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https://doi.org/10.37358/Mat.Plast.1964

The Tribology of Composite Materials Used for Manufacturing Brake Shoes

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Abstract: *The paper presents the results obtained after the tribology of composite materials with organic components intended for the manufacturing of brake shoes for motor and towed rolling stock. We analyzed the tribological behaviour of the samples of experimental composite material in comparison to the phosphorous cast iron frequently used for manufacturing brake shoes. The results show the advantages of using composite materials on brake blocks intended for rolling stock.*

Keywords*: composite, organic materials, friction coefficient, cast iron, brake shoes*

1. Introduction

Equipping the existing rail freight car park with silent braking systems is done mainly by replacing cast iron brake shoes with composite material brake shoes. This represents the most important and profitable step in reducing noise at the source [1-3]. 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 [4, 5]. The experts [6-9] advise priority to be given for measures taken at the source (rails and vehicles), as these have a higher cost – efficiency ratio. Composite brake blocks (K or LL) used on rolling stock lead to a considerable reduction in noise emissions, which is achieved in new rolling stock as well as in-service rolling stock. Overall, a reduction in noise emissions is achievable if the percentage of rolling stock equipped with cast-iron brake blocks falls below 30%. In addition, composite brake blocks shall meet the same frictional characteristics as regards cast iron brake blocks for the entire speed and load range [7-10]. Thus, composite materials must ensure: a coefficient of friction capable of guaranteeing the stopping distance regardless of weather conditions, does not lead to an increase in the amount of energy to be dissipated by the wheel and must not be more expensive than cast iron.

In the study there are phosphorous cast iron brake blocks type P10 respectively clogs made of composite material type K and LL. Characteristics of cast iron brake blocks are specified in the Specification No.1 /SFMR/SDT/2000 [6]. The use of clogs made of composite materials is made in accordance with the international standards [7-12] and the general conditions of certification require compliance with the norms in the field [13-15]. Type K clogs have a constant friction coefficient and higher than cast iron clogs. They are recommended to be used for new rolling stock. Type LL clogs have a coefficient of friction comparable to that of cast iron clogs and are recommended for equipping railway vehicles in service. Studying of brake blocks made of composite materials, disadvantages were also highlighted, such as a relatively higher wear of the wheel [14, 16]. There are also advantages in the use of composite materials [17, 18]: Reduced costs of adjusting the brake system for shoe mounting, lower shoe weight and friction coefficient similar to that of cast iron blocks. The material of the shoe has a significant influence on friction. The properties of the material [19-21] play an important role in the braking process and the achieved performance. The material influences the coefficient of friction and wear. The conditions imposed on composite materials are [22-24]: High friction coefficient (over 0,3), changes in the friction coefficient at very low speed and maintenance of friction and wear characteristics at high temperatures**.** Further efforts must be made to identify new composite materials or innovative

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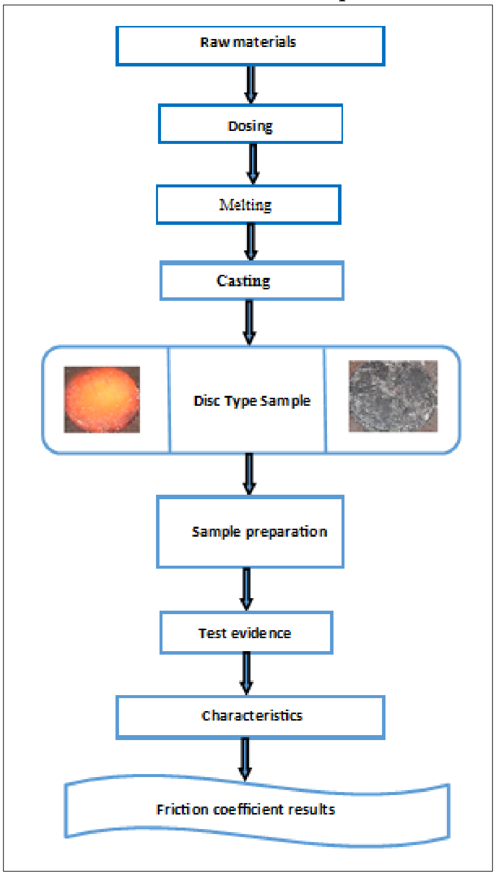
constructive solutions that lead to: reducing noise emissions, lowering the costs of obtaining brake blocks and lowering operating costs while increasing safety in operation. The main aim of the study is to obtain composite materials with characteristics comparable to those of phosphorous cast iron, a classic material used in the manufacture of brake shoes. For the testing of the experimental materials, disc samples were obtained from composite material or phosphorous cast iron for comparison, obtained in a mold [10] designed and made in the laboratory.

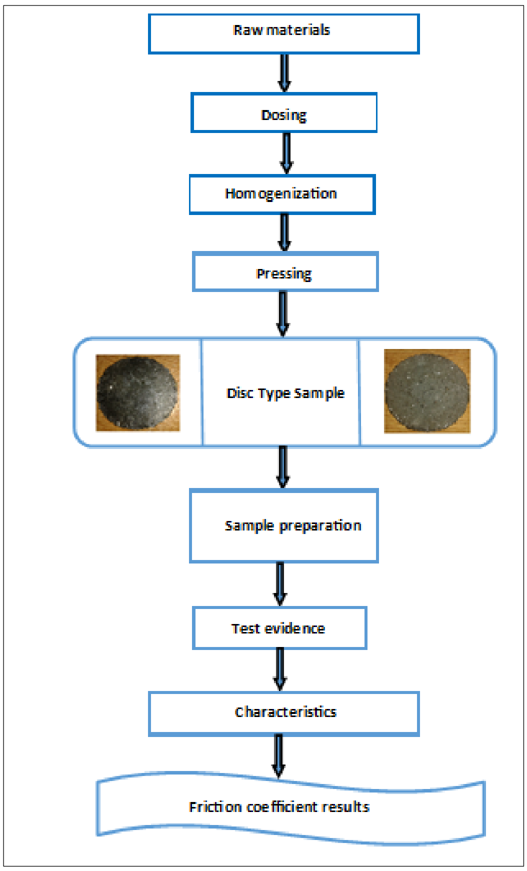
2. Materials and methods

The materials for the brake shoes were obtained in the laboratory [10]. In order to test the composite materials, we have produced disc samples, taking into consideration the characteristics of the laboratory installations for determining the friction coefficient, using an UMT-2 Universal Tribometer. To compare the results obtained on the composite material samples, we have also tested P10 cast iron samples (the conventional material used for manufacturing brake shoes).

The samples (composite/cast iron) were produced according to production and testing technologies presented in Figure1. In the mixture of the composite samples we have used: novolac, hexamethylenetetramine, sulphur, graphite, aluminium powder, brass powder and rubber. The recipe for the composite sample is presented in Figure 2. The parameters of the production process are: heating temperature for the mixture – 180^0 C, heating time – 20 min, plateau time – 20 min, hot pressure force – 50 kN. The cast iron samples were obtained in an induction oven. The metal charge was made of old cast iron (broken cast iron brake shoes). To form the cinder we used a mixture of lime and bauxite (80% lime and 20% bauxite). The time for melting the charge was 75 minutes. After melting, the metallic liquid was kept in the oven for 5 minutes more, in order to obtain chemical and thermal homogeneity. The temperature was measured using an optical pyrometer and a thermocouple. After measuring the tempertaure, the charge was poured into the ladle and after, into the moulds to obtain the samples. Samples were taken to determine the qualitative characteristics (Table 1).



cast iron



composite material

Figure 1. The technology of obtaining and testing the samples

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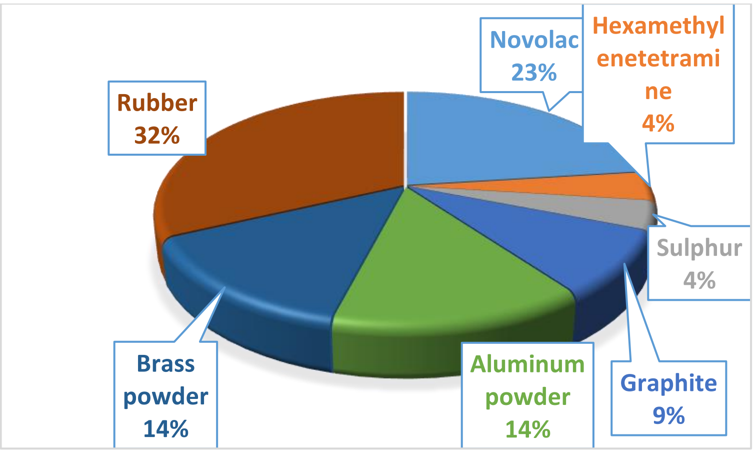

Figure 2. The recipe for the composite material sample

Table 1. Qualitative characteristics of the sample

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%

Composite material is a combination of several component materials with different properties that together lead to a new material with superior characteristics. In order to obtain a stable friction coefficient and a wear rate compared to cast iron blocks, the experimental material is composed of seven components: armature, binder, friction modifier and fillers. Aluminum powder and brass powder provide the composite material with hardness, required rigidity, wear resistance and friction coefficient stability. Binders and rubber keep the rest of the components together and maintain the structural integrity of the material. Fillers contribute to increased braking. The samples (composite/cast iron) obtained were prepared for establishing their tribological characteristics. The UMT 2 Universal Tribometer (Figure 3) allows pin-on-disk testing and observing the variation of the command parameters, as well as the measured parameters, which are selected according to necessity [10]. Experimental samples (composite / cast iron) are tested in dry slip conditions. Two variants were used for normal mean pressures (0.17MPa and 0.34MPa) and three sliding speeds (0.4m/s, 0.6m/s and 0.8m/s). Discs from the experimental materials were used for the tests. The pins are made of hardened steel.

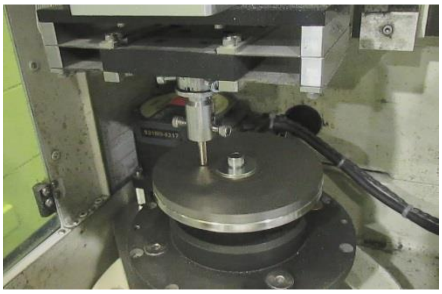

Figure 3. Sample tries – UMT Universal Tribometer [10]

To determine the variation of the friction coefficient, the regimen used for testing is that of dry friction. For each sample we used a toughened steel pin. The tries were done using three sliding speeds and two charges. The rotation speed *n* of the disc depends on the sliding speed and the working radius, and the time *t* required for each test depends on the sliding speed. Table 2 presents the calculus for determining the tries parameters. The values for the tries parameters are presented in Table 3.

Table 2. Calculus for determining tries parameters

Average pressure *P*, [MPa]	**Testing time** *T*, [min]	**Rotation speed** *N*, [rot/min]
p = Fz /A	t = L/v	n = 30·v/r

A – pin area

Table 3. Try parameters for pin-on-disc friction coupling

Sliding speed, [m/s]	**Pressing force** F_1, [N]	**Pressing force** F_2, [N]	**Rotation speed** [rot/min]	**Try time** [s]
$v_1 = 0.4$	5	10	152.8	3750
$v_2 = 0.6$	5	10	229.2	2500
$v_3 = 0.8$	5	10	305.6	1875

3. Results and discussions

The tests were performed for both experimented materials (composite material / cast iron). The experimental data resulting from the tests are recorded in text files shown in Figure 4. Also the recorded parameters are found in graphical form. As an example, Figure 5 presents the parameter charts measured by the tribometer during the try of the disc sample made of composite material (F_2=10N and v_3= 0.8m/s).

The experimental data for the values of F_1 = 5N and F_2 = 10N loads were processed in the EXCEL program. The variation of the coefficient of friction for the experimental samples (composite material / cast iron) are shown in Figures 6-9.

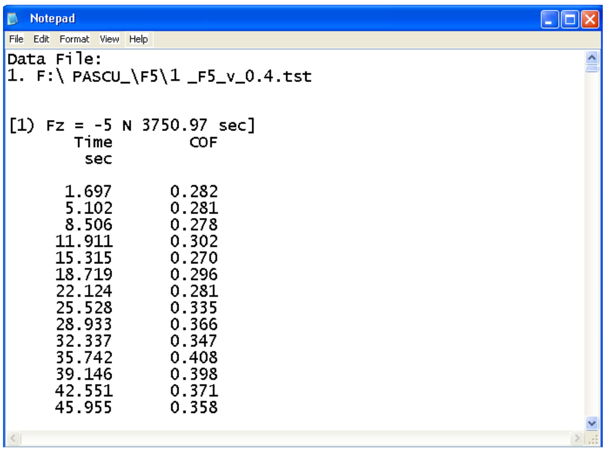

Figure 4. The data for sample tries with F_1 and v_1

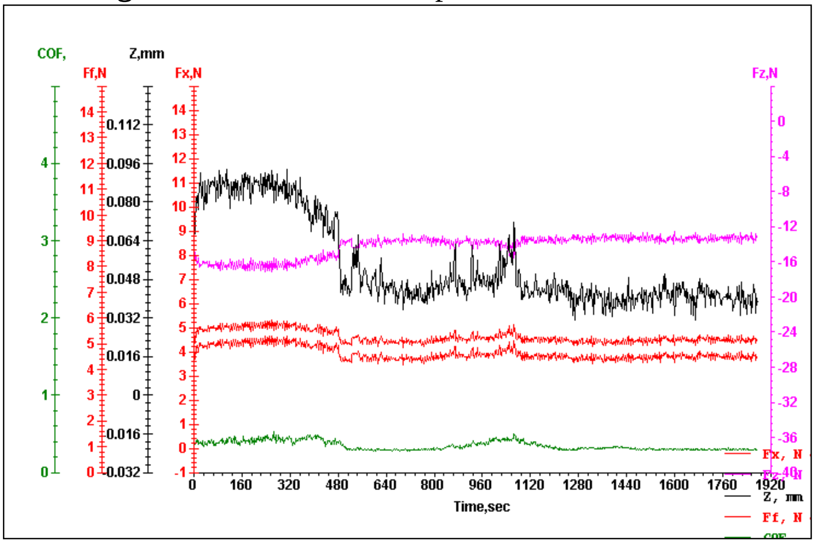

Figure 5. The charts of the measured parameters by the tribometer when testing the composite material disc sample, with F_2 and v_3

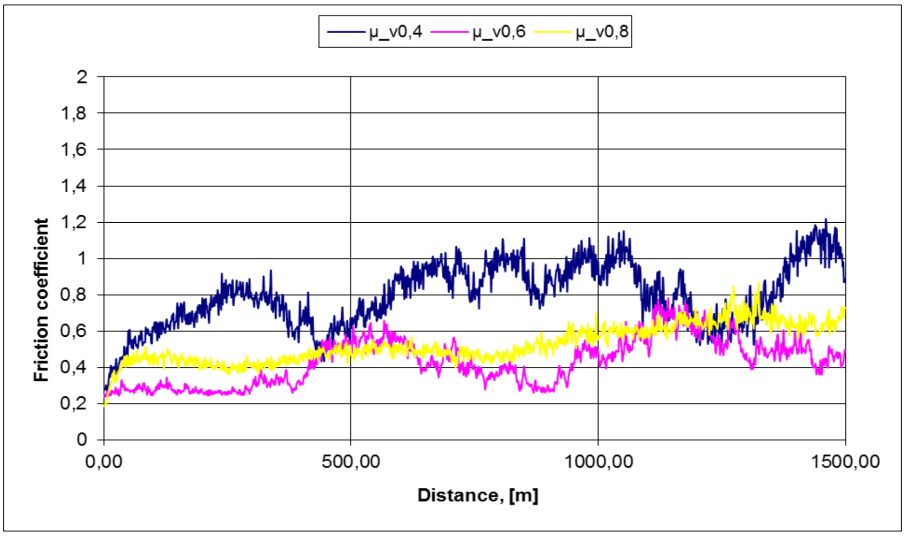

Figure 6. Variation of characteristics for the composite sample (pressing force F_1)

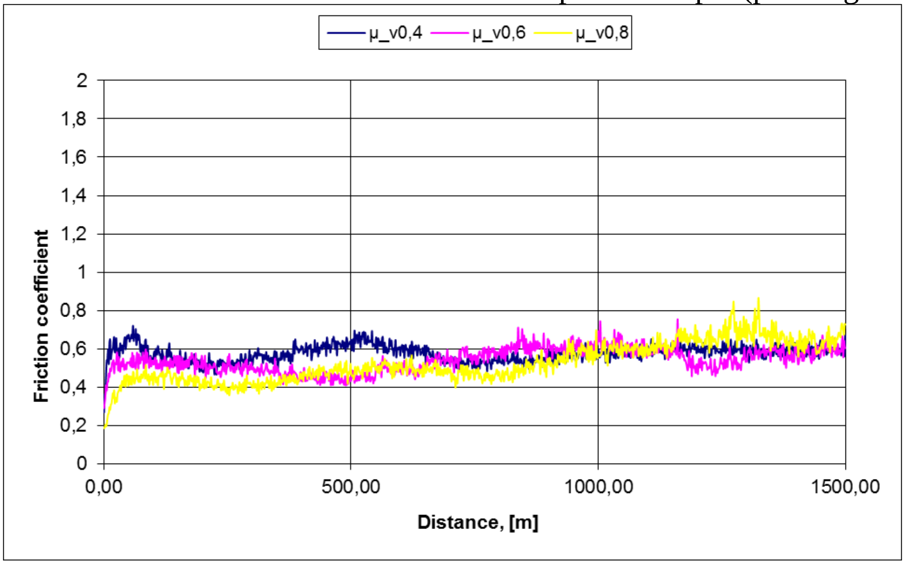

Figure 7. Variation of characteristics for the cast iron sample (pressing force F_1)

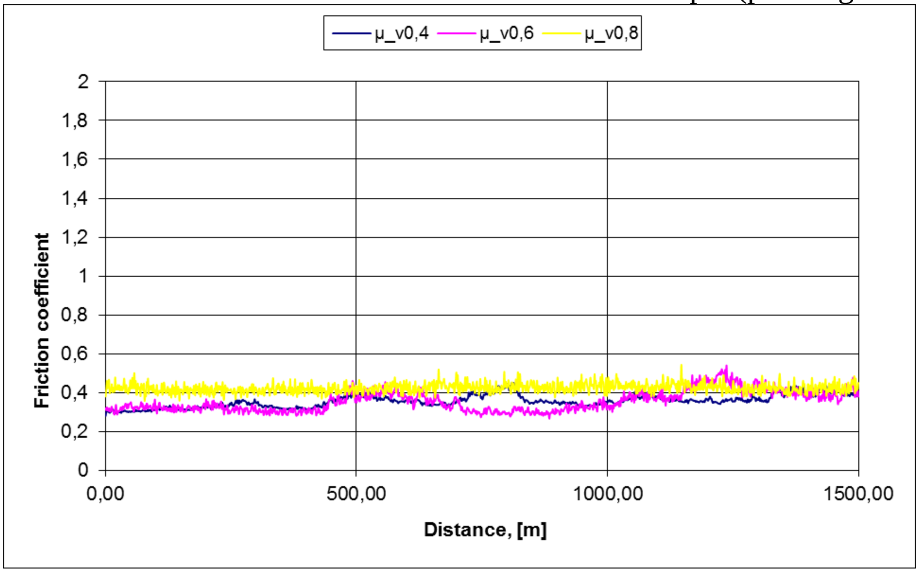

Figure 8. Variation of characteristics for the composite sample (pressing force F_2)

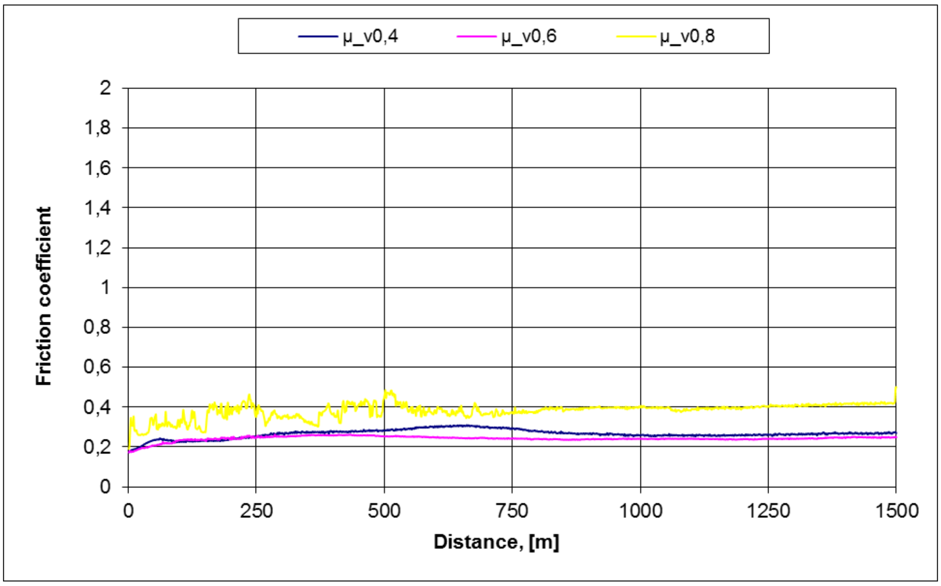

Figure 9. Variation of characteristics for the cast iron sample (pressing force F_2)

From the analysis of the data obtained for the experimental samples, a value higher than 0.3 for the coefficient of friction of both materials in the case of tests performed with the pressing force F_1 is observed, respectively a value higher than 0.25 for the tests performed with the pressing force F_2. In both materials there is an increase in braking efficiency. With the increase of the sliding speed, at the same load, an increasing evolution of the coefficient of friction is observed with the increase of the distance traveled, for both materials. The tests on cast iron samples keep the evolution of the coefficient of friction approximately constant according to the working distance. In the case of tests performed with loads F_1 and F_2, the coefficient of friction of the composite material samples increases continuously, an increase that positively influences the braking process. If the same sliding speed is maintained and the workload is increased, a decrease in friction coefficients is observed. They become much more stable over time in both composite and cast iron. The increase of the load at the sliding speed of v_1 and v_2 respectively does not lead to the increase of the coefficient of friction, only small variations appear. In cast iron samples, the coefficient of friction increases with increasing load and speed.

4. Conclusions

Knowing of the functionally optimal microgeometry of the friction coefficient, the temperature in the contact area and the intensity of wear, gives the opportunity for pertinent assessments on the durability in operation of the composite material intended for the manufacture of the brake shoe.

The tribological research performed on the composite material samples determined the influence of the material factors and the parameters of the working regime on the variation of the coefficient of friction. The experimental composite material, in comparison to phosphorous cast iron, has a superior friction coefficicent. The results obtained after testing reveal a rise in the friction coefficient related to increased speed and load. Replacing cast iron clogs with composite clogs reduces noise and increases the durability of brake shoes.

Renewing the rail freight car park is a costly and long-term undertaking; thus, there have been found solutions to diminish the noise produced by rail transport through measures taken directly at the source. The most profitable measure is to replace the braking systems.

The technology currently available cannot be considered sufficient for European-scale retrofitting, so further efforts are needed to obtain new composite materials for brake shoes in order to significantly reduce costs.

Rail traffic noise is largely a problem for freight trains and those with older wagons or locomotives and is a serious problem, especially at night. An important source of noise is rolling noise, which affects all types of train. A significant noise reduction is achieved by introducing modern rolling stock or replacing cast iron brake blocks with composite brake blocks on freight wagons. When using composite materials, the following are noted: Low costs for adjusting the brake system in view of shoe mounting, lower shoe weight, friction coefficient similar to that of conventional shoes, similar values for wheel wear, reduction of rolling noise by approx. 50%, decrease in maintenance costs of the brake system by approx. 30%, wear resistance higher than conventional, and the use of composite material does not emit toxic dust when braking.

Acknowledgments: *This paper was financially supported by the Project "Network of excellence in applied research and innovation for doctoral and postdoctoral programs" / InoHubDoc, project co-funded by the European Social Fund financing agreement no. POCU/993/6/13/153437*

References

1. *** Official Journal of the European Union, L139, **54**, 2011
2.*** http://www.afer.ro/legislatie_sti/Regulamentul%20774_2019.pdf
3. GEORGESCU G.,, DELEANU L., BOTAN M., Dry sliding of composites with PBT matrix and micro glass beads on steel, Industrial Lubrication and Tribology, **66** (3), 424 –433, 2014
4. ZGAVERDEA, A.C., RATIU, S.A., Green Carbon" from Algae for Automotive Applications, *Mater. Plast.*, **58**(1), 2021, 186-200. https://doi.org/10.37358/MP.21.1.5458.
5. STOCHIOIU, C., DECA, A., HADAR, A., GHEORGHIU, H., In-plane Shear Response of a Flax Fiber-epoxy Resin Composite Subjected to Repeated Loading and Creep-recovery Cycles, *Mater. Plast.*, **58**(4), 2021, 179-186. https://doi.org/10.37358/MP.21.4.5543.
6. *** Specification, no.1 /SFMR/SDT/2000, Brake shoes for tractors and trailers rolling.
7. *** UIC 541-4 Brakes - Brakes with composite brake shoes. General certification conditions.
8. *** UIC SET 07/2012 Design rules of composite brake blocks (K).
9. *** UIC SET 07/2013 Rules for use of composite brake blocks (LL)
10. PASCU, L., PhD thesis, Researches on Improving the Quality of Brake Shoes Meant for Use with the Rolling Stock, Politehnica Timisoara, Romania, 2015
11. NEHARKAR SURESH P., PATIL R.J., SONAWANE P.R., Study of friction and wear for optimization of disc break material for reduction of brake sound, International Journal of Research in Aeronautical and Mechanical Engineering, **2**(6), 137-144, 2014
12. MATEI, E. PREDESCU, A.M. RAPA, M. TURCANU, A. PREDESCU, C. VIDU, R. FAVIER, L. COVALIU, C.I. IGNAT, D. GRIGORE, V., Testing of Alginate/Chitosan/Glass Bubbles Adsorbent for Copper Removal from Wastewater, *Mater. Plast.*, **58**(1), 19-26, 2021, https://doi.org/10.37358/MP.21.1.5441
13. ZHANG S., WANG F., Comparison of friction and wear performances of brake material dry sliding against two Al matrix composites reinforced with different SiC particles, Journal of Materials Processing Technology, **182**, 122-127, 2007
14. DUNGAN, L., DUNGAN, M., Materials used in couplings mechanical friction braking system of high speed railway vehicles, Bulletin AGIR, **2-3**, 121-128, 2010
15. SUROJO E., JAMASRI J., MALAU V., ILMAN M.N., Investigation of Friction Behaviors of Brake Shoe Materials using Metallic Filler, Tribology in Industry, **37**(4), 473-481, 2015
16. JAMASRI J., MALAU V., ILMAN M.N., SUROJO E., Effect of ingredients on flexural strength of friction composite, Applied Mechanics and Materials, **493**, 615-620, 2014
17. QATU M. S., Recent research on vehicle noise and vibration, International Journal of Vehicle Noise and Vibration, **8**(4), 289–301, 2012
18. LEE W. K., SHIN M. W., KIM S. H., JANG H., CHO M. H., The influence of humidity on the sliding friction of brake friction material, Wear, **302**(1-2), 1397–1403, 2013

19. DRAGAN A., PIERPAOLO C., Soft Computing in the Design and Manufacturing of Composite Materials, Applications to Brake Friction and Thermoset Matrix Composites, Woodhead Publishing, 2015, p. 293
20. HONG H. R., KIM M. S., LEE H. Y., JEONG N. T., MOON H. U., LEE E. S., KIM H. M., SUH M. W., CHUNG J. D., LEE J. H., The thermo-mechanical behavior of brake discs for high-speed railway vehicles, Journal of Mechanical Science and Technology, **33**(4), 1711–1721, 2019
21. KAVITHA K. R., PRAKASH S., A review on brake lining materials, International Journal of Mechanical and Production Engineering Research and Development, **9** (6), 691–706, 2019
22. NAGESH S.N., SIDDARAJU C., PRAKASH S. V., RAMESH M. R., Characterization of brake pads by variation in composition of friction materials, Procedia Material Science, **5**, 295–302, 2014
23. PETRE V. C., STOIAN E. V., ENESCU M. C., Tribological Behavior of a Thermoplastic Material Under the Action of a Conic Penetrator in Sliding Movement, *Mater. Plast.*, **58**(1), 2021, 27-33
24. CRUCEANU C., CRACIUN C., Aspects regarding the braking capacity of composite brake shoes for railway vehicles, *Mater. Plast.*, **56**(1), 2019, 18-21

Manuscript received: 14.03.2022