SOME ASPECTS REGARDING THE WEAR BEHAVIOR OF NEW BIOMATERIALS

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Abstract: Currently no treatment to repair the cartilage is really available, except for an implant joint (arthroplasty).The discrepancies between the lifetimes in vivo and ex vivo joint implants are mainly attributed to the ex vivo test conditions insufficiently realistic vis-à-vis mechanical features and physical, chemical biological environment. Proper selection of materials for protheses and devices used in implant surgery is particularly critical and represents a challenge. Light, strong and totally biocompatible, titanium is one of the few materials that naturally match the requirements for implantation in humans. In this paper, it is presented the methodology used to test the friction proprieties of a new Ti12Mo alloy in biological conditions.

Keywords: titanium alloys, physiological serum, profilometer, scanning electron microscopy, friction tests

1. INTRODUCTION

The human body is the most complex biological existing building, which encompasses many systems. The human systems is so self-adjustable and adaptable to environmental changes being multifunctional too. Engineers, biologists and physicians face a special problem when they confront to accomplish new procedures (methods), components and systems to replace an injured part for any illness or trauma. Proper selection of materials for prostheses and devices used in implant surgery is particularly critical and represents a challenge.

2. SAMPLES PREPARATION

Every year more than 1,000 tons of titanium devices of various design and functions are implanted throughout the world. Applications for joint replacement

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continue to increase with increasing the life of the people that are prone to accidents due to more extreme sports or traffic accidents. The groups of biomaterials used in prothetic surgery are: metals and metal alloys, ceramic materials, polymers and plastics, composite materials and materials of animal origin.

Light, strong and totally biocompatible, titanium is one of the few materials that naturally match the requirements for implantation in humans. It was shown that titanium is completely resistant to biological environment, which is due to the oxide film, formed instantly at air contact with the natural environment and is very sticky, insoluble and non-transport of chemical, preventing reaction with tissue. [1]

Titanium is lighter than stainless steel, although it is tougher than this. Moreover, it has a density similar to bone, also the elastic modulus and coefficient of thermal expansion as well. The properties of titanium implant reduces the likelihood that the biological environment to yield. Titanium is susceptible to external interference, because it is not magnetic and can be processed relatively easily. [2.3]

For this study we chose to test a new titanium alloy, Ti12Mo. It was developed in the laboratory " Laboratoire Sciences Chimiques de Rennes Equipe Chimie-Métallurgie (INSA de Rennes). [5]

Samples were machined in cylindrical form, having a 12mm diameter and 3 mm in thickness. (Fig. 1) Their surface was polished to achieve the appearance of "mirror".

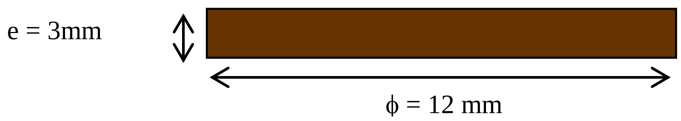


Fig. 1 Samples dimensions

3. TESTS METHODOLOGY

3.1. Samples characterization

In order to obtain data required to interpret the effects of friction on surface integrity studied were determined the physio-mechanical characteristics of the samples before the testing of the surface: wetting capacity (contact angle), roughness. Surface morphology was also recorded before application.

3.1.1. Measurements of contact angle

To characterize properties of hydrophilic surfaces, the contact angle was determined using the tensile "drop" method with a goniometer shown in Figure 2. Results are listed in Table 1.

3.1.2. The morphology of rubbing surfaces

Using a scanning electronic microscope, friction surface appearance was recorded before testing, as shown in Figure 3.

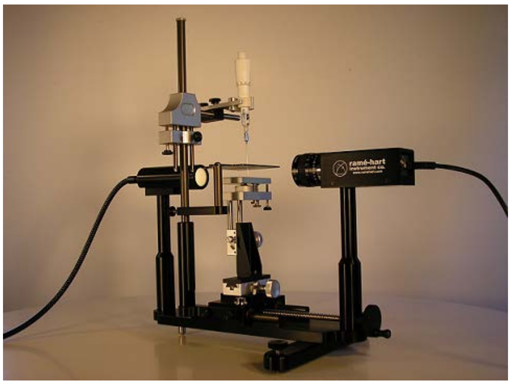
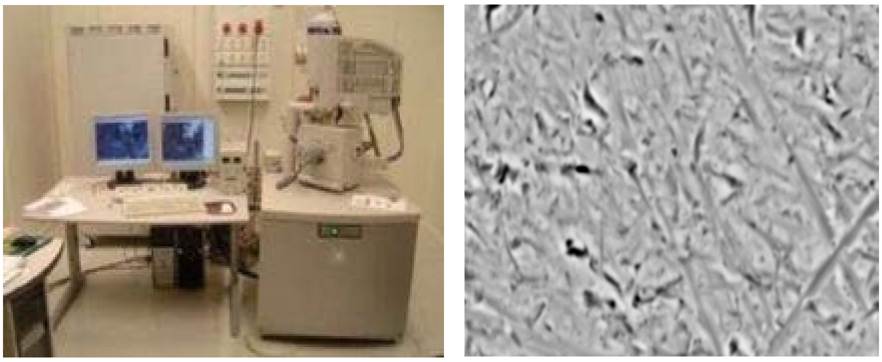


Fig. 2 Goniometer for the measurement of contact angle



a b

Fig. 3 a) scanning electron microscopy **b)** the morphology of the surface before of performing the friction test

3.1.3. Measurement Rugosities

To determine the roughness Ti12Mo alloy sample that was subjected to friction test was used the device Altisurf 500 (Figure 4). The results are presented in Table 1.

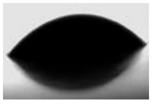
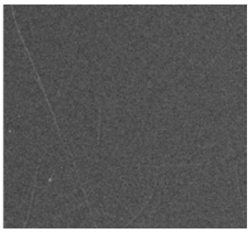
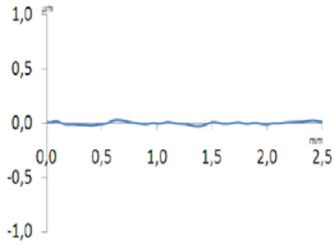
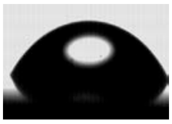
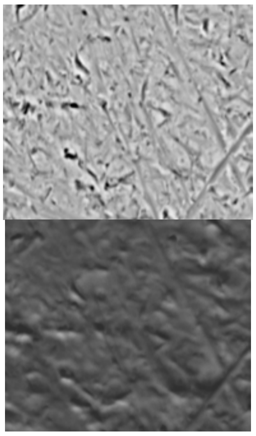
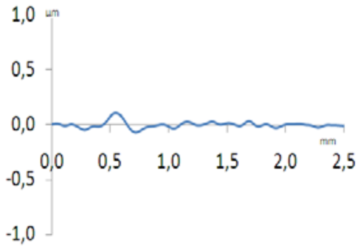
Fig. 4 Profilometer

3.1.4. Conclusions

From the analysis of the samples before the friction tests, the fallowing aspects were deduced:

- the surface of Ti12Mo alloy allthought it has a higher contact angle by compare with the one for the glass, it stays in the category of hydrophilic surfaces.
- the images obtained with the scanning electron microscopy doesn’t reveal specific particularities regarding the studied surface morphology.
- through the profilometer measurements, the value of rugosities for Ti12Mo alloy 0,063µm was determined.

Table 1 **The results synthesis of the Ti12Mo alloy characterization before performing the friction tests**

	Contact angle	MEB Image	Profilometrie
Glass	 25° ± 2°		 Ra=0,015µm
Ti12Mo alloy	 40° ± 2°		 R a=0,063µm

4. EXPERIMENTAL MECHANISM

4.1. Experimental device

To assess friction behavior of the studied material, friction tests were performed using a device specially conceived to reproduce the ex-vivo mechanics parameters. [4]

The sample of titanium alloy is fixed on a stand supported by two flexible blades. Counter glass is mounted on a circular masse, which is the normal force applied to the system. The lubricant is placed over the titanium sample support on which this is fixed. The titanium sample fixed on the system blades are mounted on a motorized table that is responsible for the movement.

A position sensor is fixed near the flexible blades. It is based on Foucault currents, and it is meant to capture the elastic deformation of the blades during the movement, so measuring the tangential force of the entire assembly. This recording takes place on paper. During this study we have performed the necessary adjustments so that the registration to be made on the computer.

Images "in situ" of the tests of friction is accomplished through an optical microscope (Carl Zeiss). The objective of this microscope is positioned at the top of the weight where the glass counter face is fixed

4.2 Experimental parameters

The images in situ were obtained using an optic microscope Carl Zeiss . Using the sensor of position (fig. 5), which records the alternative movement of the blades system, the friction curve was obtained (table 2).

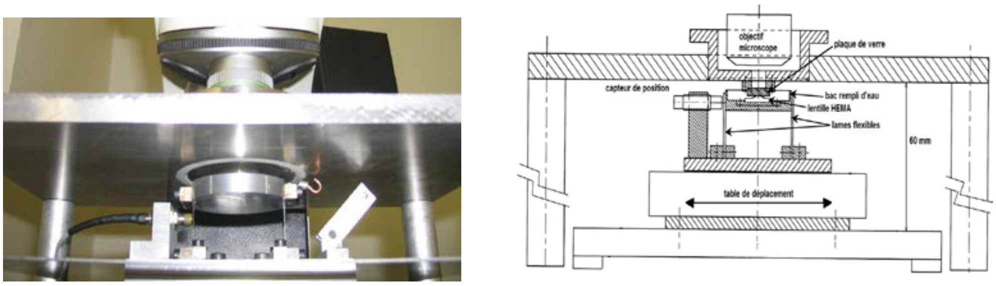


Fig. 5 Experimental device of friction

Before performing each friction test, the experimental configuration has been calibrated; a calibration curve was obtained (fig.6).

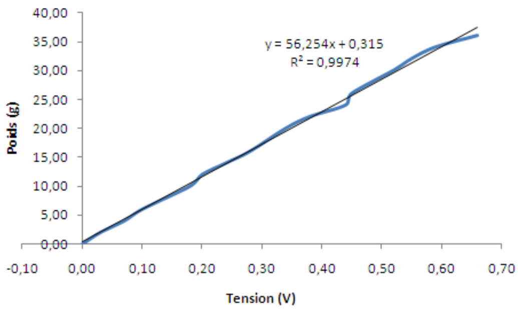
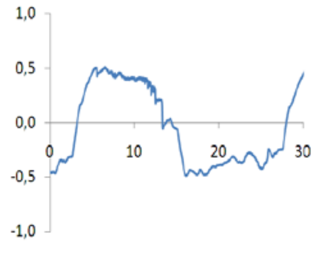
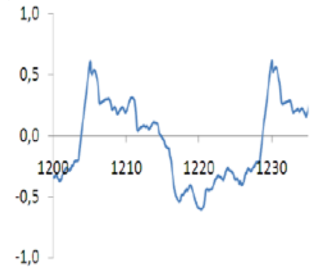
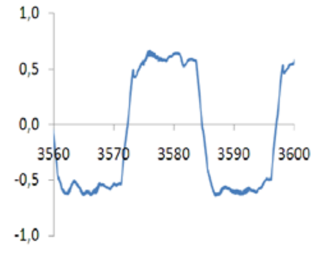
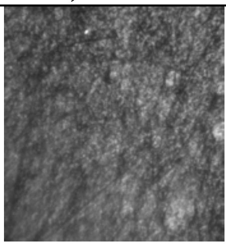
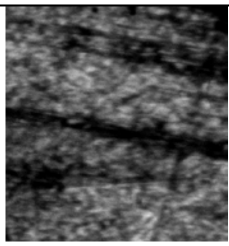
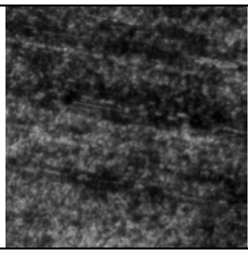


Fig. 6 Example of calibrating curve

This calibration consisted of obtaining the proportionality constant (Ke) between force and tension, that is of an order of 0,1N/V.[6], and depends of the blades thickness and their position after assembling.

The speed of the table mouvement vary between 0.1-1mm / s. For this study we chose the speed value of 0.5 mm / s.

Table 2 **Results –friction in situ. First bodies: 1)glass;2)Ti12Mo alloy. Third body-TRIS NaCl pH.7.2**

	Beginning of friction	**During friction**	**The end of friction**
Friction coefficient	 0,4	 0,4	 0,5
Optic microscopy	A 	B 	C 

4.3. Experimental determinations. Results and conclusions

Friction tests were performed for the Ti12Mo alloy against glass and in the presence of physiological serum, in order to study the friction proprieties of the alloy for the use in biomedical applications.

The results obtained in the visualization and measurement of friction coefficient in situ (Table 2) show that at the begining of friction can be detected small particles that are formed by degradation of bodies in contact (Figure A of Table 2).

These particles generate the formation of friction ridges (Figure B of Table 2). These are filled during friction with flatten particles , leading to an smooth aspect of the surface towards the end of friction.

The results of the analysis of friction surfaces (Table 3) confirms the presence of a significant wear of the glass sample (approximately 6µm thickness of glass was lost by friction) and less important for the titanium sample (about 1 mm grooves deep).

The optical and electronic microscopy analysis (visualization and EDX spectroscopy) showed that the glass surface shows strips made probably by the detaches particules of glass which remained in contact and have created an abrasive wear. Also on the glass surface we can detect particules of the titanium alloy of several micrometers. The titanium surface shows plates formed by the specif tribological transformation of the surface (zone 1) and grooves generated by the detached particules of glass.(zone 2 - high concentration of Si reveled by EDX analysis).

Table 3 **Results –after friction. Third body -TRIS NaCl pH.7.2**

<table>
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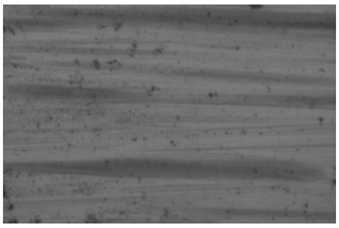
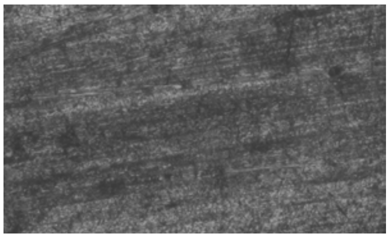
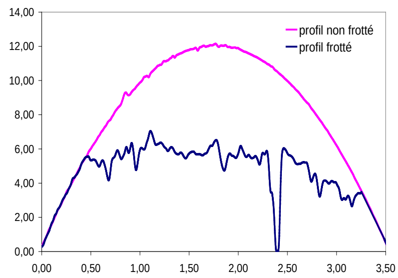
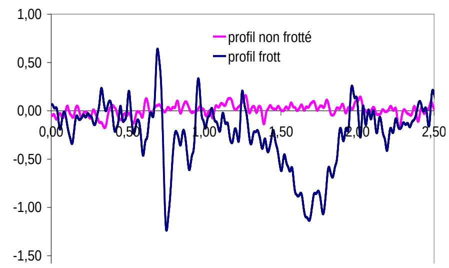
<tr><td>Optic microscopy</td><td></td><td></td></tr>
<tr><td>Profilometrie</td><td>
</td><td>
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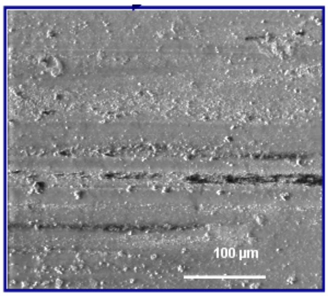
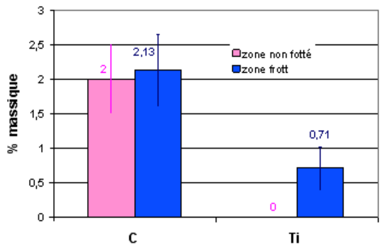
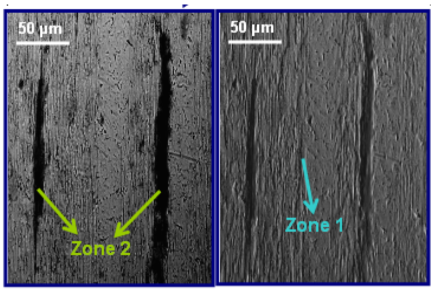
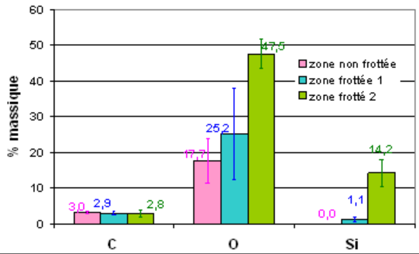
<tr><td>MEB-EDX Analysis</td><td>


</td><td>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The phase beta is dominant in the structural composition of the Ti12Mo alloy. This makes it to be biocompatible in terms of non –toxicity of the alloying elements. In this study we tested this material in biological conditions to determine the role of tribological performance of friction torque.

This paper presents only a part of the tests made and the methodology used for the validation of the use of Ti12Mo alloy in biomedical applications. From the results analysis, we can draw the conclusion that the friction for this material overcomes the conditions of use. Further studies using the same methodology are necessary to established if the use as a third body of the solution of lipid vesicles and/or of the synovial fluid instead of the physiological serum, can improve the friction behavior.

The conclusion drawn is that the saline fluid is a third body which lead to a corresponding coefficient of friction. The results reveal a high friction coefficient. Therefore the study can take into account future use as a lubricant the solution of lipid vesicles and synovial fluid.

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