THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI.
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
N^{0}. 2 – 2013, ISSN 1453 – 083X

PROFILOMETRIC ANALYSIS OF WORN SURFACE OF BRONZE, IRON AND IRON COMPOSITE SAMPLES, BY PIN-ON-DISK METHOD

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ABSTRACT

In this study are presented the results of profilometric analysis for the wear of bronze materials, cast iron and composite materials. These materials were tested under dry wear conditions, using "pin-on-disk" method on a UMT-2 tribotester at a room temperature and relative humidity of 30-45%. The tests were carried out with load of 30, 40 and 60N at a linear speed of 0.815 m/s. The resulted traces of wear were examined with a Surtonic 3 + profilometer that has Talyprof software installed on, trademarks of TAYLOR HOBSON (United Kingdom) company. The obtained results allowed for a tribological analysis of the materials and their classification from the tribological point of view.

KEYWORDS: roughness parameters, bronze, gray cast iron, composite material for iron

1. Introduction

Polymer composites are more and more often used because of remarkable mechanical properties such as stiffness, low density, mechanical strength and good resistance to wear, excellent chemical properties and good wettability. Adding filling materials to the composite ones improves other characteristics such as electricity, etc. Due to their highly performant properties regarding quality, safety and ease of use, composite materials are also used in maintenance and repair sectors of the automotive, automobile, shipbuilding, steel industry, etc. [1, 2, 3, 9].

For these reasons, their use is required in aviation or automotive industry, as alternatives to conventional materials metal alloy composites. The possibility of designing the properties of composite materials is an advantage over traditional materials.

The addition of metal reinforcers in polymer composites led to the improvement of resistance and friction mechanical properties.

There are numerous applications where friction phenomenon is very important.

2. Experimental procedure

2.1. Materials and characterization

The material samples were subjected to tribological investigations are metals (bronze CuAl19Fe3T STAS 198/2-1992 brand and gray cast iron with nodular graphite EN-GJS- 450-10 SR EN 1563:1999 brand) and a composite meant for cast iron applications. This composite [10] is produced by "Diamond Metallplastic GmbH" company in München, Germany and is marketed under the name of Multimetall Eisen. In this paper it will be marked SCC code.

Table 1. *Mechanical characteristics of metallic materials*

Material quality/Prescripions	Sample code	Rm [N/mm^2]	$R_{p0,2}$ [N/mm^2]	A_5 [%]	Hardness HB
Bronze with Al, CuAl9Fe3T brand	SA	506	-	12.0	134
Gray cast iron with graphite, EN-GJS-450-10 brand	SC	506	433	11.6	173
Steel C45	SS	687	405	22	250

The materials listed above formed the tribological couple with pin which is made from C45 SR EN 10083-2:2007 steel.

The experimenatally obtained mechanical characteristics of the mechanical materials are listed in Tab. 1.

Composite material for iron (sample code: SCC) has the following characteristics [10]: elasticity modulus 6,000N/mm^2; traction resistance 77N/mm^2, crushing strength 5.0N/mm$^{2;}$ shear strength 22.5N/mm^2, bending strength 89N/mm^2 compressive strength 160N/mm^2;

Diffractometric analysis revealed the presence of the following phases in the composite material for iron's structure: α quartz SiO_2 particles of Al and Fe_5Si_3.

Test samples are: φ6.25x25 mm steel pin C45 and φ96x6 mm bronze disc iron cast and composite material for iron. Roughness of the samples was R_a0.8.

2.2. Experimental setup and procedures

Dry testing for sliding friction using "pin on disk" method was performed on UMT-2 tribotester (CETR®, USA) at room temperature and humidity between 30-45%.

Before testing, the samples were degreased with an organic solvent and dried with hot air at the temperature of 50°C.

The actual wear tests were preceded by a 10 minute dry at the speed of 0.815m/s. Wear tests were performed on the same wear track that resulted from the grind. The testing lasted for 50minutes, at a sliding speed of 0.815m/s, on a friction distance L_f = 2445 m and load forces of: 30, 40 and 60N.

The data regarding the digital profiles was acquired with the digital Surtronic3+ Profileograph, widely used in surface geometry tribological study and they were processed in Talyprof (Taylor Hobson® equipment and software). For the present study some of the program's expert functions were used.

The wear trace profilometric analysis is often used for setting the intensity and type of the wear process [4, 5, 6, 7, 8].

Wear evaluation through profiling methods was performed by using three characteristic parameters provided by the Talyprof software: maximum depth of track profile, the area of wear track between the highest peaks that limit the track result, on the left and the right side, and the profile's bottom (area of the hole) and the average depth of the track's profile (mean depth).

Based on digital roughness profile, a complex analysis of the worn surfaces' microgeometry was carried out, especially for wear tracks:

a) the comparative study of profile charts, following the variation of quantitative parameters, that characterize the wear track: the maximum profile dept, area, average profile;

b) using bar type diagrams for the variation of the three characteristic parameters;

Talyprof program uses the transformed profile by determining the average line of the profile (STAS 5730/1-85) and therefore digital profiles of wear tracks are distorted to the real profile. Determination of the average line of the profile involves minimizing the sum of squares of profile deviations. To the wear track, due to the rectangular geometry of the track, which is generated by sliding friction contact between the pin and disc, the calculation algorithm produces "compensation" of the side edges (limits) of the track area all with a sum of many small positive areas of the profile's surface roughness, from the left and the right side of the track. Therefore the profile is strongly "lifted" up at all corners.

In order to achieve the digital profiles for the wear traces, for each of the last three parts of the disc, were performed at least three profilograms.

These profilograms have been achieved by taking into consideration the radial direction (vertical on the circular trace) at angles of 120˚C.

Since the maximum width of the wear trace is connected to the diameter of the pin, 6mm, all the profiles have been carried out on an inspection length of the probe of 8mm.

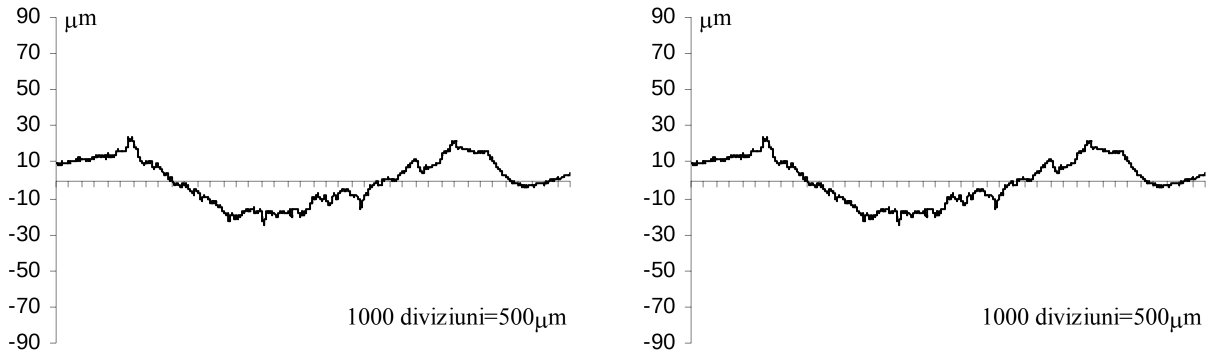
3. Results and discussion

In Fig. 1÷9 are presented the results obtained for some of the studied materials: bronze, cast iron and composite material for iron, all of these materials making tribological joints with C45 steel pin.

In the case of bronze material (Fig. 1÷3), on the 8mm inspection length, the profilograms showed the deepest wear traces in case of a force F_2 = 40N (Fig. 2). The corresponding profilograms for F_3=60N force showed wear traces with smaller depths in comparison with F_2 force. From the profiles' combined analysis of and photos taken with a microscopic of these wear traces, associated with the comments concerning pin wear surfaces, the cause of these little deep traces could be established: at the normal loading force F_3, adhesion wear was very strong, unlike the case of wear tests for F_1 and F_2, where predominant was the abrasive wear.

The detachments from the bronze particles were a phenomenon of low intensity.

Basically, on one hand, the disk material, adhered to the pin (visible phenomenon due to the material's yellow color on pin surface), and on the other hand it has been redistributed on the wear surface of the disk.



a) b)

Fig. 1. *Bronze disk and steel pin, F_1=30N;*
a) wear trace profilogram conducted on a length of 8mm;
b) extracted from the wear trace's profilogram

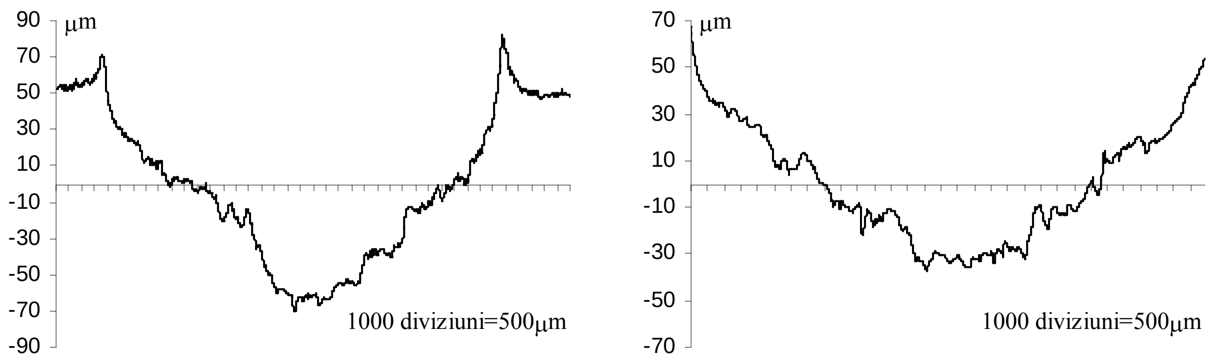


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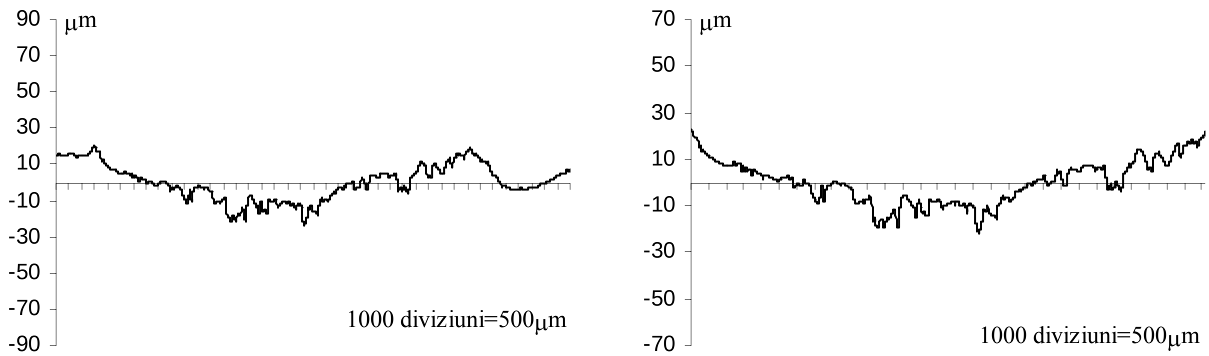
Fig. 2. *Bronze disk and steel pin, F_2=40N;*
a) wear trace profilogram conducted on a length of 8mm;
b) extracted from the wear trace's profilogram



a) b)

Fig. 3. *Bronze disk and steel pin, F_3=60N;*
a) wear trace profilogram conducted on a length of 8mm;
b) extracted from the wear trace's profilogram

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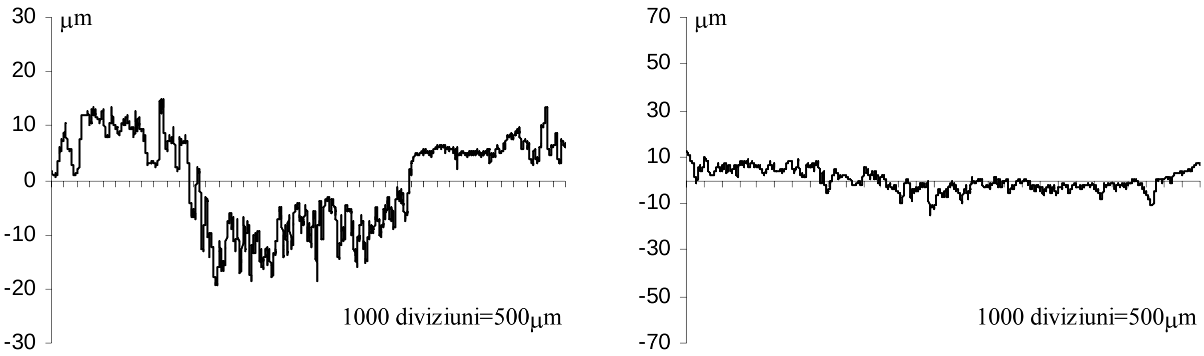
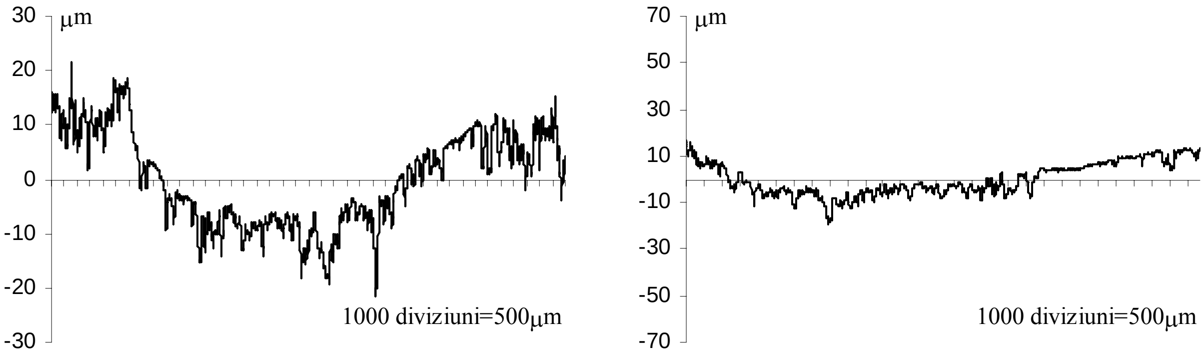


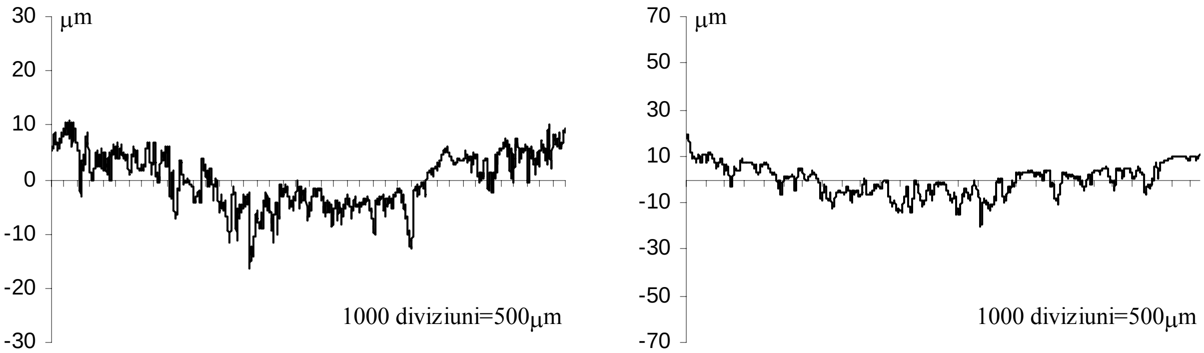
a) b)

Fig. 4. *Cast iron disk and steel pin, F_1=30N;*
a) wear trace profilogram conducted on a length of 8mm;
b) extracted from the wear trace’s profilogram



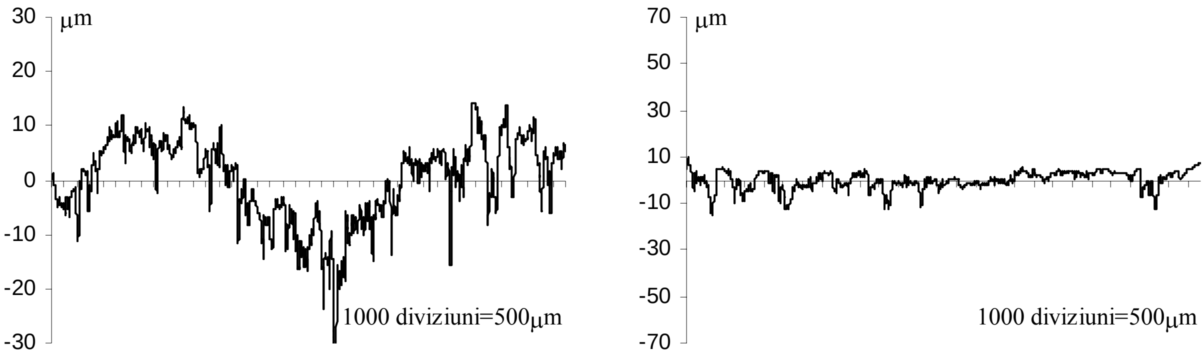
a) b)

Fig. 5. *Cast iron disk and steel pin, F_2=40N;*
a) wear trace profilogram conducted on a length of 8mm;
b) extracted from the wear trace’s profilogram



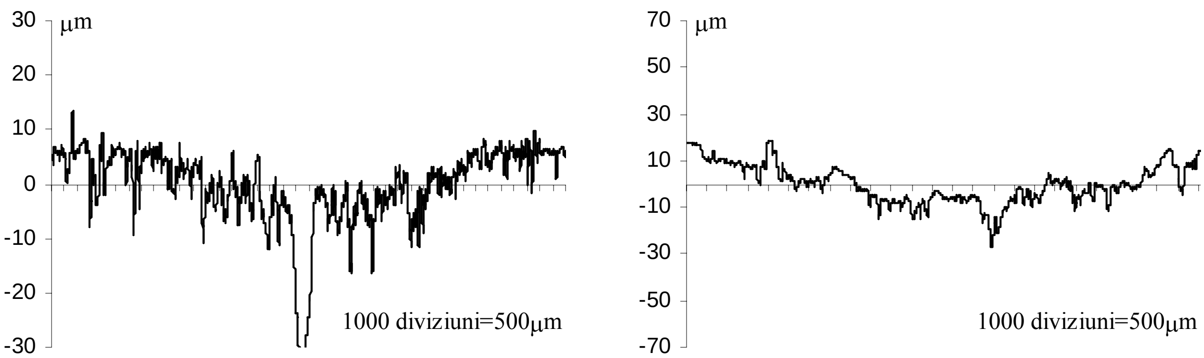
a) b)

Fig. 6. *Cast iron disk and steel pin, F_3=60N;*
a) wear trace profilogram conducted on a length of 8mm;
b) extracted from the wear trace’s profilogram



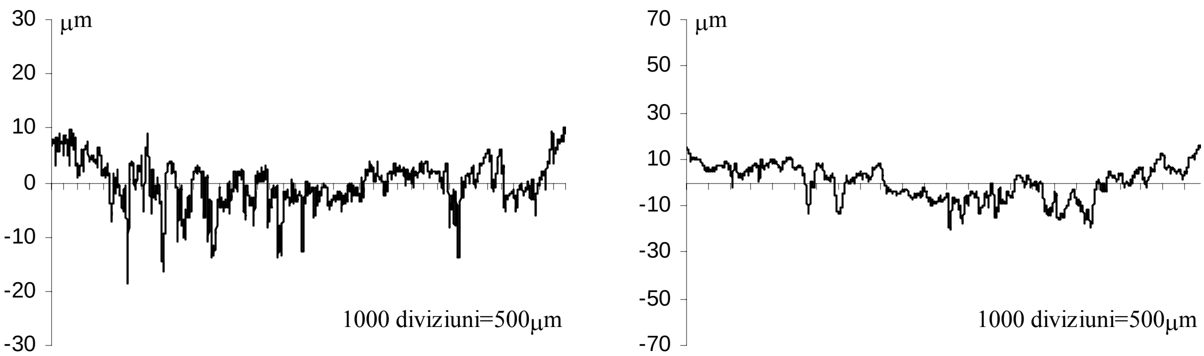
a) b)

Fig. 7. *Composite material for iron disk and steel pin, F_1=30N;*
a) wear trace profilogram conducted on a length of 8mm;
b) extracted from the wear trace’s profilogram



a) b)

Fig. 8. *Composite material for iron disk and steel pin, F_2=40N;*
a) wear trace profilogram conducted on a length of 8mm;
b) extracted from the wear trace’s profilogram



a) b)

Fig. 9. *Composite material for iron disk and steel pin, F_3=60N;*
a) wear trace profilogram conducted on a length of 8mm;
b) extracted from the wear trace’s profilogram

In case of worn disk surfaces made of the cast iron (Figure 4÷5) and, respectively, from iron composite (Figure 7÷9), wear adhesion was less pronounced than in the case of bronze disk, idea sustained by the profilograme appearance with many more peaks and dips, quite high, namely deep (from 4-5µm to 10-15µm).

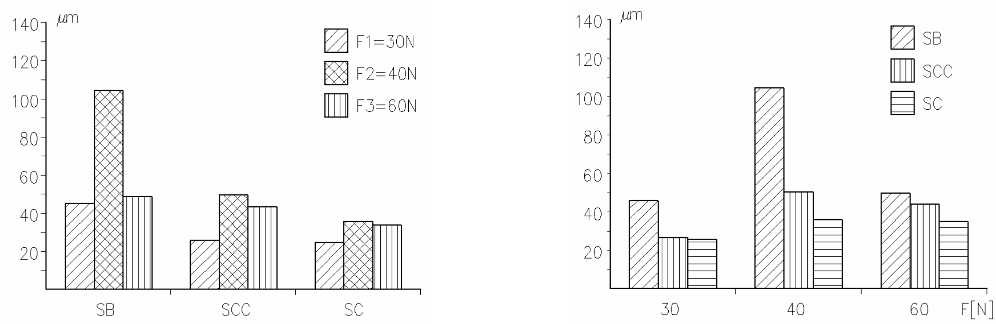
For F_3 = 60N test for iron (Figure 6), we can observe a few high peaks and very deep goals, on the worn surface which means strong smoothing of the profile’s projections roughness profile of wear. Predictably, wear depth and width increase along with force. Composite material for iron behaves better at wear than iron, fact proven by the width and depth of wear, both smaller for composite F_0, comparing to cast iron. For tests with F_1 = 30N and F_2 = 40N, the less smoother appearance of the wear trace’s profile is explained by a greater predominance of abrasive wear comparing to adhesive wear. Considering force F_3 = 60N, profiles are smoother which means an increase in the prevalence of adhesion wear. With the aid of the column diagrams (fig. 10÷11) the three parameters belonging to the wear profile were compared, and they were generated by Talyprof software: the maximum depth of the trace profile; the area of the wear trace, between the highest peaks that limit the trace, on the left and right side, and the bottom of the profile and the mean for the trace’s profile.

The three parameters were analyzed for each material depending on the normal load force and for each loading force depending on the material.

By looking at the diagrams in Fig. 10÷12 one can confirm the predominance of adhesion wear for bronze material, as well as the greater percentage of adhesive wear to abrasive wear in case of the composite material for cast iron.

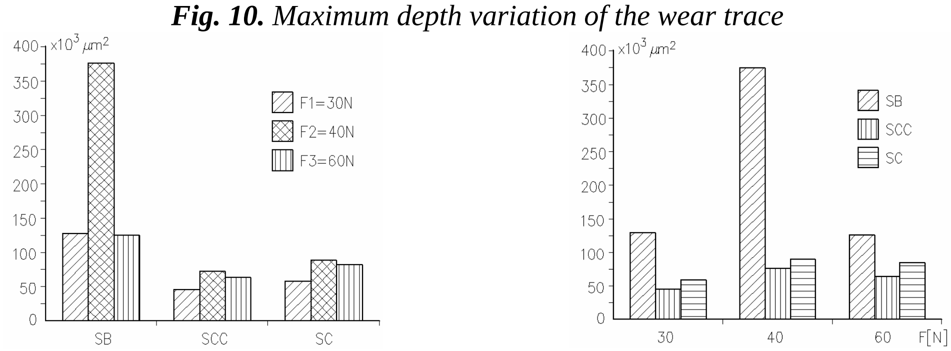
Studying Figure 10 it is revealed that, in the case of composite material for cast iron, the wasted volume is lower than the one for cast iron, but the probability that the percentage of adhesion wear would grow at bigger forces, is higher.

Comparing the behavior of materials at the same loading force (fig. 11), the following conclusion can be drawn: for all the three loading forces the lowest ear trace areas were obtained for composite material for cast iron. Of the three parameters used for the study, the one that offers the most obvious results is the wear trace area.



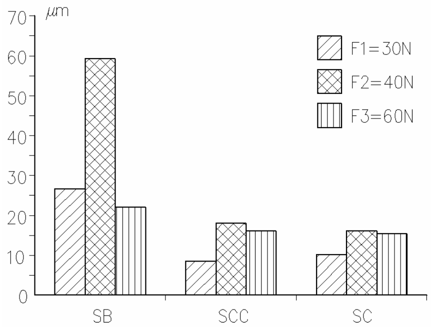
a) b)

Fig. 10. *Maximum depth variation of the wear trace*

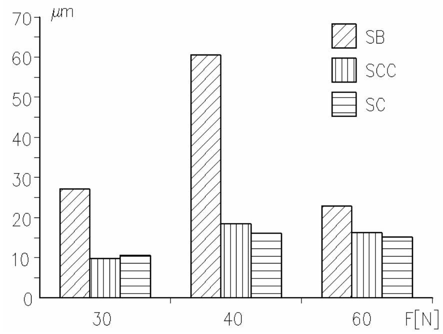


a) b)

Fig. 11. *Area variation of the wear trace*



a)



b)

Fig. 12. *Mean depth variation of the wear trace*

4. Conclusions

From the experimental results presented in the previous chapter, the following conclusions can be drawn:

For F_3=60N force, were obtained profilograms with smoother protuberances, which proves a predominance of adhesion wear

For all materials, the greatest trace wear appears at a F_2=40N force.

The area belonging to the smallest wear trace appears in the composite material for cast.

The composite material for cast iron, code F_o, presents the best profilometric characteristics of the wear trace after applying pin-on-disk method.

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