Materials and Design 32 (2011) 2387–2390

Contents lists available at ScienceDirect

Materials and Design

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

Short Communication

Correlations between aging heat treatment, ω phase precipitation and mechanical properties of a cast Ti–Nb alloy

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ARTICLE INFO

Article history:
Received 6 August 2010
Accepted 5 November 2010
Available online 11 November 2010

ABSTRACT

Ti–Nb alloys were arc melted in a water-cooled copper hearth in an inert atmosphere. After preparation, the samples were centrifugally cast in copper molds, and rapidly cooled, resulting in a martensitic microstructure. They were then aged at different temperatures. The microstructural characterization of this material suggested that martensite decomposition occurred, leading to precipitation of α, β and ω phases. Aging at higher temperatures led to ω phase decay. Mechanical characterization indicated that the heat treatment enhanced the strength and ductility of the alloys. Correlations between heat treatment, ω precipitation and mechanical behavior are discussed.

1. Introduction

Titanium and its alloys are widely utilized as biomaterials in dental and medical applications because they present interesting combinations of properties. In terms of biomedical applications, the properties of interest are biocompatibility, corrosion behavior, processability and particularly mechanical properties. It is well known that the mechanical behavior of a given material depends directly on its microstructure, which is related to the type and distribution of the phases in it.

At about 882 °C, Ti undergoes an allotropic transformation, when a HC crystal structure, stable at room temperature and named α-phase, transforms into BCC crystal structure, called β phase. The temperature at which this solid/solid phase transformation occurs is directly related to the alloying element content and, hence, the addition of elements to Ti may lead to a range of microstructures and mechanical properties. Thus, by means of alloying and heat treatments, one can produce a specific microstructure with the most appropriate combination of properties for a particular application [1]. As an example, depending on the solute content, a β-stabilizer rich Ti alloy may present a martensitic structure or stabilized β when rapidly cooled. Samples obtained by rapid cooling and subjected to aging may present α-phase precipitation, which strongly modifies their mechanical behavior. However, associated with α and β-phase precipitation, metastable ω-phase formation may occur [2–4]. In terms of mechanical behavior, precipitation of ω-phase in titanium alloys is not desirable, since it may lead to excessive embrittlement, loss of ductility and fatigue resistance, and must therefore be avoided [5].

Prima et al. evaluated the effects of aging on ω-phase precipitation [4]. The crystal structure of ω-phase was obtained by collapsing one pair of {1 1 1}β planes to an intermediate position. In addition, they suggested that ω-phase may act as the precursor of heterogeneous nucleation of the α-phase at medium temperatures. In that case, plate-like α-phase is nucleated by a displacive mechanism. In conclusion, titanium alloy aging may be applied to control, to a certain extent, the amount and distribution of α-phase precipitates. Hence, this paper discusses correlations in the aging, ω phase precipitation and mechanical behavior of a cast Ti–25Nb alloy.

2. Experimental procedures

Using high purity Ti and Nb, Ti–Nb 30 g ingots were prepared in an arc furnace with a nonconsumable tungsten electrode and water-cooled copper hearth in a high purity argon atmosphere. The ingots were flipped and remelted five times in order to improve their chemical homogeneity. The loss of mass due to sample preparation was calculated to be less than 0.1%. Since the objective was to partially stabilize the β phase, the composition Ti–25Nb (wt.%) was chosen. The samples were then centrifugally cast in a copper mold at room temperature, under a maximum rotation of 1000 min^{-1}. The cast samples were aged at 200 °C, 400 °C and 600 °C for 14.4 ks and air-cooled. The effect of aging on the microstructure was investigated by optical microscopy (Olympus BX60M), scanning electron microscopy (Jeol JXA 840A) and X-ray diffraction (Rigaku DMAX 2200), using Cu Kα radiation and operating at 40 kV and 30 mA. Energy-dispersive spectroscopy and X-ray fluorescence (Rigaku RIX 3100) were utilized to confirm the samples' chemical compositions. Metallographic sample preparation

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0261-3069/$ - see front matter
doi:10.1016/j.matdes.2010.11.012