Effect of thermomechanical treatment on mechanical properties of Ti-15Mo-1Bi alloy

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Due to their low density, excellent biocompatibility, corrosion resistance and mechanical properties, titanium and titanium alloys have been widely used for many biomedical applications today. For example, pure titanium is being used for hip cup shell, dental crown and bridge, endosseous dental implant and plate for oral maxillofacial surgery, while Ti-6Al-4V alloy is used for hip prosthesis, artificial knee joint and trauma/fixation devices (nails, plates, screws and wires). Although Ti-6Al-4V ELI is widely used as an orthopaedic implant material due to its excellent corrosion resistance and mechanical properties, studies have shown that the release of aluminum and particularly vanadium ions from the alloy might cause such long term health problems as peripheral neuropathy, osteomalacia and alzheimer diseases. Other negative considerations for Ti-6Al-4V alloy include its relatively low wear resistance and high elastic modulus that is considered to potentially cause "stress shielding effect." Reported in this presentation is the effect of thermomechanical treatment on the mechanical properties of a newly-developed beta-phase Ti-15wt%Mo-1wt%Bi alloy [1].

The material was 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 three times to improve chemical homogeneity. Prior to casting, the ingots were re-melted again in an open-based copper hearth under an argon pressure of 1.5 kgf/cm^2. The difference in pressure between the two chambers allowed the molten alloys to instantly drop into a graphite mold at room temperature.

To evaluate the effect of thermomechanical treatment on mechanical properties of Ti-15Mo-1Bi alloy, the as-cast beta-phase alloy samples underwent a series of different thermomechanical treatments, including cold-rolling, vacuum-annealing, water-quenching, and/or aging in argon atmosphere.

A servo-hydraulic type testing machine (EHF-EG, Shimadzu Co., Tokyo, Japan) was used for tensile and fatigue tests. The tensile testing was performed at room temperature at a constant crosshead speed of 8.33×10^{-6} m s^{-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. For fatigue testing, a tension-to-tension stress mode was used. The smooth plate specimens were subjected to uniaxial fatigue loading at room temperature in air at a frequency of 10 Hz with a stress ratio R = 0.1. The specimens were cycled with constant stress amplitude until failure, or for 10^7 cycles if they did not fail. The initial load was set up at a maximum level estimated at about 65% YS.

The experimental results indicate that the mechanical properties of the alloy are sensitive to its thermomechanical treatment history (Table 1). For example, compared to as-cast Ti-15Mo-1Bi alloy, YS and UTS of certain thermomechanically-treated (aged) alloy could be increased by as much as 80% and 54%, respectively, apparently as a result of an age-hardening effect. The fatigue strength of the thermomechanically-treated alloy reached 600+ MPa.

References

1. C.W. Lin, C.P. Ju and J.H. Chern Lin, "Comparison among mechanical properties of investment-cast c.p. Ti, Ti-6Al-7Nb and Ti-15Mo-1Bi alloys," Materials Transactions, 45(10):3028-3032, 2004.

Table 1. Tensile properties of Ti-15Mo-1Bi

Condition	YS (MPa)	UTS (MPa)	Modulus (GPa)	Elongation (%)
As-cast	662	819	78	30
As-rolled	850	1450	96	15
Solution-treated	744	897	83	37
Aged	1190	1260	98	11