Alloys and Intermetallics

MS.6.P174
Microstructural SEM characterization, mechanical properties and corrosion rate evaluation of heat treated Ti-6Al-4V

A. S. Khalil[1], R. A. Abdel-Rehim[2]

[1]Mining and Metallurgy Department, Tabbin Institute for Metallurgical Studies (TIMS), Helwan, POB 109, Cairo, Egypt
[2]Casting and Foundry Department, Central Metallurgical Research and Development Institute (CMRDI), Helwan, POB 87, Cairo, Egypt

askhalil2004@yahoo.com
Keywords: Ti-6Al-4V Alloy, Heat Treatment, Scanning Electron Microscope, Mechanical Properties, Corrosion Rates

Ti–6Al–4V alloy has excellent combination of properties such as low density, high specific strength, high fatigue life, creep resistance, corrosion resistance and high biocompatibility. The alloy has been considered as one of preferential engineering materials in aeronautic, medical implants, automotive and marine industries and is considered the workhorse of titanium industry as it accounts for about 50 % of total titanium world usages [1,2].

The alloy contains 6 wt% aluminum for the close-packed (hcp) α phase stabilization and 4 wt% vanadium for the body centred cubic (bcc) β phase stabilization. These two phases coexist were the β phase distributes along the boundaries of α phase [2].

In this work, we used scanning electron microscope (FEI Inspect-S50) observations in combination with several experimental methods to assess the effects of heat treatment on the microstructure, the mechanical and electrochemical properties of commercial cast Ti-6Al-4V. The alloy chemical composition (in wt %) is: 5.9% Al, 3.65% V, 0.2% Fe, 0.2% O, 0.1% C and Ti-balance.

Samples for heat treatment were cut in the form of ~1.5 cm side cubes. The samples were solution treated in the $\alpha+\beta$ range in an inert argon atmosphere at 975 ^{o}C and held isothermally for 15 minutes followed by water quenching. The samples then aged for 6 hours duration at two different temperatures of 480 ^{o}C and 595 ^{o}C followed by water quenching. Samples for SEM observations were prepared by standard metallographic techniques which consist of polishing and etching.

In “Figure 1a.” the microstructure of the as-received sample shows the fully lamellar structure were alternating laths of α and β phases coexist in a “basket-weave” pattern. In “Figure 1b.” the acicular martensitic morphology for the quenched sample is shown, here the β phase appears to be transformed to the acicular $\alpha^{\backslash}$ supersaturated (hcp) martensite phase by the rapid cooling from 975 ^{o}C which is below the transus β temperature. The needle-like structures $\alpha^{\backslash}$ exists along the primary α phase [2]. The aging treatment, leads to the decomposition of these $\alpha^{\backslash}$ needles into fine α and β phases especially along the grain boundaries as shown in “Figure 1c.” and “Figure 1d.” for both the aging temperatures [3]. However, for the higher aging temperature (595 ^{o}C) finer α and β phases were formed accompanied by larger fraction of α phase regrowth. The microstructures were further illustrated in close-up SEM micrographs in “Figure 2b.” and in “Figure 2c.” for both aged samples in comparison with the initial martensitic structure of the quenched sample depicted in “Figure 2a.”.

In “Table 1.” a summary of the experimental results of mechanical (Vickers hardness at 30 kg load and wear resistance for 0.3 bar load and 275 rpm for 30 minutes) were presented. In addition, the corrosion rate evaluation for immersion in simulated body fluid condition was presented (using open circuit potential-time measurements and potentiodynamic polarization technique) [4].

The large increase in hardness of ~1.5 times for the quenched sample (martensitic structure) is expected. Increase of hardness values (strengthening) is also expected following aging treatment.

Aging also leads to noticeable increase in wear rates compared to that of the as-received and quenched samples. However, aging at higher temperature (595 ^{o}C) gives a lower wear rate value relative to aging at the lower temperature (480 ^{o}C). On the contrary, the corrosion rate values suggest that lamellar α and β phases microstructure favors much lower corrosion rate values compared to the very large increase for martensitic structure (water quenched sample) and the finer $\alpha+\beta$ phases (aged samples). This might be due to the large increase in interphase boundaries volume fraction formed as a result of finer observed microstructures in both quenched and aged samples and which might acts as dissolution locations enhancing the corrosion rates [4].

1. R. Boyer, Mater. Sci. and Eng. A213 (1998), p. 103.
2. E. Morita *et al,* Materials Transactions 46 (2005), p. 1681
3. G. Welsch in “Materials Properties Handbook: Titanium Alloys”, ed. G. Welsch, (ASM-Ohio) (1994), p. 1501
4. M. Atapour *et al,* Corrosion 66 (2010), p. 1

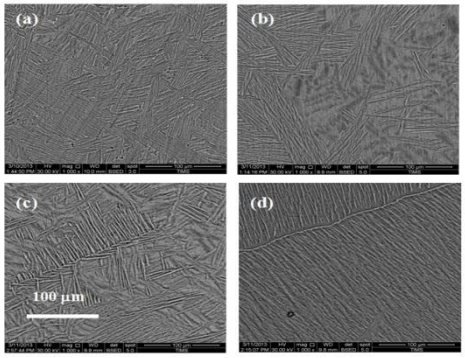

Figure 1. Backscattered electron images (magnification X1000) depicting the microstructure of (a) the as received sample, (b) water quenched, (c) aged for 6 hours at 480 C and in (d) aged for 6 hours at 595 C.

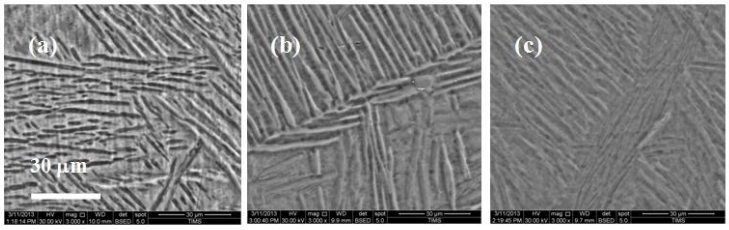

Figure 2. Backscattered electron images (magnification X3000) illustrating the acicular martensitic structure of thequenched sample and the finer $\alpha+\beta$ structure for the samples aged at 480 ^{O}C and 595 ^{O}C.

	As-Received	Water Quenched	Aged at 480 ^{O}C	Aged at 595 ^{O}C
Vickers Hardness (HV30)	390	564	569	468
Wear Resistance (Weight loss %)	1.68 %	1.62 %	3.24 %	2.77 %
Corrosion Rate (mm/year)	1.25×10^{-3}	78.90×10^{-3}	60.10×10^{-3}	82.53×10^{-3}

Table 1. A summary of the Vickers hardness, Wear resistance and corrosion rate for the different heat treatment conditions.