A Comparison of Single and Duplex Annealing Treatment Effects on Microstructure and Tensile properties of Ti-6242 Alloy

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Abstract

The aim of this research is to investigate the effects of duplex solution annealing treatment on microstructure and also high and low temperature tensile properties of a near alpha titanium alloy, Ti-6Al-2Sn-4Zr-2Mo, in comparison with single solution annealing treatment. In this regard, the single solution annealing process was carried out for one hour on samples at 955 °C, and then continued by aging process for 8 hours at 600 °C. After that, the microstructural and mechanical characteristics were investigated. In the following and in order to study around the effects of duplex solution annealing, after the single annealing, the samples experienced second annealing routes as 800 °C, 850 °C and 900 °C for 30 minutes which then followed by aging as above. Note that all specimens were air cooled after each heat treatment. Microstructural investigations revealed that secondary alpha phase thickness in the transformed beta matrix of higher temperatures duplex annealed samples is more than single annealed ones. Also the volume fraction of primary alpha phase was increased by second annealing. Finally, the results of high and low temperature tensile tests indicated an increase in strength and a decrease in elongation of duplex annealed samples.
Keywords: Near alpha Ti-6242 alloy, Single annealing, Duplex annealing, Alpha phase, Tensile properties

Experimental procedure

The Ti-6242 alloy was refined at a 1150 °C for 4 hours after initial refluxing in a VAR furnace and subsequently hot rolled (75% RA) And it was cold in the water. Then in order to create a high energy structure and also to provide recrystallization conditions in the next steps the second hot rolling was carried out at 975 °C and 60% RA, and it was cooled in the air. Also, the results of EDS analysis of the alloy are shown in Table 1. Metallographic images and microstructural studies were carried out to determine the beta-degenerative temperature (the temperature at which the alpha phase is converted to beta and vice versa) and this temperature was obtained at about 1000±15 °C. Four samples (8×8×12 cm) were prepared. At first, single-stage dissolution annealing operation was carried out at 955 °C for one hour on a sample of alloys and after air cooling then aging for 8 hours at 600 °C and then cooled in the air. Three other samples were placed under dual annealing; after annealing one hour at 955 °C and air cooling, each one separately heat treated for 30 minutes at 800 °C , 850 °C and 900 °C and finally cooled in air. At the end, similar aging operations were performed. After the completion of the thermal cycles, the samples were taken to remove the oxide layer and the surface of the crust known as a surface alpha layer (about 1 mm). The cold and hot strength test held respectively at 25 °C and 480 °C, and with the INSTRON 8502, according to ASTM E8 and ASTM E 21 standards, at a strain rate of 10^{-3} (gauge speed 2 mm/min). In order to metallography investigation Krol solution containing HF 5 mm, HNO 3 mm 10 and HF 90 mm was used. Also to prevent the recurrence and long details of the thermal treatment cycles, the codes dedicated to samples; 1A1: single stage heat treatment; and second annealing 900 °C, 850 °C and 800 °C respectively named with the codes 2A1, 2A2 and 2A3.

Discussion

Table 1. Chemical composition of Ti-6242 alloy used in this study

Element	Al	Sn	Zr	Mo	O	N	H	Ti
(wt %)	5.95	2.15	3.90	2.00	0.12	0.02	0.007	Balance

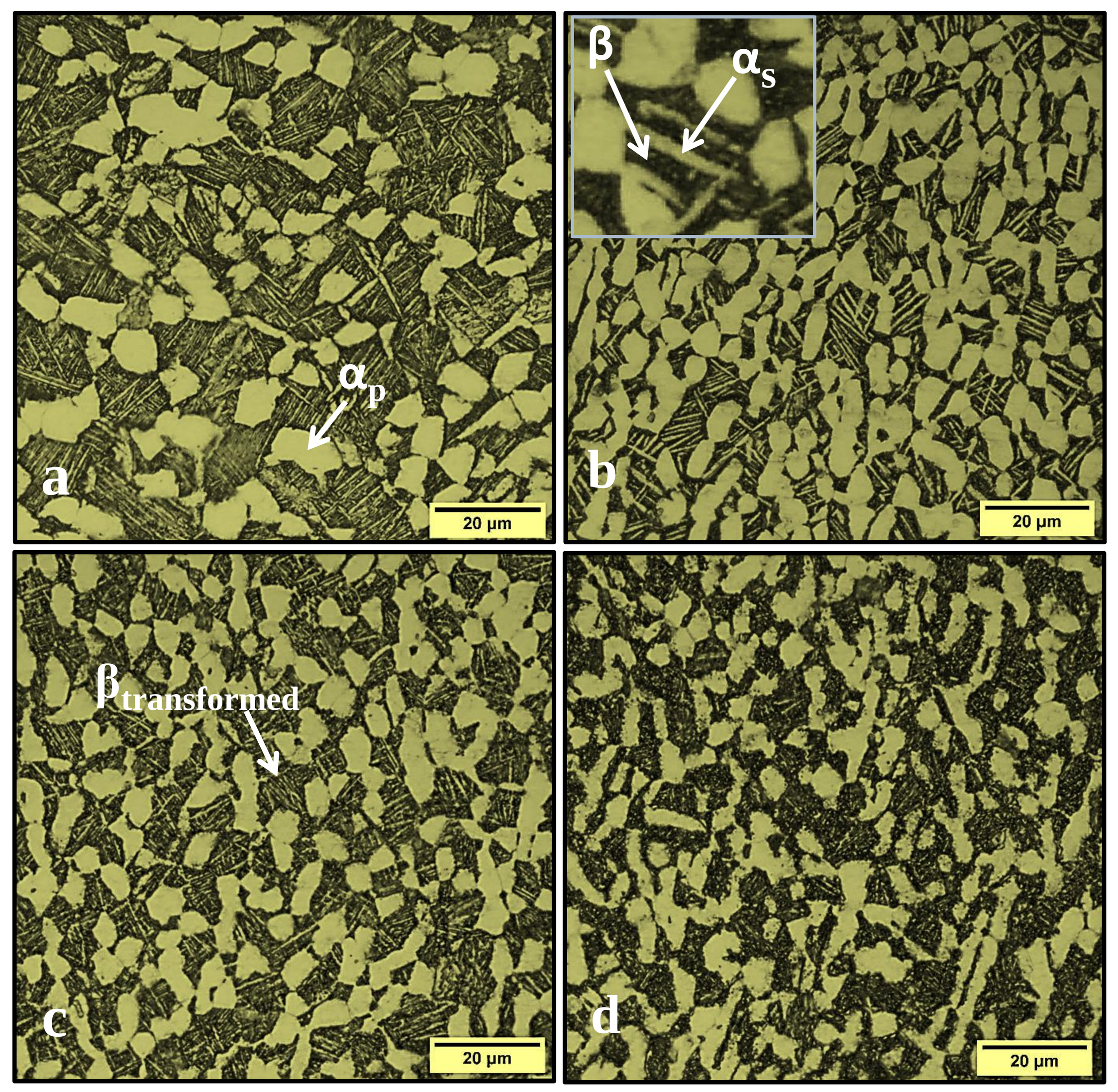

Figure 1: Optical microscopy image of alloys a) 1A1, b) 2A1, c) 2A2 and d) 2A3 with a magnification of 1000x.

The alloy element portioning effect (AEPE) and the amount of crossover of the alpha phase are one of the most important factors affecting the strength of dual microstructures (alpha/beta). Therefore, it is expected that by increasing the alpha phase and increasing the distribution of the alloying elements, the loss of the strength of the layered regions in the dual structure is expected. On the other hand, the increase in the alpha phase size reduces the beta colony size and decreases the tensile strength of the high temperature and increases the lower temperature strength of the alloy. It should be noted that by increasing the test temperature and minimizing the negative effects of AEPE on the strength by facilitating intrusive processes, the amount of changes in the length and the reduction are lower (Table 2). In addition, the observation and careful study of metallographic images of titanium alloys and especially these alloys (Fig. 1) is taken to mean that cracking, after nucleation and growth, from within the set of alpha layers and beta phases move on and continue their path. Metallographic and microstructure images of the alloys are presented in Fig. 1. As can be seen, with the increase of the second annealing temperature, the thickness of the secondary alpha (α_s) layers is sharper in the degenerate beta phase, which is due to the alpha phase stability at high temperatures, which increases the high temperature stability of the alloy 2A1 compared to other alloys.

Also, the increase in the temperature of the second annealing leads to an increase in the initialization of the initial alpha phase, which will result in increased ductility and resistance to fatigue failure. In Fig. 1, it is observed that by decreasing the temperature of the second annealing and not creating conditions for the occurrence of penetrating reactions and in the course of the growth of the alpha phase, the thickness of the layers of this phase will be reduced in the beta transformed field. Important point in the metallographic images of Ti-6242 alloy (Fig. 1) is the increase in the number of initial or primary alpha phases (α_p) by increasing the second annealing temperature. So that by increasing the second annealing temperature, the volume fraction of alpha phase in alloys 2A1, 2A2, 2A3 and 1A1 will be more (Fig. 3). The slip plates in bcc beta phase are more than the hcp alpha phase, so it will be easier to slip and flood the alloy. This justifies the increase in the percentage reduction in cross-sectional area as well. A comparison of the thickness of the secondary alpha phase layers is also presented in Fig. 2. As it is seen, the thickness of this phase has increased with the increase of the second annealing temperature and the greater penetration of the alpha phase stabilizer elements. In addition, as the above mentioned, the increase in temperature, increases the spherical shape of the αp phase. As shown in Figures 1 and 2, the thickness loss of the alpha phase layers in the 2A3 alloy was more than predictable, due to the rapid increase in the amount of molybdenum in the transformed beta phase. Because the presence of molybdenum causes during decreasing the temperature, the beta-phase stability will occur at a higher rate and this fact leads to the dominance of this phase in the alloy field. Another significant point is the increase in the difference between the yield strength and the final tensile strength of the dual aniline specimens and the second annealing temperature. As shown in Fig. 4, this increase is due to the increase of the beta phase (bcc) by decreasing the temperature of the second annealing, which causes the material flow during the tensile test to increase and the plastic tensile curve - The thickness of the alloy will increase.

Table 2. Ti-6242 alloy lower temperature tensile properties

Alloy	YS (MPa)	UTS (MPa)	El (%)	RA (%)
1A1	927	991	13.6	32.0
2A1	852	918	10.0	12.2
2A2	863	941	14.0	24.0
2A3	877	985	19.0	32.0
AMS 4976	827	896	10.1	25.0

Table3. Ti-6242 alloy high temperature tensile properties

Alloy	YS (MPa)	UTS (MPa)	El (%)	RA (%)
1A1	530	652	17.5	30.3
2A1	595	674	19.9	31.0
2A2	547	661	19.0	33.0
2A3	510	640	21.0	36.5
AMS 4976	483	621	15.0	30.0

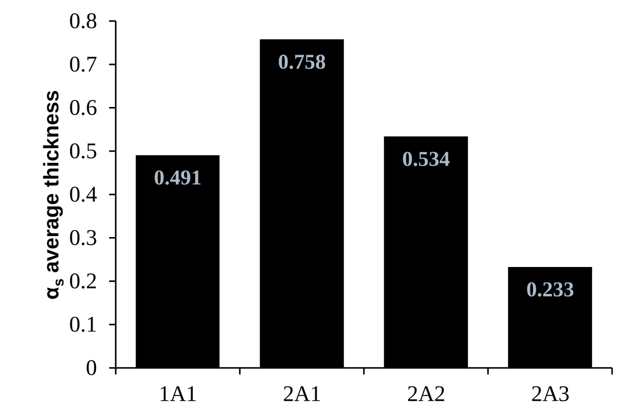

Figure 2. Comparison of α_s average thickness

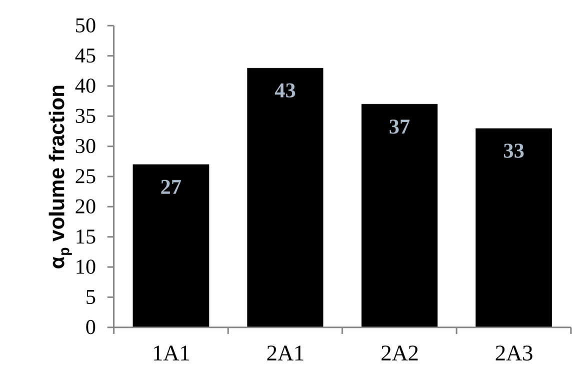

Figure 3. Comparison of α_p volume fraction

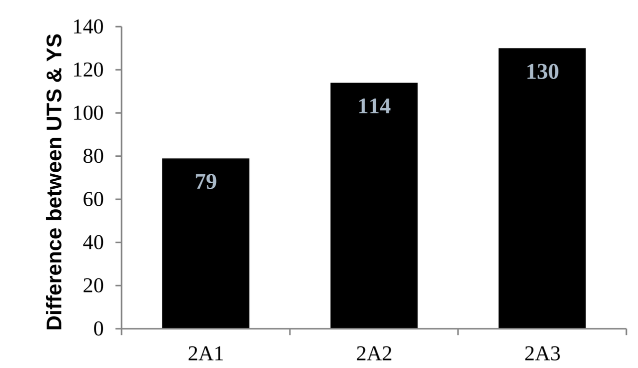

Figure 4. Difference between ultimate tensile strength and yield strength

Conclusion

1. By increasing the second annealing temperature in the dual annealing process, the thickness of the alpha phase layers increases in the beta transformed field.
2. By increasing the second annealing temperature in the dual annealing process, due to the higher stability of the beta phase and the increase of the molybdenum element, the thickness of the alpha phase layers decreases rapidly.
3. By increasing the second annealing temperature and preparing the conditions for penetration, the initial alpha phase spheralization rate in the alloy is increased and this will lead to an increase in the alloy ductility.
4. In dual annealed samples, the decrease of the second annealing temperature will increase the difference between the final strength of the elasticity and the strength of the substrate, which is due to the increase in the percentage of the beta-soft phase in the alloy field and in the further increase will have plastic properties.

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