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ASSESSMENT OF WEAR AND TRIBOLOGICAL BEHAVIOR OF SPARK PLASMA SINTERED TI

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Abstract: *The paper presents an assessment of tribological behavior in terms of coefficient of friction (COF), friction force and wear rate of spark plasma sintered titanium. Spark plasma sintering is a relatively novel sintering technique consisting in a pulse DC current that directly passes through the die and the powder compact in case of conductive samples. The internally generated heat facilitates a high heating rate implying a very fast sintering process in contrast to the conventional hot pressing, where the heat is generated by external factors. The SPS process was applied for two different temperatures 1000^{0}C and 1100^{0}C and two different values for the dwell time 10' and 20'. The ball-on-disc wear tests were employed to analyze the wear rate for all SPS samples in order to check the influence of sintering temperature and dwell time.*
Key words: *coefficient of friction, wear rate, spark plasma sintering, titanium*

1. INTRODUCTION

The interest in the tribological behavior of titanium alloys was fuelled up due to its wide applications in aerospace, medicine and chemical industry. Titanium known for high corrosion resistance and a very good specific strength proved also to be a feasible option for osseous surgery, implants due to its biocompatibility. However, Long &Rack pointed out the tendency of titanium to gall and seize in applications where relative sliding between different surfaces was conducted (Long & Rack, 2001; Lee et al., 2008). Extensive research work has been done (Kustas & Misra, 1992; Waterhouse & Iwabuchi, 1985; Molinari et al. 1997) especially focused on titanium's fretting behavior, galling and sliding wear behavior. Few additional studies have been performed in order to analyze the influence of elaboration technology of the titanium versus the tribological behavior and wear rate. Wear and corrosion resistance of biometallic materials are two very important properties that can make the difference in terms of implant surgery (Parks & Lakes, 1992). A comparison between stainless steel and Ti–6Al–4V alloys has been carried out (Choubey et al, 2004) and the results revealed that titanium alloys have a lower wear resistance than stainless steels. In this case it was considered that the main wear mechanism was the plastic deformation corroborated with mass transfer. Spark plasma sintering (SPS) has been developed for the fabrication of ceramics and metallic materials but recently is used also for the fabrication of Ti. This specific technique allows rapid due to the direct heating of the powder and dies using pulsed current electrification. The SPS technique has a specific feature that consists in heating the sample both from outside and inside and significantly increases mass transfer (Ahmad & Sueyoshi, 2009).

Therefore, the research work presented in this paper was mainly focused on the influence of the spark plasma sintering process parameters on the tribological behavior and wear rate of the titanium in dry sliding tests against 100Cr6 hardened steel balls.

2. MATERIALS AND EXPERIMENTAL PROCEDURE

The titanium samples were processed from titanium powder with 100μm particles via spark plasma sintering technology at (1000-1100)^{0}C with a dwell time of 10 and 20 min for each temperature. The four samples were pressed with a 7kN load and the heating rate employed was 10^{0}C /min.

The tribological behavior and the wear rate assessment has been performed on a TRB 01-0254 tribometer (CSM Instruments SA) with a linear reciprocating module, equipped with a data acquisition software, InstrumX, version 2.5A.

Fig. 1 Tribometer TRB 01-254

The coefficient of friction and the friction force were determined using ball-on-disc dry sliding tests. The balls were made of DIN 100Cr6 hardened steel, 60-64 HRc, Ra=3.2μm and a 6 mm diameter. The titanium samples acted as static counterpiece discs. The friction parameters used were: normal load 2 N, sliding linear velocity = 1 cm/s, room temperature 23^{0}C, testing time =788 s which means approximately 5 m length for the distance elapsed.
The wear rate was measured using a profilometer Surtronic 25, from Taylor Hobson Precision equipped with Talyprofile Silver software for data acquisition.

3. RESULTS AND DISCUSSIONS

The coefficient of friction COF for all the titanium samples as well as the friction force was determined and the results are presented in tabel 1. The variation of the coefficient of friction with the SPS parameters is presented in figure 1

	A	B	C	D
COF μ	0.515	0.493	0.524	0.566
Friction force Ft [N]	0.94	0.92	0.95	0.84

Table 1. COF and friction force Ft for different SPS Ti samples

A- sample obtained by SPS at T=1000^{0}C, and t=20 min
B- sample obtained by SPS at T=1000^{0}C, and t=10 min
C- sample obtained by SPS at T=1100^{0}C, and t=20 min

D- sample obtained by SPS at T=1100^{0}C, and t=10 min

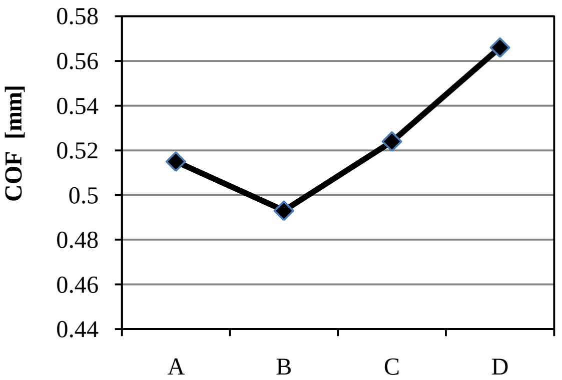

Fig. 2. Variation of coefficient of friction

From table 1 and figure 2 it can be appreciated that the temperature as well as the dwell time during the SPS technology does not have a significant influence on the COF and the friction force. In figure 3 is presented the profile of the wear track in cross-section determined as an area.

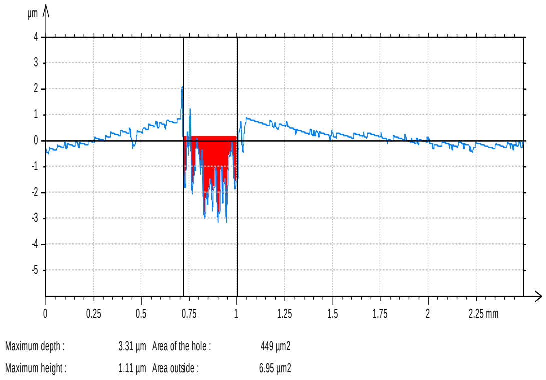

Fig. 3. Wear track depth and area for one of the three different cross-sections regarding the A sample

The same measurements have been performed for all four samples A, B, C and D.

In figure 3 is presented the profile of the wear track in cross-section determined as an area. The wear rate for all Ti samples is showed in figure 4.

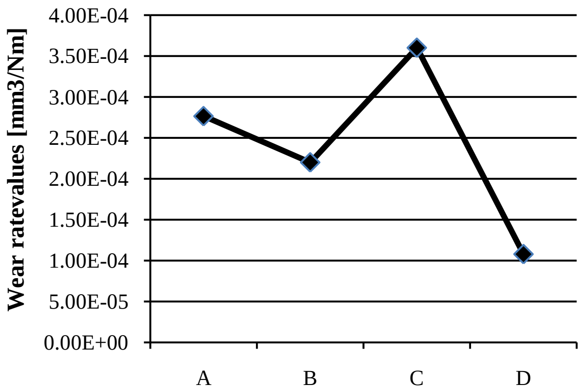

Fig.4. Variation of wear rate for the Ti samples

According to figure 4 it is obvious that lowest wear rate has been attained when the D sample was tested, which can lead us to the conclusion that the most appropriate SPS parameters were T=1100^{0}C and dwell time t=10 min.

Figure 5 presents the microstructure of the wear track with for sample D with 50x magnifying. When comparing sample D with the lowest wear rate and sample B with the second lowest wear rate it can be concluded that that the temperature was the main factor that affected the wear rate because the dwell time was maintained constant.

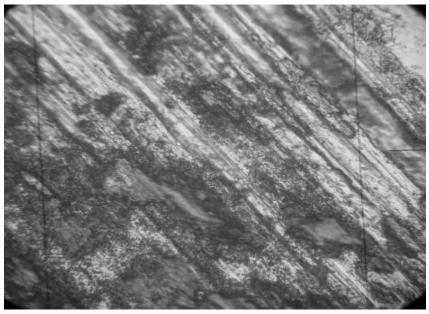

Fig. 5. Wear track pattern of Ti sample D 50X.

The wear pattern shows the small regular wear grooves on the ball track but also some particles of ball material (dark spots) that seemed to adhere to the surface. The surface is rather flat comparing to other samples and this is confirmed by the low wear rate presented in figure 4.

4. CONCLUSIONS

1. The SPS parameters (temperature and dwell time) do not affect significantly the coefficient of friction and the friction force. The B sample presented the lowest coefficient of friction during the tribological tests..
2. The lowest wear rate was obtained for the D sample i.e. for SPS at T=1100^0 C and a dwell time of 10 min which seemed to be most appropriate parameters for sintering if wear rate is concerned.

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