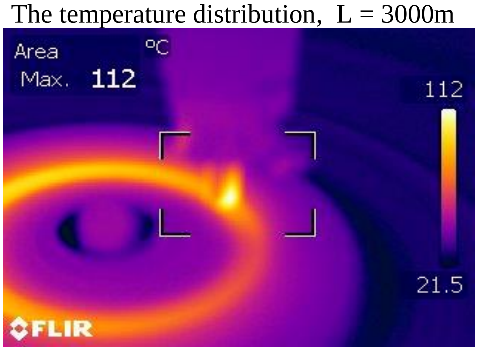
The temperature distribution, L = 2500m



The temperature distribution, L = 3000m

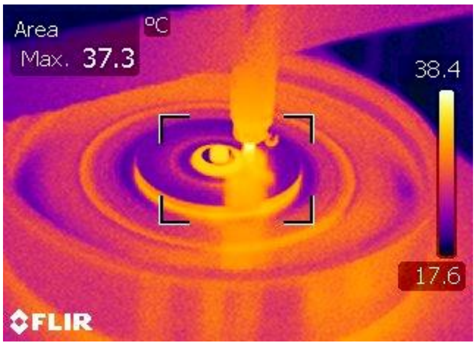


Sample temperature at the end of the trial

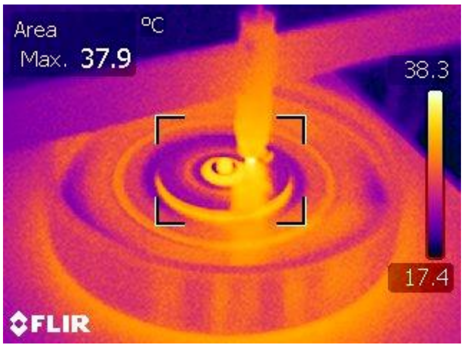


Pin temperature at the end of the trial

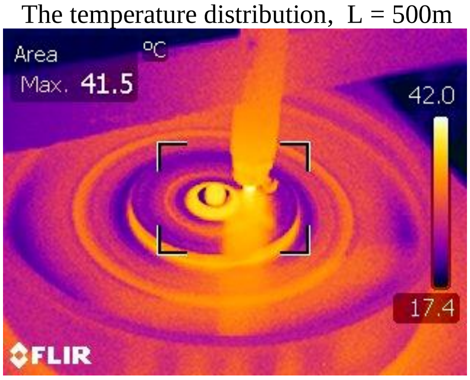
Fig.5. The evolution of temperature for the composite material sample



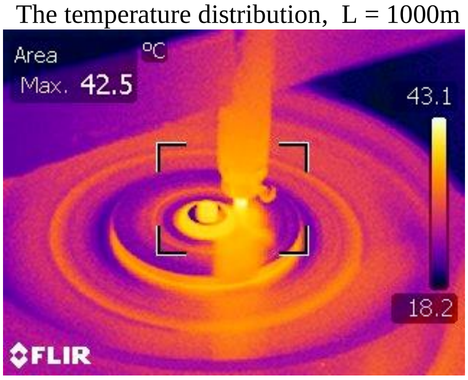
The temperature distribution, L = 500m



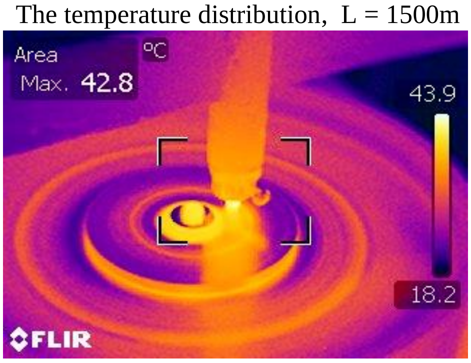
The temperature distribution, L = 1000m



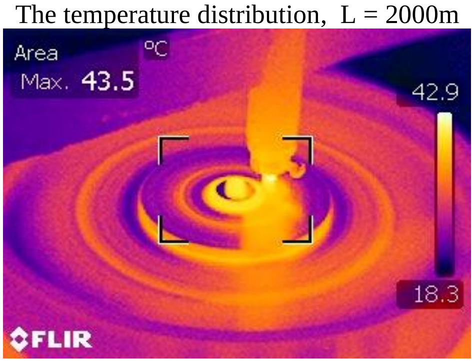
The temperature distribution, L = 1500m



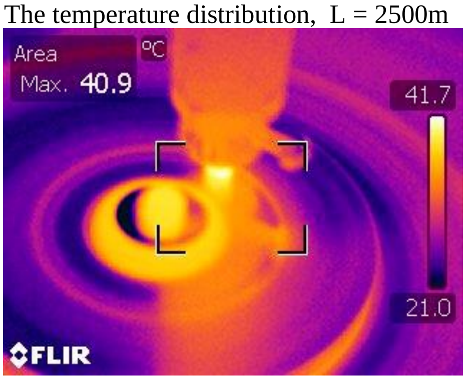
The temperature distribution, L = 2000m



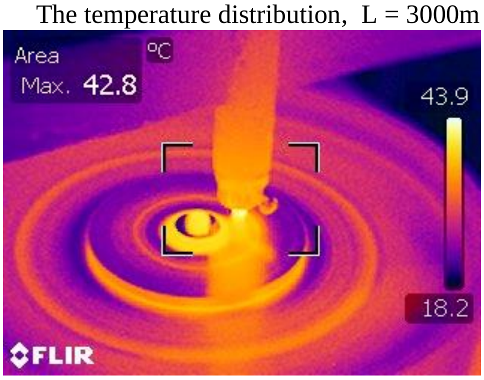
The temperature distribution, L = 2500m



The temperature distribution, L = 3000m



Cast iron temperature at the end of the trial



Pin temperature at the end of the trial

Fig.6. The evolution of temperature for the cast iron sample

Based on the obtained data, we drew the following conclusions:

- the temperature of the contact area rises rapidly during the first part of the trial, such that when covering a distance of 500 m, it reaches 116^{0}C in the contact area;

- between 500 – 1000 m covered, the temperature rises slightly, only by 7^{0}C. It can be said that between these distances the temperature stabilises;

- at over 1000 m covered the temperature begins to decrease, so that by the end of the trial it goes to 104^{0}C;

- the temperature of the friction trace on the composite material at the end of the trial is relatively low, reaching 57.1^{0}C.

The conclusions about the distribution of temperature in the cast iron specimen are:

- the fastest increase in temperature (37.3 ^{0}C) in the contact area takes place during the first 500 m covered during the trial;

- during the following distance covered and until the end of the trial, the temperature rises slowly between 37.9 – 43.5^{0}C;

- at the end of the trial the cast iron disk has a temperature of 40.9^{0}C and the pin has 43.9^{0}C.

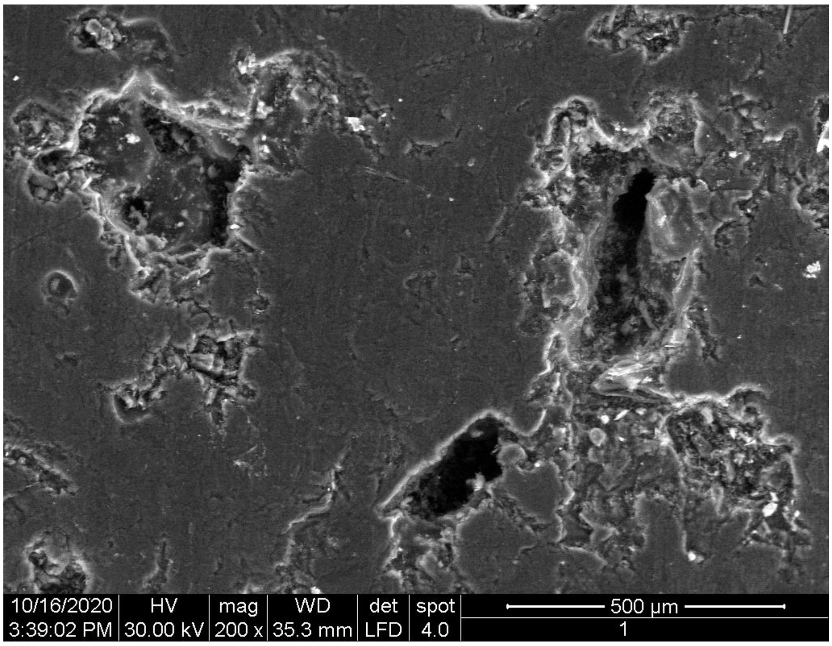


Fig. 7. Not worn composite material sample, 200x

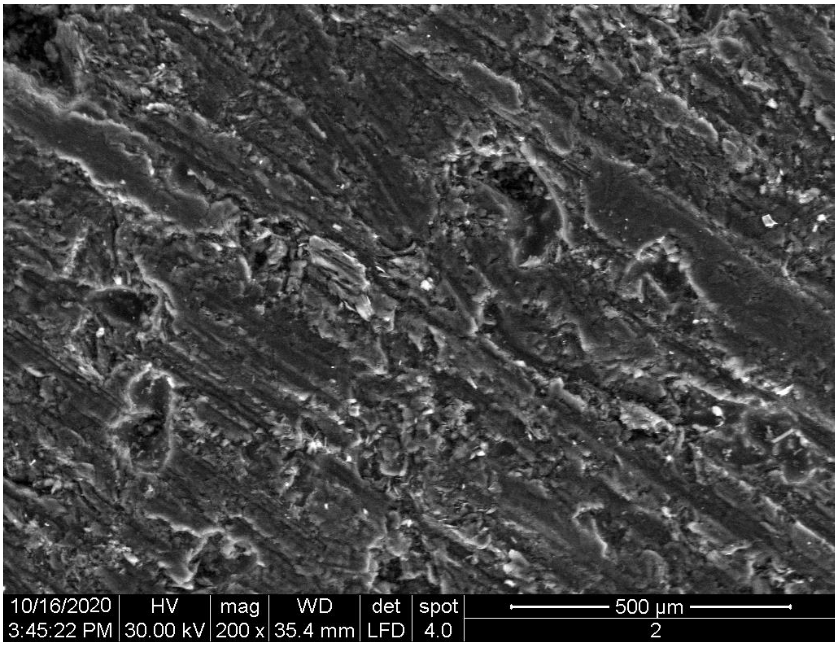


Fig. 8. Worn composite material sample, 200x

A (SEM) scanning electron microscope with an integrated EDS system was used to analyse the superficial layer of the composite material samples, and the results are presented in Fig. 7 and 8.

From analysing the structure, a subtle exposure of the metallic particles in the sample can be observed. The holes in the mass of the composite are a result of the rapid cooling of the non-metallic mass when coming into contact with the metallic mass. Some pores can be observed in the mass of the composite as a result of manufacturing imperfections. The coefficient of friction increases because of wear particles released at contact and because of holes being created, on the one hand, and, on the other hand, because of the alternation between the metallic and non-metallic masses. The abrasive wear caused by exfoliation can be observed when wear particles are released, thus causing the exposure of the metallic particles in the structure of the sample.

4. Conclusions

The need to study the phenomena and physical processes that take place in the superficial layers of the composite material samples is imposed by various strain conditions, such as: high sliding speeds over the friction coupler surfaces between the wheel and the shoe, high pressures due to braking force, the diverse strain conditions of the materials (low or high temperatures, humidity, etc.). An assessment of the degree of degradation of the materials subjected to the wear process can be made only when the evolution of the parameters of the superficial layer is known. These parameters are checked through physical methods of investigation, which must not affect the structure and the physical and chemical state of the superficial layer.

The temperature in the contact area of the composite material samples rises to about 116^0C for the first 500 m of test road, it then has a relatively constant evolution up to 1000 m of road covered, and then decreases so that, by the end of the test road (3000 m) it reaches 43.5^0C. The temperature in the contact area for the cast iron samples rises up to about 37.3^0C for the first 500 m of test road, it then increases slowly between 37.9-43.5^0C up to 1000 m, and then decreases so that, by the end of the test road (3000 m) it reaches 40.9^0C.

The SEM images of the friction traces left on the composite material samples subjected to tribology testing using the pin-on-disk method reveal a subtle exposure of the metallic particles in the mass of the sample. The holes in the mass of the composite are visible as a result of the rapid cooling of the non-metallic mass in contact with the metallic mass. The increase of the coefficient of friction is caused by the holes in the material, on the one hand, and on the other hand, by the alternation between the metallic and the non-metallic masses, as well as the release of wear particles.

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