Wear behavior of sintered steels obtained by gas-carburizing process

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The paper presents experimental research regarding the wear evolution of some steels obtained by GAS-CARBURIZING process function the composition of steel and compacting pressure. For the experimental work six mixtures of iron were used: Fe powder, Fe+0,2%Gr, Fe+1,5%Cu, Fe+3%Cu, Fe+1,5%Cu+0,2%Gr, Fe+3%Cu+0,2%Gr. The mixtures were pressed at three pressures 400, 500 respectively 600 MPa and the green compacts were gas carburizing for 90 minutes and sintered in the same cycle. To determine the wear behavior a CSM Instruments ball on disk tribometer was used.

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Keywords: Steels, Gas carburizing, Wear rate

1. Introduction

Sintered steels are widely used in industrial applications for components which work under application of sliding friction or contact. The most common applications are found in automotive industry and especially in parts such as gears and cams. For this reason, it is imperative to understand wear behavior of industrial components made from sintered materials.

In the automotive industry about 80% of parts are obtained by Powder Metallurgy (PM) technology and this is justified by their low production cost. Compared with other technologies (casting, forging) PM responds to a great goal, namely saving material and energy [1].

Gas carburizing is one of the most commonly used methods to obtain steels because it offers several advantages, such as: the ability to control the depth of carburizing, good working atmosphere control, possibility of automation, better productivity due to a shorter time than other methods of carburizing [2-4].

It is important that, the materials used for making gears have high wear resistance at the surface corroborated with higher toughness in the core. To obtain these properties required by gears and other similar parts one of the technique is GAS-CARBU-SINTERING (GCS) which consist in carburizing the green parts at a temperature of 910 ^oC, maintaining at the carburizing temperature and sintering at 1150 ^oC in the same thermal cycle [5-7]. Copper and its alloy such as bronze and brass are widely used in the sliding parts of machines (bearings, bushings) [8]. Studies concerning the wear behavior of mechanical and bimetal sintered parts were presented in other papers [9–12].

This study is focused on the influence of composition and compacting pressure on the wear behavior of some steels obtained by PM route.

2. Experimental

For the research electrolytic copper powder type SE from Pometon and conventional iron powders DWP 200 from Ductil SA Buzau and were used.

The powders properties are presented in Table 1-3.

Table 1. Properties of Cu powder.

<table>
<tr><th colspan="6">Physical properties</th></tr>
<tr><td>Properties</td><td colspan="2">Admitted Values</td><td colspan="3">Standard</td></tr>
<tr><td>Apparent density [g/cm^3]</td><td colspan="2">2.30-2.50</td><td colspan="3">SR EN 23923-1/98</td></tr>
<tr><td>Flow time [sec/50g]</td><td colspan="2">Max 40</td><td colspan="3">SR ISO 4490:2000</td></tr>
<tr><th colspan="6">Chemical composition</th></tr>
<tr><td>Element</td><td colspan="2">Admitted Values</td><td colspan="3">Standard</td></tr>
<tr><td>Cu</td><td colspan="2">Min. 99,7</td><td colspan="3">IL-08-0-94</td></tr>
<tr><td>O_2</td><td colspan="2">Max 0.15</td><td colspan="3">SREN 24491-4:1994</td></tr>
<tr><th colspan="6">Particle size distribution</th></tr>
<tr><td>Average grain size [µm]</td><td>>212</td><td>180-212</td><td>180-106</td><td>106-45</td><td><45</td></tr>
<tr><td>Cu</td><td>Min. 99,7</td><td>Max 2</td><td>25</td><td>45-65</td><td>rest</td></tr>
</table>

Table 2. Chemical properties of Fe powder.

CHEMICAL ELEMENT	MAX [%]
Carbon, C%	0,02
Sulfur, S%	0,015
Phosphorus, P%	0,02
Silicon, Si%	0,05
Manganese, Mn%	0,20
Oxygen, O%	0,22

Table 3. Physical properties of Fe powder.

PROPERTY	MIN	MAX
Hall Apparent Density [g/cm^3]	2,5	2,70
Hall Flow Rate [sec/50g]	31	33
Particle size distribution		
+212 μm (%)	---	0,1
-212/+160 μm (%)	---	15
-160/+100μm (%)	20	40
-100/+63μm (%)	20	40
Pan (%),	25	45
GREEN PROPERTIES		
Compressibility (at 600MPa-43,5tsi, 0,75% Acrawax) [g/cm^3]	6,95	---

The iron powder was homogenised with different concentrations of graphite and copper for 30 minutes as following: Fe+0,2%Gr, Fe+1,5%Cu, Fe+3%Cu, Fe+1,5%Cu+0,2%Gr, Fe+3%Cu+0,2%Gr. The homogenous mixtures and simple iron powder were unilateral pressed at three pressures (400, 500 and 600 MPa) and the green compacts were subjected to GCS treatment according to the diagram presented in Fig. 1.

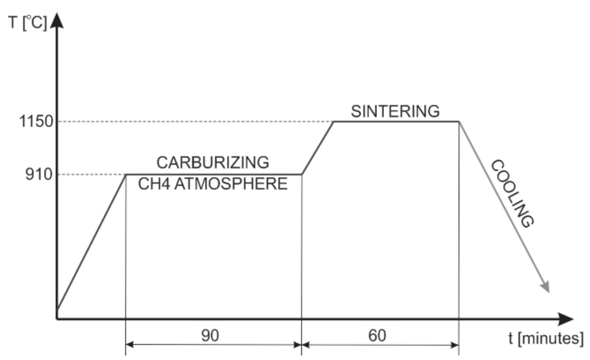


Fig. 1. GCS diagram.

For the tribological measurement a CSM INSTRUMENTS ball on disk tribometer was used, Fig. 2, with the following characteristics: force: 5 N; linear test; amplitude: 10mm; linear speed: 10cm/s; distance: 40 m; 100Cr6 ball with Φ=6 mm, temperature: 25 ^{o}C.

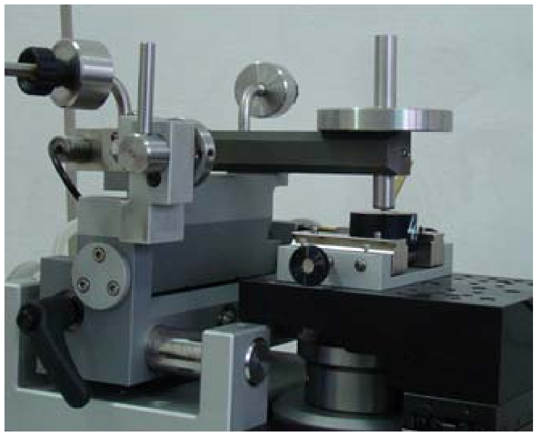


Fig. 2. Tribometer mechanism.

After friction coefficient was measured, in order to calculate the wear rate was measured the worn track section with a Surtronic 25+ profilometer, Fig. 3.

Fig. 3. Surtronic 25+ profilometer.

All the samples were transversely cutted and was measured the friction coefficient and the worn track section both in the core and in the marginal layer as it is shown in Fig. 4.

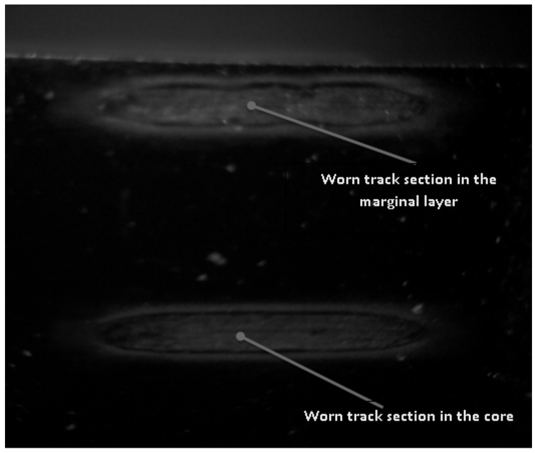
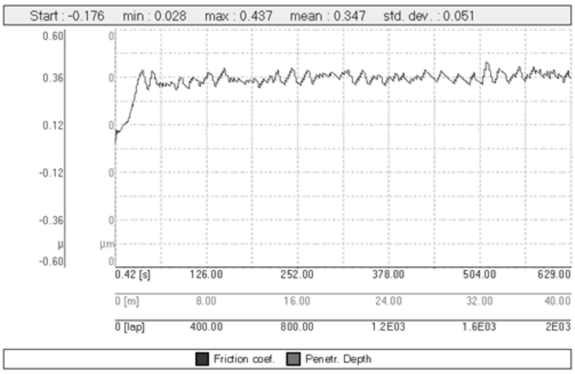


Fig. 4. Image of the worn track section.

3. Results and discussion

In Fig. 5-10 are presented the friction coefficients and the worn track section in the layer for the samples obtained from powders pressed at 400 MPa.



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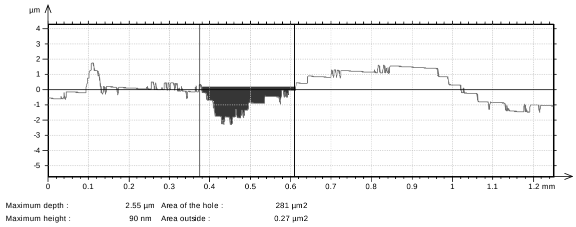

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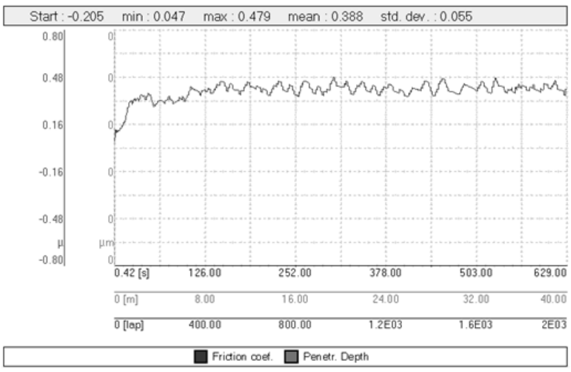
Fig. 5. a) Friction coefficient and b) worn track section for the samples obtained from iron powders.



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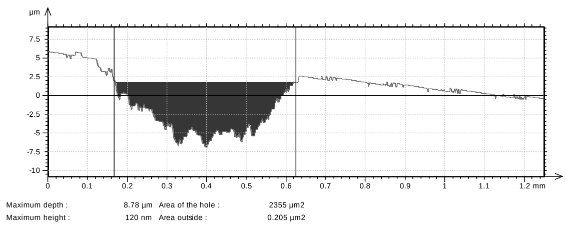
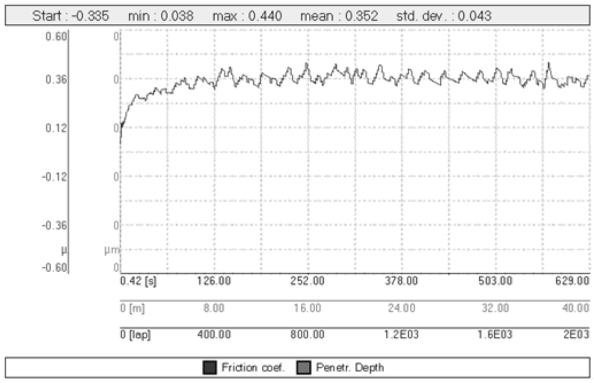


b)

Fig. 6. a) Friction coefficient and b) worn track section for the samples obtained from Fe+1,5%Cu powders.



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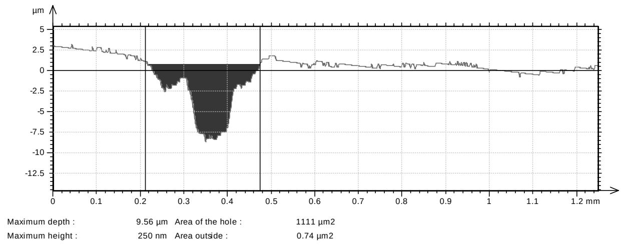
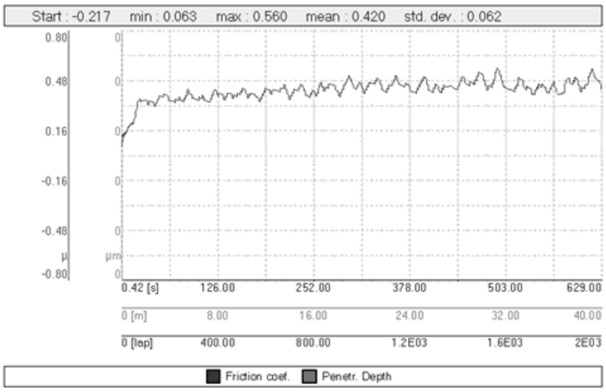


b)

Fig. 7. a) Friction coefficient and b) worn track section for the samples obtained from Fe+3%Cu powders.



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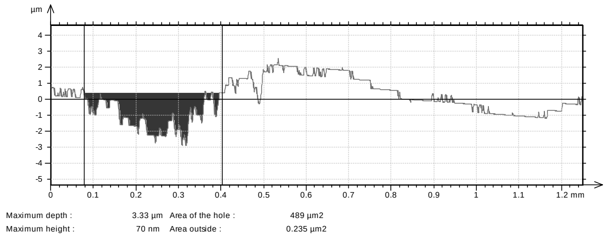

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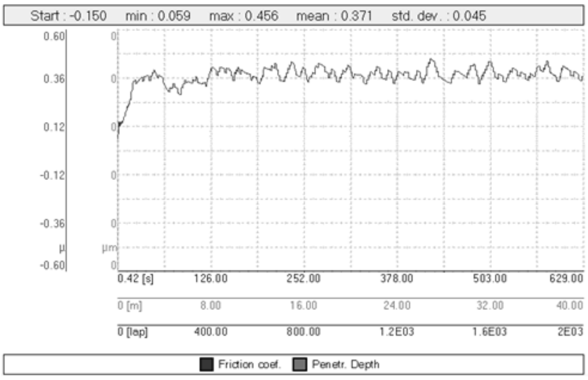
Fig. 8. a) Friction coefficient and b) worn track section for the samples obtained from Fe+0,2%Gr powders.



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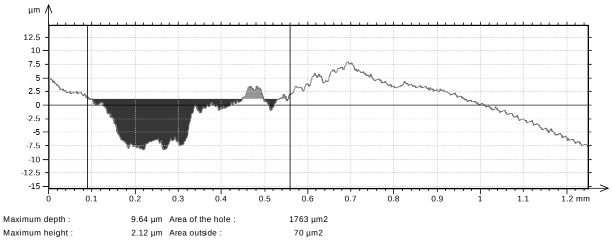

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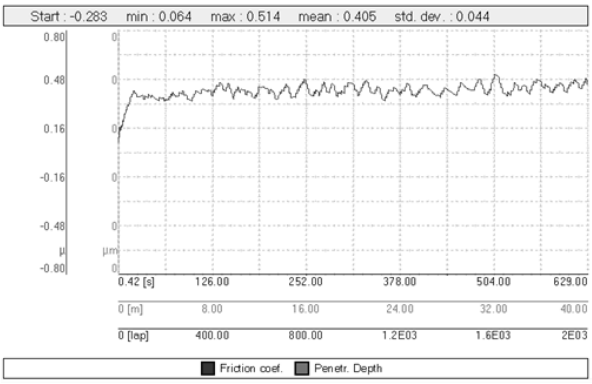
Fig. 9. a) Friction coefficient and b) worn track section for the samples obtained from Fe+0,2%Gr+1,5%Cu powders.



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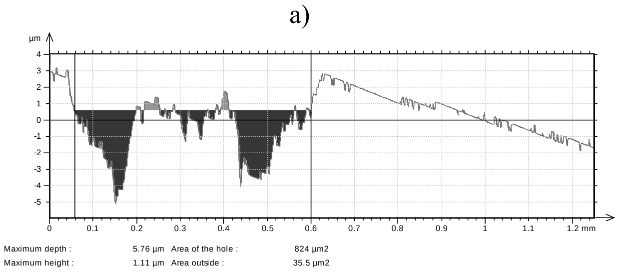
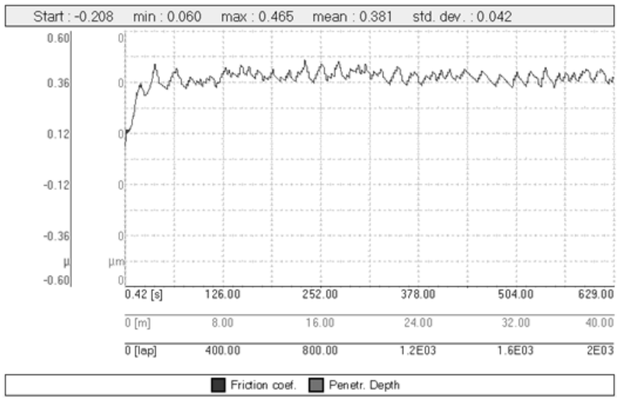


b)

Fig. 10. a) Friction coefficient and b) worn track section for the samples obtained from Fe+0,2%Gr+3%Cu powders.

In Fig. 11-16 are presented the friction coefficients and the worn track section in the core for the samples obtained from powders pressed at 400 MPa.



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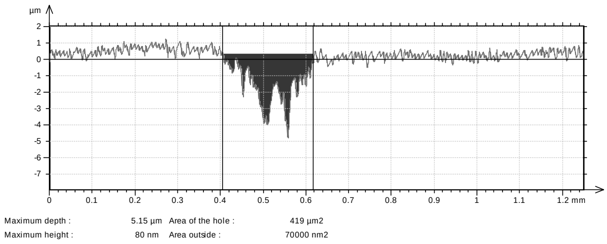

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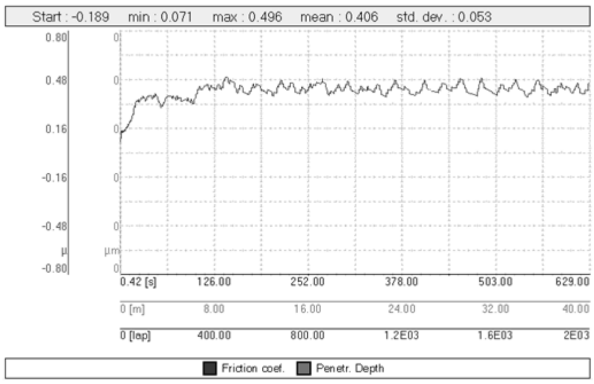
Fig. 11. a) Friction coefficient and b) worn track section for the samples obtained from iron powders.



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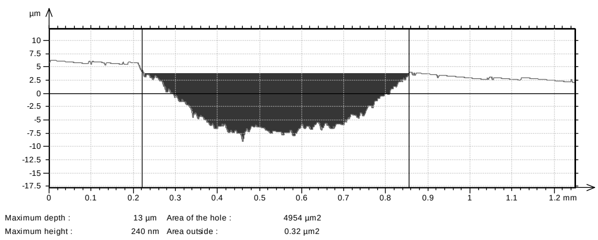

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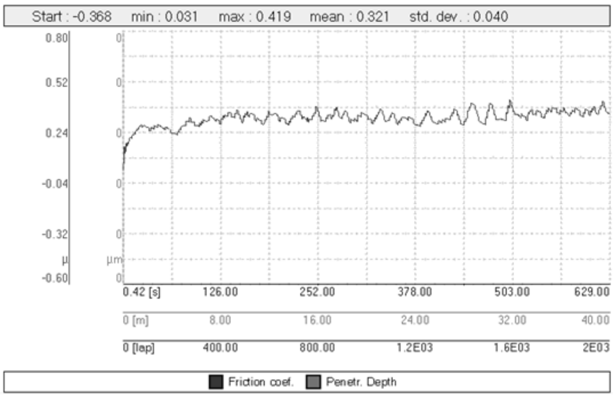
Fig. 12. a) Friction coefficient and b) worn track section for the samples obtained from Fe+1,5%Cu powders.



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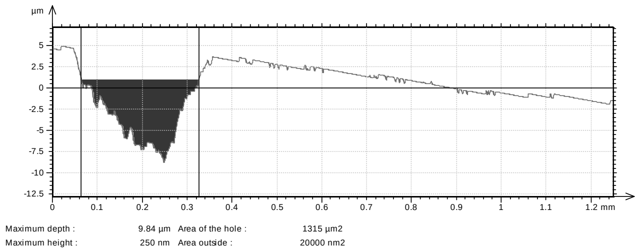

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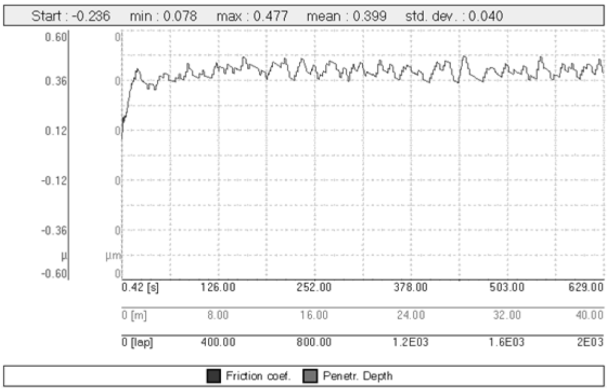
Fig. 13. a) Friction coefficient and b) worn track section for the samples obtained from Fe+3%Cu powders.



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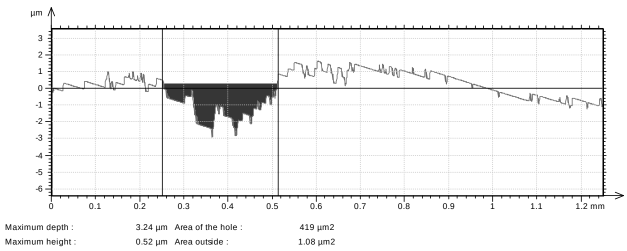
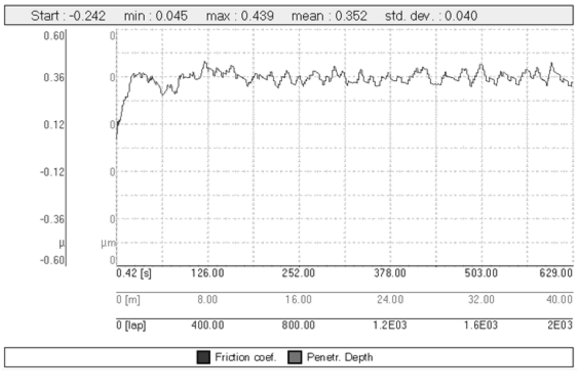


b)

Fig. 14. a) Friction coefficient and b) worn track section for the samples obtained from Fe+0,2%Gr powders.



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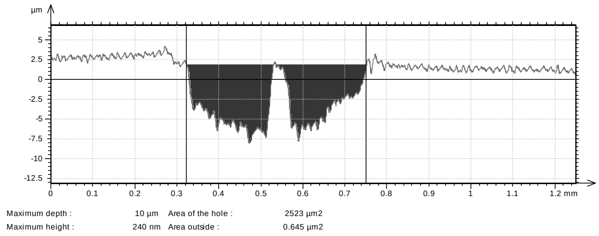

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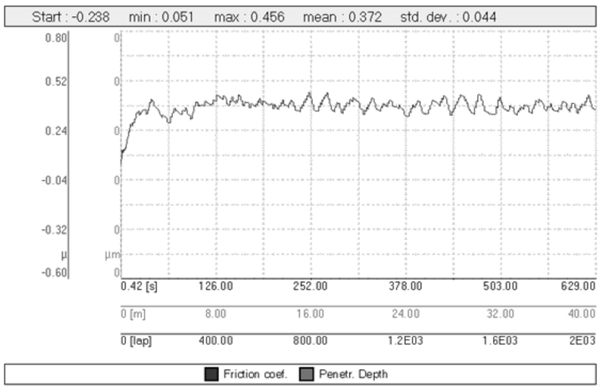
Fig. 15. a) Friction coefficient and b) worn track section for the samples obtained from Fe+0,2%Gr+1,5%Cu powders.



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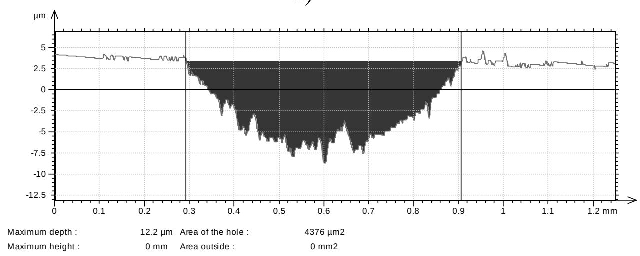

b)

Fig. 16. a) Friction coefficient and b) worn track section for the samples obtained from Fe+0,2%Gr+3%Cu powders.

Due to structural particularity materialized through porous sintered materials the evaluation of tribological behavior of sintered steels differs from concepts of conventional steels. Open pores are areas where waste is collected during wear testing and are loaded with this waste, so that, at the end of the wear test sintered material will behave similarly to wear counter-part material that is made of conventional steel.

Because of that friction coefficent values are not liniar and are influenced by compacting pressure. Also there are cases in which friction coefficients values are higher in the layer comparatively with the core. Coroborating the friction coefficients values with values of worn track sections, in Fig. 17 is presented the evolution of wear rate function the composition and compaction pressure.

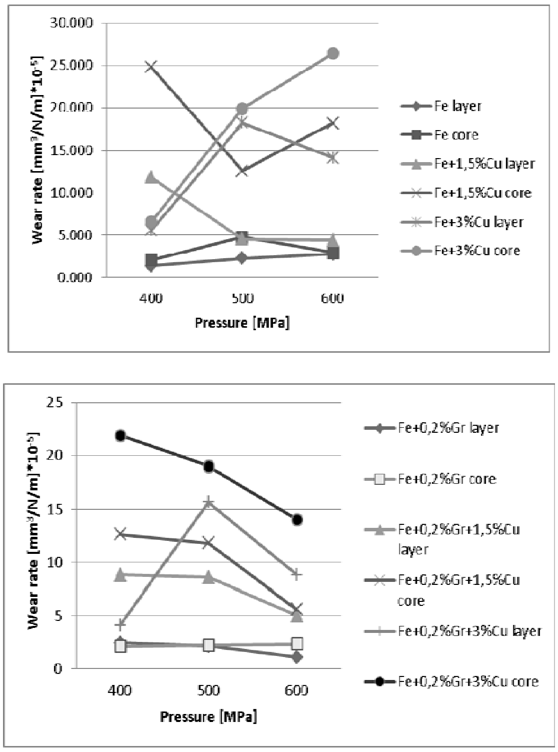

Fig. 17. Evolution of wear rate.

4. Conclusions

According to experimental results there are some conclusions as following:

- friction coefficients are influenced by pressure and composition of the steels. Not all the values of them are higher in the layer comparatively with the core. For example the best value of the friction coefficient was attained in the core of the sample Fe+0,2%Gr pressed at 500 MPa (μ=0.272);

- good values of worn track section were attained for the samples without copper;

- to satisfy the conditions of automotive wear parts, the wear rate it's important to have lower values in the layer. In fig. 17 it can be seen that al the samples have lower values of wear rate in the layer comparative with the core. The best value of the wear rate was attained for the sample Fe+0,2% Gr pressed at 600 MPa (1,09 [mm3/N/m]).

- the samples with copper have higher values of wear rate than the other without copper.

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