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Mohamed LABAIZ, Mamoun FELLAH, Omar ASSALA, Alain IOST - FRICTION AND WEAR BEHAVIOUR OF Ti-6Al-7Nb BIOMATERIAL ALLOY - In: 25 èmes journées internationales francophones de tribologie, France, 2013-05 - JIFT 2013 - 2013

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## FRICITION AND WEAR BEHAVIOUR OF Ti-6Al-7Nb BIOMATERIAL ALLOY

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### MOTS CLES

Friction, Wear, Biomaterial, Total hip prosthesis, Ti-6Al-7Nb

### INTRODUCTION

Titanium and its alloys have been used as implant materials due to their very good mechanical and corrosion resistance and biocompatibility [1,2]. The most used biomaterials were commercially pure titanium (CP-Ti) issued in clinics, although CP-Ti has been pointed out to have disadvantages of low strength, difficulty for polishing, and poor wear resistance. Therefore, Titanium is still insufficient for high-stress applications ; e.g., long spanned fixed prostheses and the frameworks of removable partial dentures. Ti-6Al-4V alloy, originally developed as an aeronautical material, has been tested as a replacement for CP-Ti, because of its high mechanical properties with sufficient corrosion resistance[3], however, the cytotoxicity of elemental Vanadium is questionable. Subsequently, some researches prove that vanadium and aluminum ions released from this ternary alloy can induce cytotoxic effects or neurological disorders, respectively [4]. Also, for long-term, this alloy has transferred in sufficient load to adjacent bones, resulting in good resorption and eventual loosening of the implant. Another ternary alloy used as implants was vanadium free,  $\alpha+\beta$  alloy, especially Ti-6Al-7Nb alloy that revealed improved mechanical characteristics, corrosion resistance and biocompatibility , developed for orthopedics application as a wrought material, has been evaluated as a new alloy for total hip prostheses. Niobium exhibits a similar effect to vanadium instabilizing  $\beta$  phase in the Ti-Nb binary system, which is necessary for providing the  $\alpha-\beta$  two-phase structure. Therefore, niobium was used as the ternary element to produce the desirable microstructure in the Ti-6Al-7Nb alloy. As compared with Ti-6Al-4V alloy, in a tensile test, these alloy show slightly lower strength and about 40% higher elongation.

### MATERIALS AND EXPERIMENTAL METHODS

Materials used in this study are the Ti-6Al-7Nb as a total hip prosthesis (femoral stem), and Ti-6Al-4V, Al<sub>2</sub>O<sub>3</sub> ceramic for comparison. The Ti-6Al-4V was cut from a Ti-6Al-4V cylindrical bar corresponding to ISO5832-3 part 3 / 01- 07-199. It is known that the fixation of the implant is greatly dependent on good mechanical interlocking between the rough surface of the implant and tissue. So, the surfaces of the alloys were abraded with 600 abrasive papers firstly and polished with colloidal silica to a surface roughness of about Ra 0.025 $\mu$ m, all the samples were cleaned in an ultrasonic bath with acetone, ethanol, and distilled water, respectively, for 10 min and then dried in hot air. The microstructure was studied using optical microscopy. The chemical composition was acquired using spectrometer and energy-dispersive spectroscopy. The phases were identified by X-ray diffractometry. Scanning electron microscopy and energy dispersive X-ray analysis (EDX) were used to study the chemical composition of the Ti Alloys. The roughness on 3D was studied using Surface Data.

In this work oscillating friction and wear tests have been carried out in ambient air with

oscillating tribometer in accord with standards ISO 7148, ASTM G99-95a, ASTM G 133 – 95, under different condition of normal load (3N, 6N and 10N) and sliding speed (1mm/s, 15mm/s and 25mm/s), as a counter pairs we used the ball of 100Cr6, 10mm of diameter..

## RESULTS

The weight loss of the received samples (Ti-6Al-7Nb, Ti-6Al-4V and ceramic), tested at 3.5 N load appears approximately proportional to the number of revolutions. Nevertheless, the wear was systematically greater on the top samples Ti-6Al-7Nb. The behavior observed for both samples suggests that the wear mechanism during the test is the same. In the case of Ti-6Al-4V and ceramic samples, its weight loss was approximately 50% and 90 % respectively of the one observed for the samples Ti-6Al-7Nb. The weight loss of as received Ti-6Al-7Nb is less than Ti-6Al-4V, that's due to surface coating of as received femoral stem (Ti-6Al-7Nb). According to the Archards law, the volumetric loss of the material is inversely proportional to the hardness value of the material. This implies that the higher the hardness of the material, the smaller is the volume loss. The present alloys exhibit significant difference in hardness values, so that the experimental sliding wear data correlate well with Archard's law.

## CONCLUSION

The friction and wear tests were carried out to see the type of wear and to quantify the loss of mass on the one hand, and to see the variation in the friction coefficient of the studied couples Ti-6Al-7Nb/100C6, Ti-6Al-4V and ceramic/100C6 under different conditions of load (3N, 6N and 10N) and sliding speed (1mm/s, 15mm/s and 25mm/s), as a counter pairs we used the ball of 100Cr6, 10 mm of diameter, on the other hand. The obtained results show that the weight loss quantifying the wear of a soft body slipping on a hard surface is proportional not only to the distance from the slip, but also with the normal load applied. The sliding speed has for a principal effect to act on the temperature of the contact zone. The going beyond a critical speed involves the surface fusion of the most fusible body. The increase in the temperature of the contact with the speed induced to structure transformations and increases the reactivity of surfaces with respect to the environment (oxidation in the presence of air). Above a certain temperature and thus for speeds of slip higher than a breaking value, the oxide film, resulting from a permanent oxidation, is reconstituted with the fur as it is destroyed by wear. The behavior observed in both samples under different condition suggests that the wear mechanism during the test is the same for the Ti alloys samples, to increase the wear and friction resistance of biomedical titanium alloys used in total hip prosthesis (femoral stems) the surface coating and surface treatment is necessary.

## Références

- [1] M.Ninomi, "Mechanical *biocompatibilities of titanium alloys for biomedical application*". Journal of the Mechanical Behavior of Biomedical Materials. 1, (2008) pp 30–42.
- [2] C. Zhen-bing , Z. Guang, Z. Yong, and al "Torsional fretting wear of a biomedical Ti6Al7Nb alloy for nitrogen ion implantation in Bovine serum". Tribology International Volume 59 (2013) pp 312–320
- [3] S. Ramos, C.R., Sundaram, F.A, N.Diffoot-Carlo, "Tribological properties of Ti-based alloys in simulated bone implant interface with Ringer's solution at fretting contacts". Journal of Mechanical Behavior of Biomedical Materials. 3(2010) pp: 549–558.
- [4] M.Geetha, M., A.K. Singh, R.Asokamini, R., A.K. Gogia, "Ti based biomaterials, the ultimate choice for orthopaedic implants—a review". Progress in Materials Science. 54 (2009), pp :397–425