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The tribological behavior of some steel samples prepared by powder metallurgy sintered in microwave field

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Abstract. The objective of this research is to study the influence of the sample composition on the wear testing for some steel samples elaborated by powder metallurgy technology. For obtaining the steels there were used iron powders and graphite powders. The powders were homogenized in a high energy ball mill Pulverisette 6, cold compacted and then sintered using a Muegge type microwave heating installation. The influence of the samples' composition on the wear parameters is studied using both a tribometer and a profilometer.

Introduction

Nowadays, the requirement for friction systems that operate in hard conditions are growing constantly [1]. Steels, considered to be the most important material in engineering, are widely used and applied, but in atmosphere conditions it oxidates [2,3]. Thus, powders addition are used in order to obtain better tribological properties in steels [4,5]. So, recent research proved that high wear resistance was obtained in steels, by incorporating powders additions, together with the improvement of hardness [6,7]

The objective of the current research is to study the influence of the sintering technique on the tribological behavior of the samples prepared through the powder metallurgy (P.M.) route.

Materials and experimental procedure

The samples were prepared using a P.M. specific route, the two starting materials used in the research were iron and graphite powders and the ratios between them were the following: 99,5% iron/0,5% graphite; 99% iron/1% graphite and 98,5% iron/1,5% graphite.

The powders were homogenized in a high energy ball mill, cold compacted and sintered using a Muegge type microwave heating installation (figure 1).

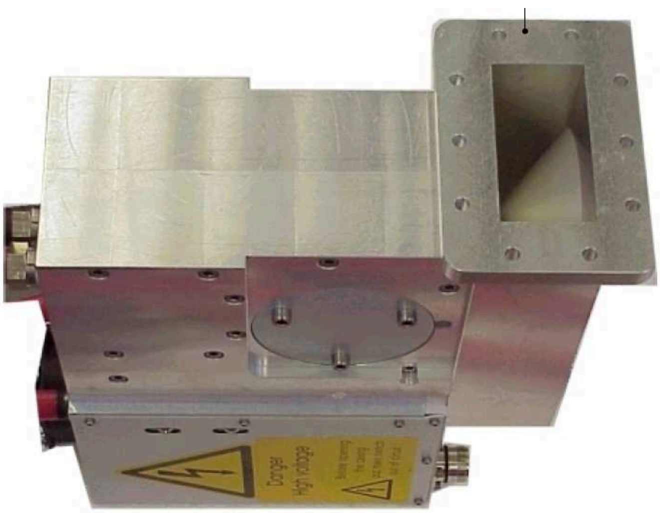

Fig. 1. The microwave heating installation

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The microwave sintering parameters are presented in table below (tabel 1).

Table 1. The microwave sintering parameters

Sample	Compacting pressure, [MPa]	Temperature, [°C]	Maintaining time, [sec]
99,5%Fe/0,5%C	500	1100	120
99%Fe/1%C			
98,5%Fe/1,5%C			

After that the samples were wear tested using a pin-on-disk tribometer from CSM Instruments in order to determine the evolution of the friction coefficient in time. Also, with a Surtronic 25 profilometer there were determined the worn track depth, the worn track surface and the wear rates of the samples.

Results and Discussions

The results of the wear testing performed on the samples prepared to the P.M. itinerary are presented in table 2.

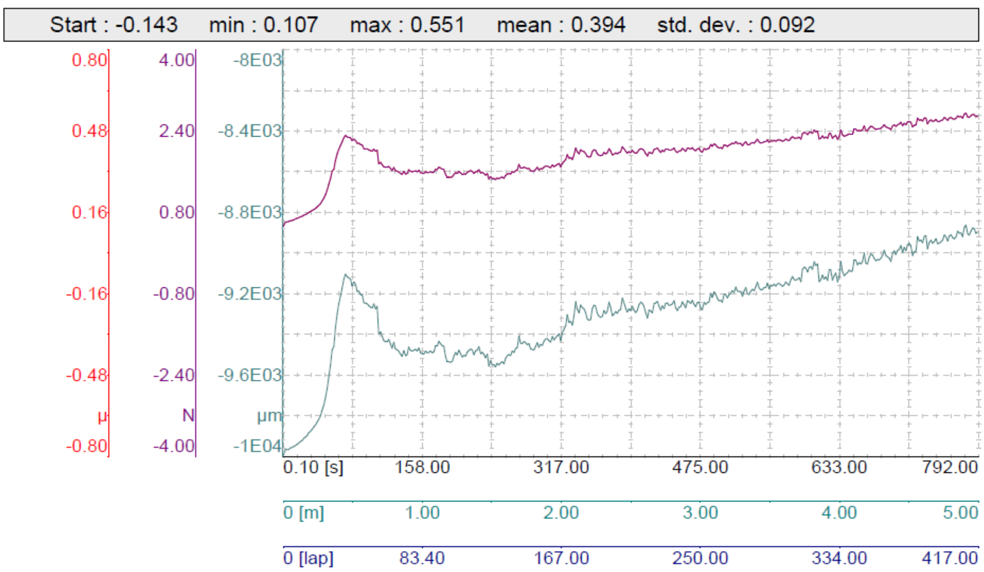
Table 2. Parameters of the worn track profiles of the samples

Sample	Friction coefficient [μ]	Worn track depth [μm]	Worn track surface [μm^2]	Wear rate [mm^3/Nm]
99,5%Fe/0,5%C	0,556	3,21	459	$1{,}101\cdot10^{-4}$
99%Fe/1%C	0,444	3,44	182	$4{,}365\cdot10^{-5}$
98,5%Fe/1,5%C	0,394	3,03	125	$2{,}998\cdot10^{-5}$

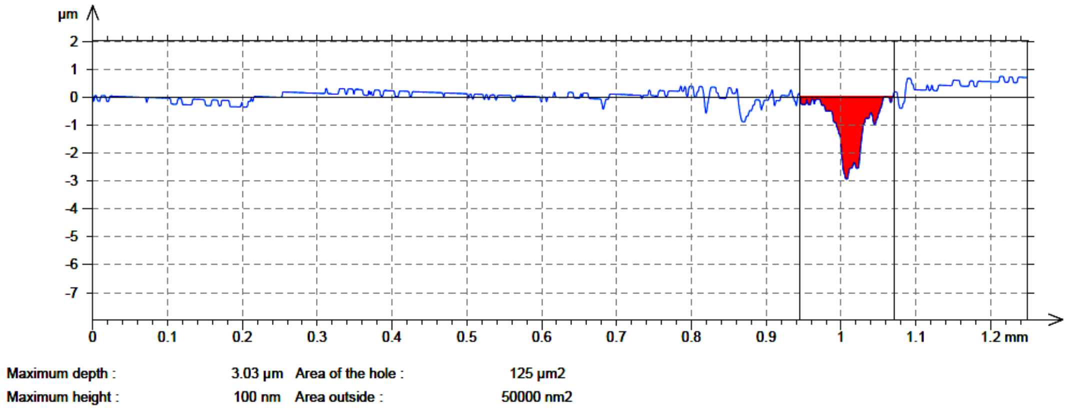
By the *worn track depth* point of view, the smallest value (3,03 μm) is obtained for the sample 98,5%Fe/1,5%C, while the biggest value (3,44 μm) is obtained for the sample 99,5%Fe/0,5%C. More, the smaller *worn track surface* (125 μm^2) was obtained for the sample 98,5%Fe/1,5%C, while the biggest worn track surface (459 μm^2) was obtained for the sample 99,5%Fe/0,5%C.

Regarding the *wear rate* obtained for each sample, the best value was obtained for the sample 98,5%Fe/1,5%C, while the worst value is obtained for the sample 99,5%Fe/0,5%C.

In figure 2 there are presented the evolution of the friction coefficient (figure 2a) and the profile of the worn track (figure 2b) for the sample 98,5%Fe/1,5%C.



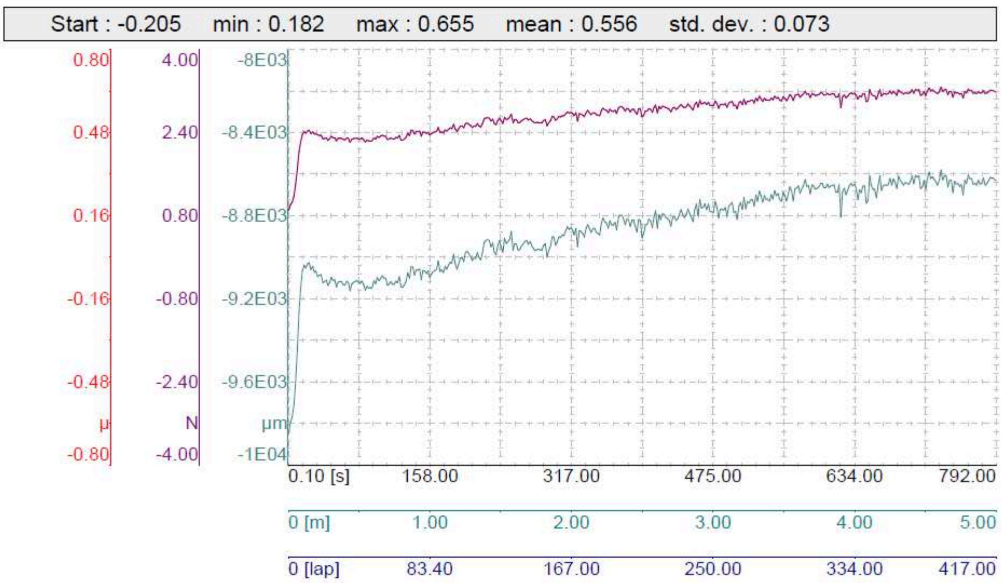
a.



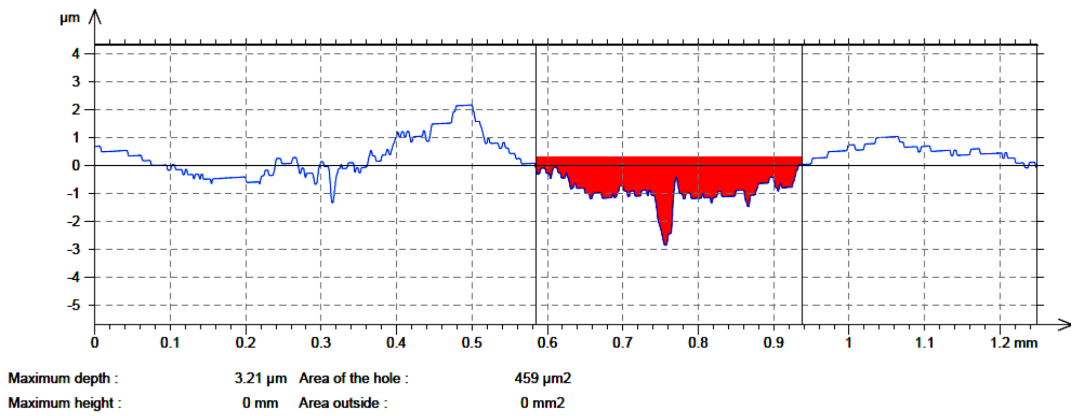
b.

Fig. 2. Wear testing results for the sample 98,5%Fe/1,5%C:
a. evolution of the friction coefficient; b. profile of the worn track

In figure 3 there are presented the evolution of the friction coefficient (figure 3a) and the profile of the worn track (figure 3b) for the sample 99,5%Fe/0,5%C.



a.



b.

Fig. 3. Wear testing results for the sample 99,5%Fe/0,5%C:
a. evolution of the friction coefficient; b. profile of the worn track

Until the temperature of 500°C, the temperature evolution is constant, with a 10°C/minute heating gradient. After the 500°C temperature, due to the transformations from the structure of the nacelle material, it became powerful microwave absorbing, which led to the increase of the heating gradient with 5°C/minute, thus becoming 15°C/minute.

Conclusions

The steels prepared through a P.M. specific route showed a good wear behaviour, being obtained good wear parameters.

The sintering in microwave field technique provided the main advantage of the short sintering time (120 seconds), compared to the classic sintering technique.

The general assessment of the wear behaviour of the steel samples is that the sintering in microwave field technology delivers the advantage of the good wear behaviour of the processed materials, with no debris pulled out of the worn surface.

Overall, the best wear parameters were obtained for the sample 98,5%Fe/1,5%C, while the worst wear parameters were obtained for the sample 99,5%Fe/0,5%C.

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