EFFECT OF VANADIUM ADDITION ON MECHANICAL PROPERTIES OF Ti-8Al-1Mo ALLOY

J.H. Chern Lin, S.J. Lin, C.C. Chung, C.W. Lin and C.P. Ju

Department of Materials Science and Engineering, National Cheng-Kung University, Tainan, Taiwan

Introduction

Due to their high strength-to-weight ratios, excellent mechanical properties and corrosion resistance, titanium and titanium alloys have become one of the backbone materials for many aerospace, energy, sports, marine, chemical and biomedical applications.

In the present study, the mechanical properties of in-house fabricated Ti-8Al-1Mo and Ti-8Al-1Mo-1V alloys were measured. A specific emphasis was placed on the investigation of the effect of the addition of 1 wt% V on the mechanical behavior of Ti-8Al-1Mo alloy under as-cast as well as hot-rolled conditions.

Experimental

The materials used for this study, Ti-8wt%Al-1wt%Mo and Ti-8wt%Al-1wt%Mo-1wt%V alloys, were prepared using a commercial arc-melting vacuum-pressure type casting system (Castmatic, Iwatani Corp., Japan). Prior to melting/casting, the melting chamber was evacuated and purged with argon. An argon pressure of 1.5 kgf cm^{-2} was maintained during melting. Appropriate amounts of metals were melted in a U-shaped copper hearth with a tungsten electrode. The ingots were re-melted several times to improve chemical homogeneity of the alloys.

Prior to casting, the alloy ingots were re-melted in an open-based copper hearth in argon under a pressure of 1.5 kgf/cm^2. The difference in pressure between the two chambers allowed the molten alloy to quickly drop into a mold at room temperature.

Hot rolling of the alloys was conducted using a variable frequency hydraulic power system. (TOSHIBA VF PACK-P1, Chun Yen Testing Machines Co., Taichung, Taiwan). The cast alloy ingots to be hot-rolled were first coated with an oxidation-resistant coating. Prior to rolling, the coated ingots were heated to 1050℃ for 5 minutes in a furnace. The hot ingots taken from the furnace were immediately rolled down from a thickness of 4 mm to 1.5 mm (62.5% in thickness reduction) in a single pass.

X-ray diffraction (XRD) for phase analysis was conducted using a Rigaku diffractometer (Rigaku D-max IIIV, Rigaku Co., Tokyo, Japan) operated at 30 kV and 20 mA with a scanning speed of 2^o/min. A Ni-filtered CuKα radiation was used for the study. A silicon standard was used for the calibration of diffraction angles. The various phases were identified by matching each characteristic peak in the diffraction patterns with JCPDS files.

Microstructural examination of the series of materials was performed using an optical microscope (Leica TMX 100, Germany).Surfaces of the materials for light microscopy were mechanically polished via a standard metallographic procedure to a final level of 0.05 micron alumina powder, followed by chemical etching in a mixture of water, nitric acid and hydrofluoric acid (85:10:5 in volume).

A servo-hydraulic-type testing machine (EHF-EG, Shimadzu Co., Tokyo, Japan) was used for tensile testing. The testing was performed at room temperature at a constant crosshead speed of $8.33\times10^{-6}ms^{-1}$. The average ultimate tensile strength (UTS), yield strength (YS) at 0.2% offset, modulus of elasticity and elongation to failure were taken from five tests under each condition. One-way ANOVA followed by Student-Newman-Kuels test was used to evaluate statistical significance of the data. In all cases the statistical differences were considered significant at $p < 0.05$.

Results and Discussion

The XRD patterns (Fig. 1、Fig. 2) indicate that both Ti-8Al-1Mo and Ti-8Al-1Mo-1V alloys under as-cast and hot-rolled condition exhibited a hexagonal α'phase with a distorted hcp crystal structure. Fig. 3 and Fig. 4 shows that both alloys had an acicular martensitic morphology with barely visible retained β-phase grain boundaries.

Tensile testing data indicate that the average YS (886 MPa) and UTS (1095 MPa) of as-cast Ti-8Al-1Mo-1V alloy were respectively larger than those of as-cast Ti-8Al-1Mo alloy (791 and 1026 MPa) (Table 1), possibly due to a solution strengthening effect. However, the as-cast Ti-8Al-1Mo alloy had a much larger elongation (10%) than as-cast Ti-8Al-1Mo-1V (5.4%). Table 1 shows that the average tensile modulus values of both as-cast alloys were similar (113 GPa for Ti-8Al-1Mo and 112 GPa for Ti-8Al-1Mo-1V).

Under hot-rolled condition, the average YS (1195 MPa) and UTS (1418 MPa) of Ti-8Al-1Mo-1V alloy were still respectively larger than those of Ti-8Al-1Mo alloy (950 and 1363 MPa). Again, the elongation value of hot-rolled Ti-8Al-1Mo alloy (10.6%) was much larger than that of hot-rolled Ti-8Al-1Mo-1V (4.3%). Table 1 also shows that the average tensile modulus value of hot-rolled Ti-8Al-1Mo alloy (118 GPa) was significantly larger than that of hot-rolled Ti-8Al-1Mo-1V alloy (105 GPa).

The significant difference in elongation between the two alloys is clearly demonstrated in their distinctive hot rolling results. After the same hot rolling procedure as indicated in Experimental, about half of the Ti-8Al-1Mo-1V samples were found fractured in different manners, while all Ti-8Al-1Mo samples were entirely crack-free. A typical example is given in Fig. 5.

As a conclusion, the results of the present study show that the addition of 1 wt% V in Ti-8Al-1Mo alloy can increase YS and UTS values under both as-cast and hot-rolled conditions, but significantly decrease the elongation and hot workability of the alloy.

References

1. W.W. Cheng, J.H. Chern Lin, C.P. Ju, Materials Letters., 57: 2591– 2596, 2003.

Acknowledgement

The authors would like to acknowledge the support for this research by National Science Council of Taiwan, Republic of China under the research grant NSC 97-2320-B-006-007-MY3.

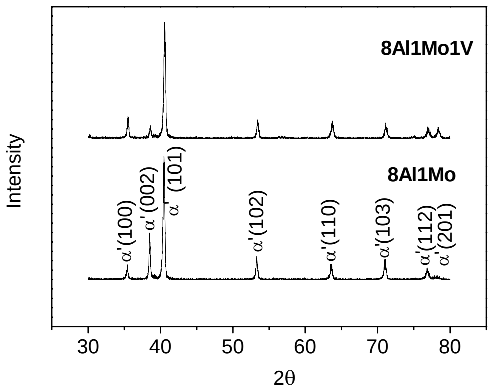

Fig. 1. XRD patterns of as-cast Ti-8Al-1Mo and Ti-8Al-1Mo-1V alloys.

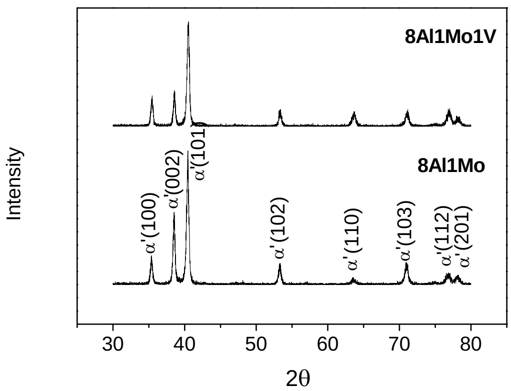

Fig. 2. XRD patterns of hot-rolled Ti-8Al-1Mo and Ti-8Al-1Mo-1V alloys.

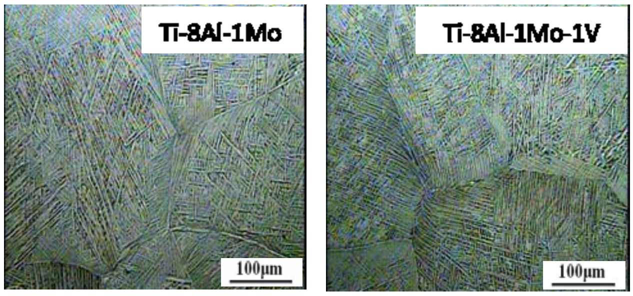

Fig. 3. Optical micrographs of as-cast Ti-8Al-1Mo and Ti-8Al-1Mo-1V alloys

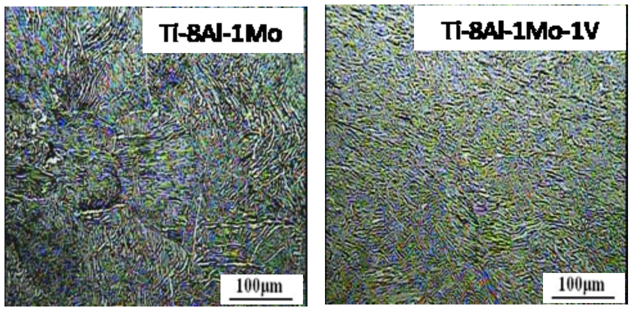

Fig. 4. Optical micrographs of hot-rolled Ti-8Al-1Mo and Ti-8Al-1Mo-1V alloys

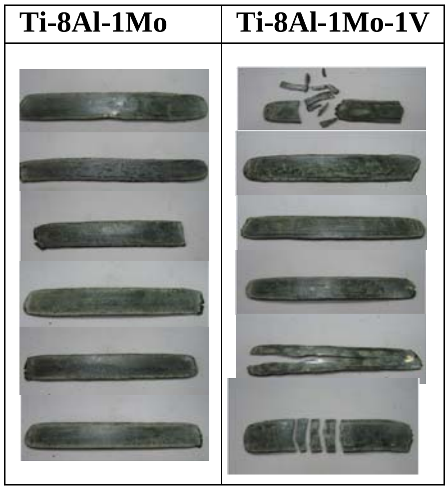

Fig. 5. Hot-rolled samples of Ti-8Al-1Mo and Ti-8Al-1Mo-1V alloys

Table 1. Tensile test data

Material	YS (MPa)	UTS (MPa)	Tensile modulus (GPa)	Elong (%)
Ti-8Al-1Mo (as-cast)	791±90	1026±66	113±6	10±3
Ti-8Al-1Mo -1V (as-cast)	886±81	1095±47	112±10	5.4±1.8
Ti-8Al-1Mo (hot-rolled)	950±90	1363±66	118±6	10.6±3.4
Ti-8Al-1Mo -1V (hot-rolled)	1195 ±81	1418±47	105±10	4.3±1.8