Materials and Design 32 (2011) 2934–2939

Contents lists available at ScienceDirect

Materials and Design

journal homepage: www.elsevier.com/locate/matdes

Influence of oxygen content on microstructure and mechanical properties of Ti–Nb–Ta–Zr alloy

Qianqian Wei [a], Liqiang Wang [a], Yuanfei Fu [b], Jining Qin [a], Weijie Lu [a,*], Di Zhang [a]

[a] State Key Laboratory of Metal Matrix Composites, Shanghai Jiao Tong University, Shanghai 200240, PR China
[b] Ninth People's Hospital, School of Medicine, Shanghai Jiao Tong University, Shanghai 200011, PR China

ARTICLE INFO

Article history:
Received 27 August 2010
Accepted 22 November 2010
Available online 26 November 2010

Keywords:
A. Beta titanium alloy
F. Microstructure
E. Mechanical properties

ABSTRACT

The influence of oxygen content on microstructure and mechanical properties of Ti–22.5Nb–0.7Ta–2Zr (at.%) alloy was investigated in this work. According to experiments, the grains were refined apparently when the oxygen content was between 1.5% and 2.0%. The ultimate tensile strength (UTS) increased and elongation decreased with increasing oxygen content. But at the content of 1.0%, the elongation was nearly the same to that of the original alloy (about 16%). The elastic modulus remained comparatively low (<65 GPa) when the content was lower than 1.5%, and then increased dramatically. Therefore, there existed the best oxygen content-1.0%, at which fine grains were obtained, as well as UTS of 750 MPa, elongation of 16% and elastic modulus of 65 GPa. The Ti–22.5Nb–0.7Ta–2Zr–1.0O alloy maintained typical ductile fracture characteristics of beta titanium alloy, and had a little superelasticity.

1. Introduction

The first generation of titanium alloys used as biomedical materials are commercially pure titanium and Ti–6Al–4V. Till now, Ti–6Al–4V is still the material most widely used for implant applications, mainly due to its corrosion resistance, fatigue resistance, in addition to its exceptional strength in comparison to pure titanium [1]. However, recent studies have reported that vanadium and aluminum in Ti–6Al–4V can be released from the alloy to the human body. Vanadium ions are cytotoxic and can cause poor osteointegration and limited life span of the prosthesis, while aluminum ions can lead to neurological disorder. These concerns have led to the development of $\alpha + \beta$ type titanium alloys without Al/V and with mechanical properties and corrosion properties similar to those of Ti–6Al–4V [2]. But the elastic modulus of these alloys is much higher than that of the bones (~30 GPa). This gives rise to the "stress shielding" effect, which can cause bone resorption and loosing of implants [3,4]. Compared with these alloys, beta titanium alloys have low elastic modulus, superior resistance to wear and abrasion, as well as excellent biocompatibility [5]. Tissue reaction studies have identified Nb, Zr and Ta as non-toxic elements, and Nb and Ta are found to reduce the elastic modulus when alloyed with titanium in certain preferred quantities [6–8].

Recently, Satio et al. [9,10] developed a new multi-functional beta titanium alloy with high strength, low Young's modulus and excellent cold workability. This alloy, Gum Metal, is composed of group Va additional elements such as Ta, Nb, group IVa elements such as Zr, a small amount of oxygen, and the balance Ti. The chemical composition is characterized by three electronic magic numbers (e/a of 4.24, Bo of 2.87, Md of 2.45) [11]. It is fabricated by powder metallurgy forging method, and the unique properties of the alloy appear only after substantial cold working. A dislocation-free plastic deformation mechanism is supposed to explain the origin of the multi-functional properties, but it has been challenged by recent studies, in which conventional deformation mechanisms were found in Gum Metal [12]. As Gum Metal maintains properties different to Ti–Ni–Ta–Zr alloy with almost the same chemical composition, the influence of oxygen is taken into consideration as one of the possible reasons for the "superproperties".

In this study, Ti–22.5Nb–0.7Ta–2Zr–(0.5–2.5) O were developed. After hot-rolling and solid solution, tensile and cyclic tensile tests were carried out. Microstructure and fracture surfaces were observed. The purpose was to investigate the influence of oxygen content on microstructure and mechanical properties of beta titanium alloy. The changes of fracture characteristics and superelasticity after the addition of oxygen were also discussed in this paper. The main difference between the studied alloys and Gum Metal was the manufacturing mode. Vacuum consumable/non-consumable arc melting were introduced in the experiments, while Gum Metal was fabricated by powder metallurgy forging method. Moreover, hot-rolling was utilized, in order to eliminate the influence of cold working.

* Corresponding author. Tel.: +86 02134202641; fax: +86 02134202749.
E-mail address: luweijie@sjtu.edu.cn (W. Lu).

0261-3069/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.matdes.2010.11.049