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THE INFLUENCE OF THE TRIBOLOGICAL TESTING CONDITIONS ON THE WEAR RATE FOR SOME TITANIUM PLATES PROCESSED BY SPARK PLASMA SINTERING ROUTE

Adrian Olei[1], Gabriel Benga[1], Iulian Stefan[1]
[1] University of Craiova, Faculty of Mechanics, Department of IMST, Drobeta Turnu Severin, ROMANIA
adrian_olei@yahoo.com, gabrielbenga@yahoo.com, stefan_iuly@yahoo.com

Abstract: *The paper presents the experimental results obtained during the tribological tests developed on Ti plates processed by SPS route. The material used in the current research is micrometric Ti powder (<150µm). The Ti plates are processed by SPS at (1000-1100)°C and (10-20) min. dwell time. The wear rate and wear tracks' morphology are studied vs. the sintering route parameters as well as the wear testing conditions (stainless steel and sapphire testing ball, normal load=2N, sliding speed=1cm/s).*
Keywords: *powder metallurgy, titnium, spark plasma sintering, tribology*

1. INTRODUCTION

Modern medicine has made advances by improving the biomedical implants as the population ages and needs implants. Titanium and its alloys, introduced in the early 1950s, have been used as materials for biomedical implants, due to their proved biocompatibility and physical-chemical and mechanical properties related to these kind of applications [1-3]: replacement of hard tissues in devices such as artificial hip joints, total knee replacement and dental implants.
One of the main mechanical performances requested for these applications is the wear strength. Experimental data on Ti wear strength provide information about different processing technologies for Ti implants able to perform low wear rates. For example, Masmoudi et al. [4] used the powder metallurgy (PM) technology to obtain TiO_2 passive films at the Ti and Ti6Al4V surface. These films are lubricating and, by consequence, provide low wear rates about 1.7-2.3x10^{-4}mm^3/Nm range.
Other researchers [5] have applied the pasivation technology on Ti-5Al-4V and Ti-6Al-3,5Fe alloys in order to obtain a multifilm structure. The results were confirmed by the mechanical point of view that is the model is realised by two films deposition (one interior which acts as a barrier and has a high compactity and one exterior, porous), and thus the technology facilitates the mineral ions incorporation and improves the wear resistance.
In this paper, the spark plasma sintering route is analyzed by the influence on the wear strength point of view.

2. MATERIALS AND EXPERIMENTAL PROCEDURE

The material used in the research is micrometric Ti powder (<150µm). The Ti powder is water atomized and the particles are irregular-shaped. Figure 1 presents a SEM image of the Ti micrometric powder used in the research.
SPS technology is a new PM route to obtain high performance PM materials due to the advantages offered by lower sintering temperatures and dwell times as compared to the classic sintering parameters (see figure 2).

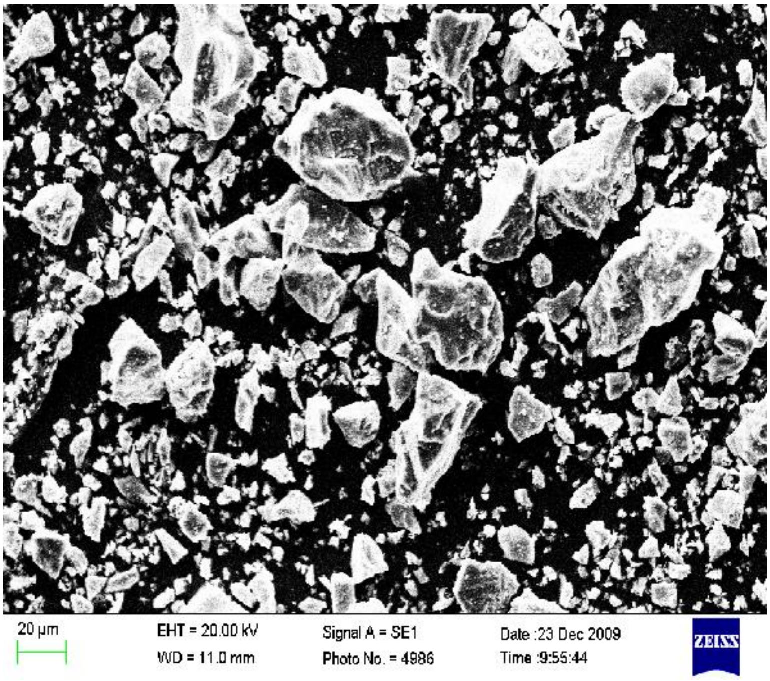


Figure 1: SEM image of the Ti powder particles

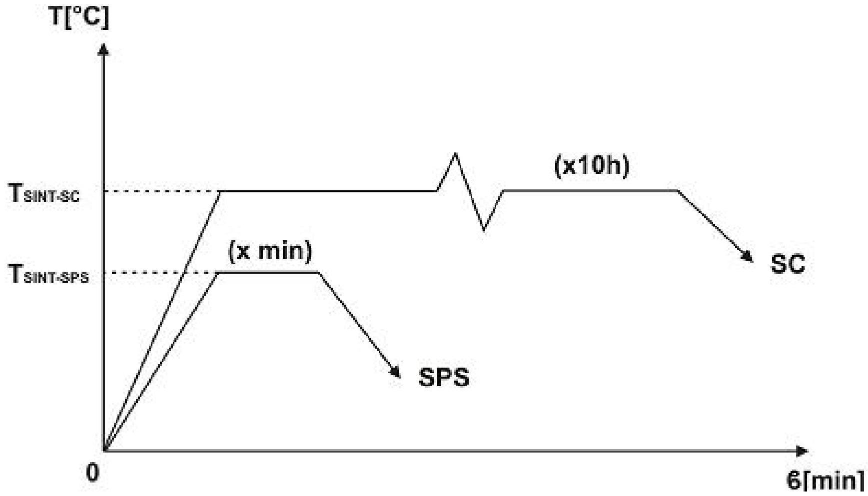


Figure 2: Comparative representation for the SPS with classical sintering parameters

For this research the SPS treatment has been developed in vacuum at 1000^0C, respectively 1100^0C, the dwell times for each temperature being 10 min. and 20 min. The heating rate was for 10^0C/min. and the punches load was 7kN.

Table 1: The parameters of the SPS process

Sample number	Sintering route	Sintering parameters	
		Temperature	Maintaining time
1	SPS	1000	20
2		1000	10
3		1100	20
4		1100	10

The wear tests have been performed on a TRB 01-02541 tribometer (CSM Instruments SA, Switzerland – figure 3), with linear reciprocating module, equipped by InstrumX software. The parameters determined by the tribometer are the friction coefficient, μ, using ball on disc friction couple, and the wear rate. The friction parameters are: sliding linear velocity = 1cm/s; room temperature (RT) = 23^0C, room humidity = 30%; the normal load is 2N. These parameters were chosen according to the literature [4, 6] in order to compare the experimental results obtained by this research.

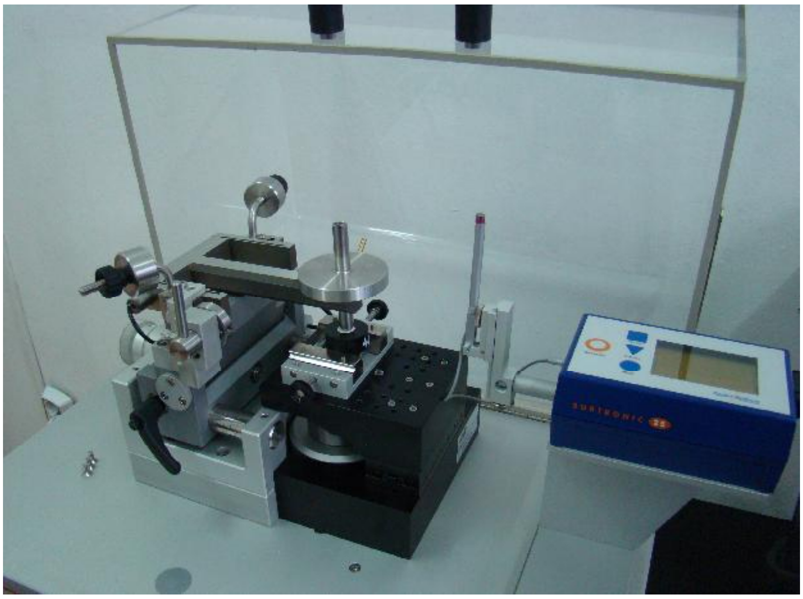


Figure 3: CSM Instruments tribometer

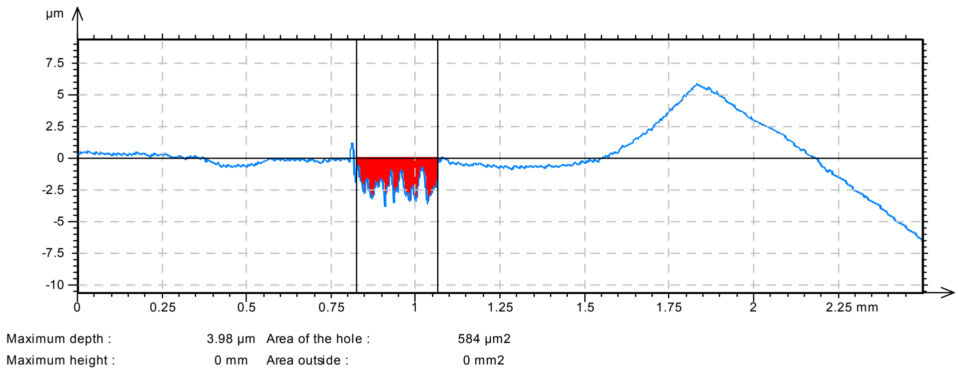
3. RESULTS AND DISCUSSIONS

Tabel 2 presents the results obtained during the wear tests.

Table 2: Results obtained for the Ti samples sintered through SPS

Sintering technology	T_1/τ_2 [°C/min]	Friction coefficient, μ		Wear rate, ω [mm^3/Nm]		Worn track depth, h [μm]	
		Steel	Sapphire	Steel	Sapphire	Steel	Sapphire
SPS	1000/10	0,49	0,49	$2{,}2 \cdot 10^{-4}$	$5{,}759 \cdot 10^{-4}$	3,17	5,07
	1000/20	0,52	0,43	$2{,}764 \cdot 10^{-4}$	$1{,}709 \cdot 10^{-3}$	3,18	5,36
	1100/10	0,57	0,74	$1{,}019 \cdot 10^{-4}$	$3{,}022 \cdot 10^{-4}$	2,6	2,98
	1100/20	0,52	0,27	$3{,}603 \cdot 10^{-4}$	$2{,}814 \cdot 10^{-4}$	4,12	3,47

The lowest wear rate is obtained for the Ti sample processed at (1100°/10'), tested with the steel ball for which the wear track has a 2,6 μm depth. The morphology of the worn track for this sample and the coefficient of friction are presented in figures 4 and 5.



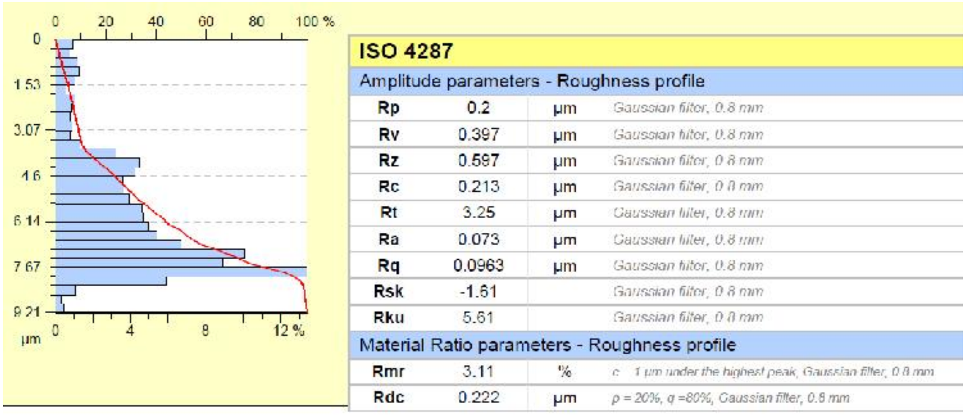


Figure 4: The morphology of the worn track for the sample processed at 1100°/10'

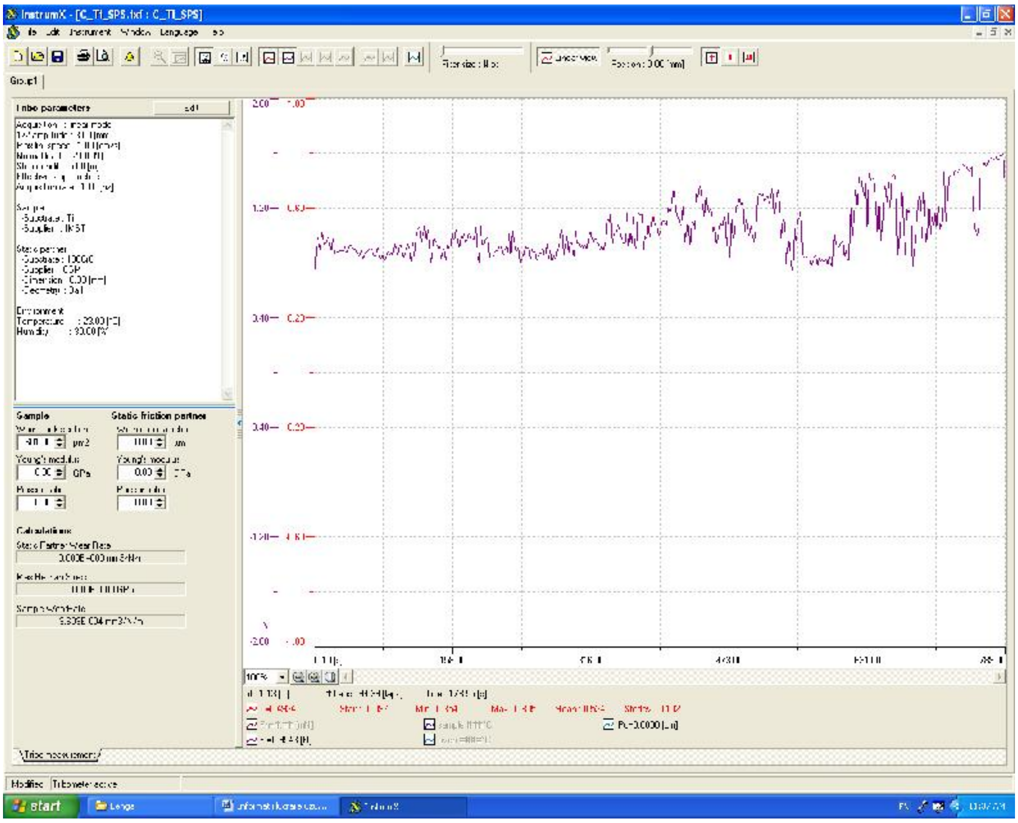
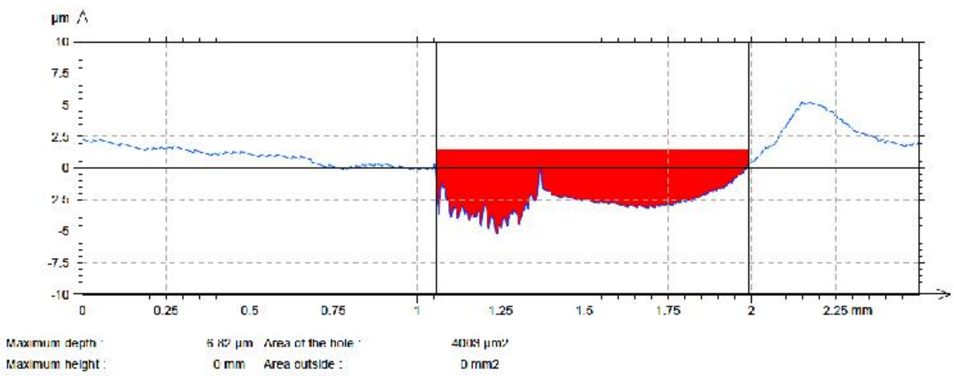


Figure 5: Variation of the friction coefficient tested with the steel ball for the sample processed at 1100°/10'

The highest wear rate is obtained for the Ti sample processed at 1000°/20 min., tested with sapphire ball. The sample has a 5,36 µm wear track depth. The morphology of the worn track for this sample and the coefficient of friction are presented in figures 6 and 7.



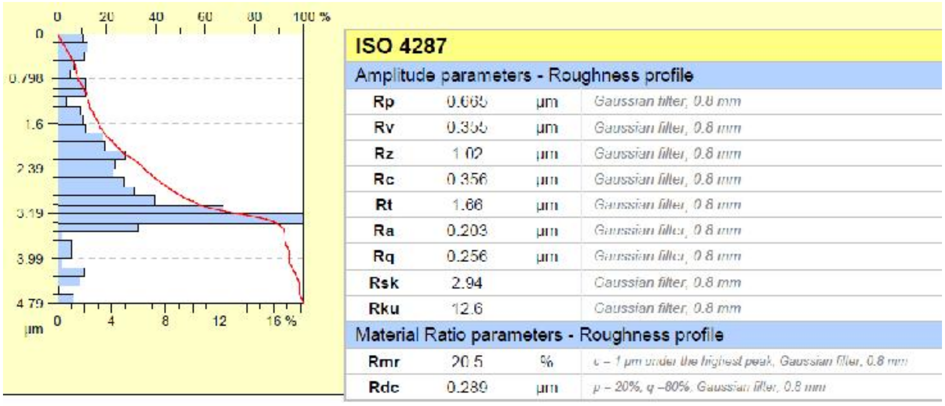


Figure 6: The morphology of the worn track for the sample processed at 1000°/20’

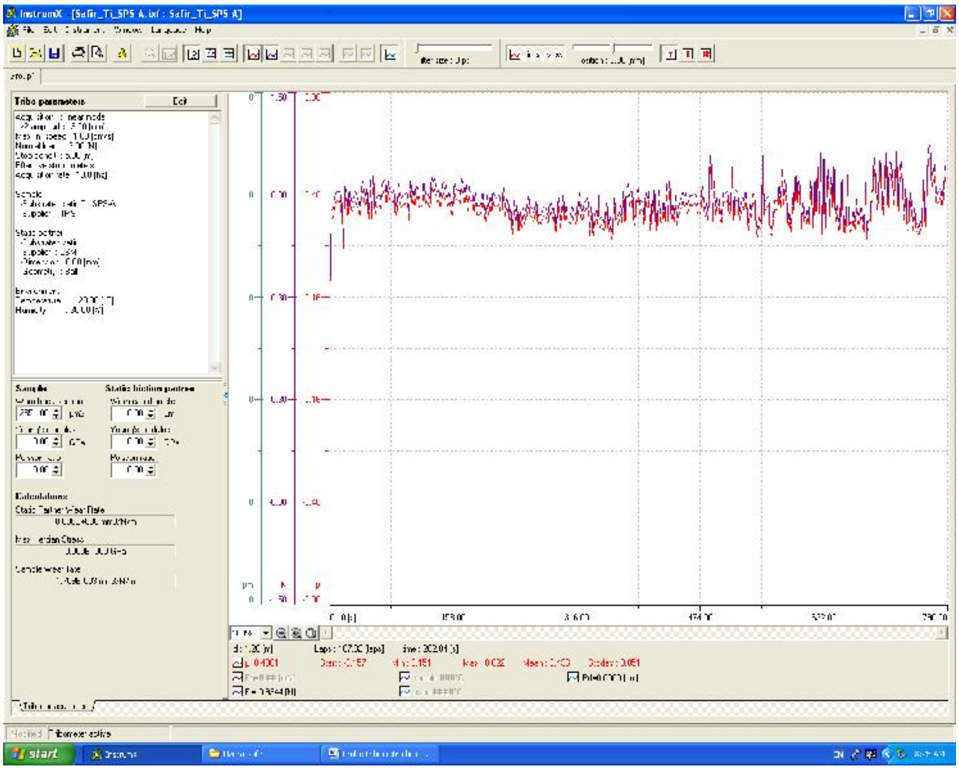


Figure 7: Variation of the friction coefficient for the sample processed at 1000°/20’

4. CONCLUSIONS

The most important issue regarding the wear behavior of PM Ti implants is the influence of the wear debris on the human health. These debris could be metallic (from the steel ball) or ceramic (from the sapphire ball) and can remain in the human body along the patient life and may cause/or not the hard/soft tissue inflammation nearby the implant place.

In conditions of the testing with the steel ball, the lowest coefficient of friction is obtained for the sample processed at 1100º/10 min, while the highest coefficient of friction is obtained for the 1100º/20 min.

In conditions of the testing with the sapphire ball, the lowest coefficient of friction is obtained for the sample processed at 1000º/10 min, while the highest coefficient of friction is obtained for the 1000º/20 min.

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