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TITANIUM AND ITS ALLOYS AS A MATERIAL FOR MICROPROTHESIS USED IN BIOMEDICAL ENGINEERING

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Abstract: *Titanium is one of t he most desirable material due to its durability, low density, toughness, corrosion resistance, highly creep-resistant and biological compatibility. All of these mechanical and physical qualities make titanium useful in al most every area of life, especially in biomedical engineering. In ossiculoplasty they play important role, because it is possible to create very small prosthesis, which is light, strong and has satisfactory acoustic properties. This p aper presents results of uniaxial compression experiments on cylindrical samples.*

Key words: *titanium, mechanical properties, otolaryngology, middle ear implant*

1. Introduction

The reason why titanium and its alloys are so popular in biomedical engineering is its specific mechanical and physical properties [4]. In otolaryngology, it is the best choice for middle ear microprothesis, which should be made from biotolerate material which has similar mechanical characteristics to those of a normal middle ear.

Hearing loss affects approximately 30 million people in U.S. [7] Conventional hearing aids are widely used by people with hearing problems. Often such hearing aids are inadequate for individuals with high-level hearing loss. Conventional hearing aids still involve certain problems such as acoustic feedback, a limited functional gain, sound distorsion, wearing discomfort, and a poor cosmetic appearance [2] It is very important to find solutions which are the best for patients.

2. State of Art

Titanium and its alloys can be classified into α-type, (α+β) type, and β-type alloy groups. ASTM specification classified different groups of titanium. Under the category “unalloyed grades” there are five materials classified in this group: grade 1 (99,5%Ti), grade 2 (99,3%Ti), grade3 (99,2%Ti), grade 4 (99,0%Ti), and grade 7 (99,4%Ti). Grade 1 is the lowest strength unalloyed titanium. Commercial pure (CP) grade 2 is the most frequently selected titanium grade

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in industrial service (but not only), having well-balanced properties of both strength and ductility. Grade 3 possesses a slightly higher strength whereas grade 4 is the highest strength grade of the CP Ti series. [5] Nowadays, pure titanium and α+β type Ti-6Al-4V ELI (Extra Low level of Interstitial content) alloys are widely used in many fields.

Historically, the basis for most advances in steel product performance has fallen under the general heading of microstructural engineering. Nowadays, researchers use different methods to develop ultra-fine grained structure of the materials. Titanium with normal grain is very good quality material, but titanium with ultra-fined grain can provide better performance.

3. Samples preparation

3 materials were investigated:

- Titanium grade 2 (Ti gr2),
- Titanium grade 5 (Ti gr5),
- Nanostructural Titanium (nTi).

Each of these 3 materials was cut into cylindrical-shape samples. Samples dimensions were: diameter of 5 mm and length of 5 mm.

4. Uniaxial tensile test

Uniaxial compression test was performed for each titanium samples. Tests were made at room temperature and 400ºC. Special heating system was used to obtain the temperature of 400ºC.

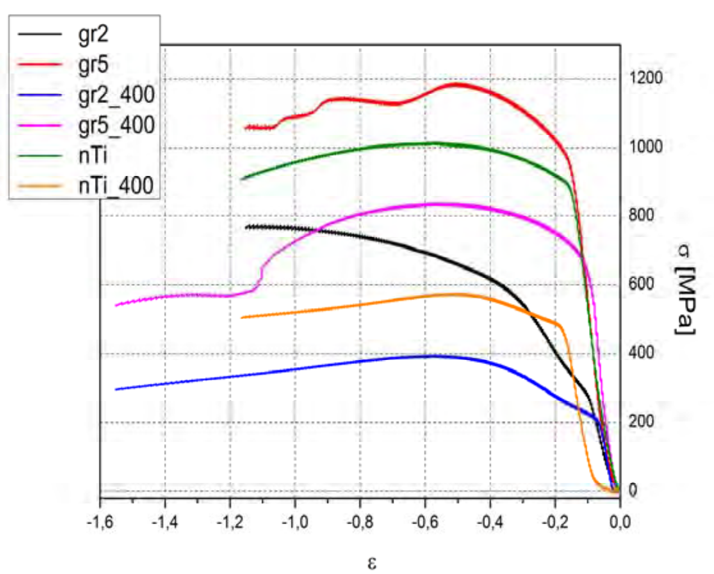

Fig. 1. *Typical stress-strain curves for 3 titanium materials (grade2, grade5, nanoTi)*

5. Experimental Results

The stress-strain curves were determined for each samples type (Fig.1.). At elevated temperatures the mechanical behaviour of all investigated materials changes. Strength between:

- Ti gr2 and Ti gr2 in 400ºC differs by 49%,
- Ti gr5 and Ti gr5 in 400ºC differs by 30%,
- nTi and nTi in 400ºC differs by 43%.

Two parameters for each specimen were defined: strength (table 1.) and elastic moduli.

Strength of titanium materials Table 1.

Titanium Sample	Strength [MPa]
Grade 2	780±21
Grade 2 in 400ºC	396±18
Grade 5	1190±26
Grade 5 in 400ºC	828±22
nTi	1020±18
nTi in 400ºC	583±25

Of all mentioned materials Titanium grade 5 is the strongest and grade 2 is the weakest. The same situation is at elevated temperature - the strongest is also titanium grade 5 and the weakest is grade 2. Elastic moduli is almost the same in each case and its value is about 106 GPa.

6. Discussion and Conclusions

It is shown that each of investigated titanium materials has different mechanical properties. Of all mentioned materials titanium grade 5 is the strongest and grade 2 is the weakest at both elevated and room temperature. Their mechanical properties are good enough for different (also complex) construction of medical implants.

Ordinary steels are insufficient for the implants, because under interaction with biological tissues or liquids, they cause toxic and allergic reactions. The high corrosion resistance of titanium is due to the quick formation on its surface of passive oxide film. This precludes the contact of metal with corrosion-active medium. It is important especially in middle ear implant, because in some cases there is 2 kinds of interactions: bone tissue-implant interaction and soft tissue-implant interaction. Density has also influence on acoustic transmission. Human ossicles density is 3,3 g/cm^3, so their mass is about 64,57 mg (malleus 28,45, incus 33,59, stapes 2,531 mg). [1,6] Young modulus of ossicles is 2000 MPa. It is much less than elastic modulus of titanium, but it is still more similar to elastic modulus of ossicles than elastic modulus of ordinary steel.

The main parameters that may be investigated are mass, shape, stiffness and position of the implant. With a better understanding of the effect of of these parameters on sound transmission, implant designs could be optimized to produce transmission characteristics that are seen in the normal human ear. [1]

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