

Effect of Heat treatment on Microstructure and Mechanical Properties of Ti-6Al-2Zr-1Mo-1V Bar

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Abstract

In this paper, the microstructure evolution and mechanical properties fluctuation of Ti-6Al-2Zr-1Mo-1V forging state bar after the first stage heat treatment at 950°C~955°C and the second stage heat treatment at 760°C~840°C were studied. In the first stage of heat treatment, the content of primary α and the tensile strength decreases with the increase of temperature, and the high temperature duration time is obviously prolonged. During the second stage of heat treatment, the metastable β phase precipitates third α phase, and with the increase of temperature, the tensile strength increases and the high temperature duration time prolongs.

1. Introduction

Ti-6Al-2Zr-1Mo-1V is a kind of near- α titanium alloy with high aluminum equivalent, which has good thermal stability, corrosion resistance and weldability. It is widely used in aircraft structure and engine field. The microstructure of titanium alloy has an important effect on the properties^[1-2]. In this paper, the microstructure and mechanical properties of Ti-6Al-2Zr-1Mo-1V forging state bar after the first stage heat treatment at 950°C~955°C and the second stage heat treatment at 760°C~840°C were studied.

2. Material and Experiments

The experimental material is Ti-6Al-2Zr-1Mo-1V forging state bar adding 0.035% Si element produced by Western Superconducting Technologies Co.,Ltd., The diameter of the bar is 350mm, and the phase transition point is 993°C.

The first stage heat treatment temperature is 950°C/2.5h AC or 955°C/2.5h AC, The second stage heat treatment is 760°C/2.5h AC,800°C/2.5h AC,820°C/2.5h AC or 840°C/2.5h AC. The sample numbers and the corresponding heat treatment status are shown in Table 1.

Table1 Sample number corresponding to different Heat treatment status

Sample	Heat treatment condition
A	Forging state sample, heat treatment stage at 840°C
B	the first heat treatment stage at 950°C, the second heat treatment stage at 840°C
C	the first heat treatment stage at 955°C, the second heat treatment stage at 840°C
D	the first heat treatment stage at 955°C, the second heat treatment stage at 760°C

E	the first heat treatment stage at 955°C, the second heat treatment stage at 800°C
F	the first heat treatment stage at 955°C, the second heat treatment stage at 820°C

The test temperature of high temperature tensile is 500°C, the temperature of high temperature duration test is 500°C, the stress is 470MPa.

3. Results and Discussion

3.1 Effect of the first stage heat treatment on microstructure and properties

The optical micrographs of A, B and C samples were shown in Fig.1, and the scanning electron microscopy (SEM) images showed in Fig.2. The content of primary α phase (area fraction) of A, B, C is 60%, 52.4%, 44.6% respectively. After the first stage heating treatment, the primary α phase content decreased 7.6% and 15.4% after the forging state bar heated treatment at 950°C and 955°C, respectively. The thickness of the second α phase becomes thinner and the length increases.

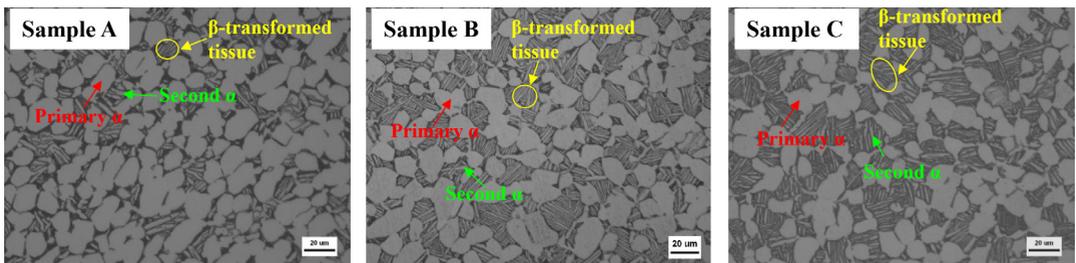


Fig.1 Optical micrographs of A, B and C

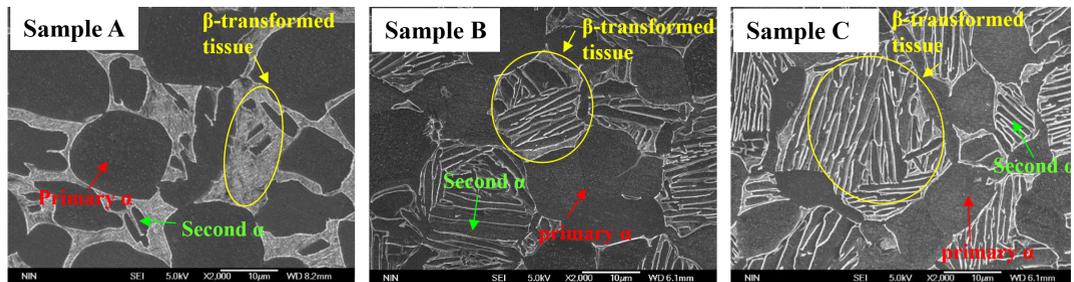


Fig.2 SEM images of A, B and C

Table 2 The mechanical properties of A, B and C

Sample	Rm/MPa	Rp _{0.2} /MPa	A/%	Z/%	High-temperature duration time/h
A	1005	922.5	18.5	41	48.6

B	984.8	902.8	15.8	44.3	76.6
C	971	880	15.8	42.5	98

The mechanical properties of samples A, B and C are shown in Table 2. After the first stage of heat treatment and the second stage at 840°C, the strength of the bar decreased and the high temperature duration time is significantly prolonged. The tensile strength and yield strength of sample B were about 20MPa lower than the sample A, but the change of elongation or surface shrinkage is not obvious, and the duration time is increased by 28 hours. The tensile strength of C sample is about 14 MPa lower than that sample B, and the duration is increased by 21.4 hours.

After heat treatment at 950°C or 955°C, the content of β -transformed tissue increases, which leads to the increasing of dislocation slipping distance and the decreasing of the tensile strength. The high temperature duration time increases with the decrease of the content of primary α phase, which is due to the better durability of β transformation structure than that of primary α phase [3-7].

3.2 Effect of the second stage heat treatment on microstructure and properties

After the first stage of heat treatment at 955°C, D, E, F and C were treated at 760°C, 800°C, 820°C and 840°C respectively. Their 2000× SEM images are shown in Fig.3, the 10000× SEM images are shown in Fig.4, and the mechanical properties are shown in Table 3. The variations of tensile strength, yield and duration time for different temperature are shown in Fig.5, Fig.6.

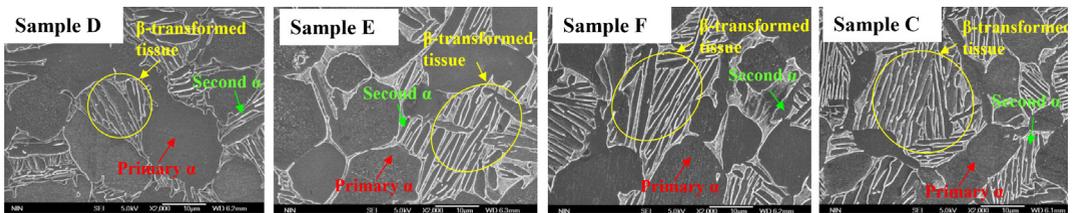


Fig.3 SEM images of D, E, F and C (2000×)

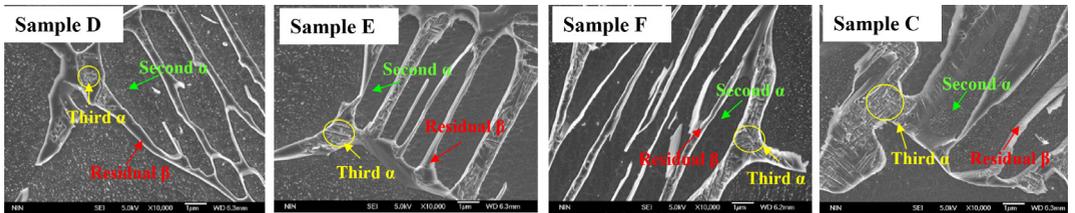


Fig.4 SEM images of D, E, F and C (10000×)

The third α phase precipitates in the residual β phase, after the samples heated in the second stage of heat treatment. From Fig.4, it can be seen that with the increasing of temperature in the second stage of heat treatment, the content of the third α phase increases. As can be seen from Table 3 and Fig.5, Fig.6, the tensile strength and yield strength increases gradually with the increase of heating temperature, and the duration time is significantly prolonged. After heat treatment from 760°C to 840°C, the tensile strength and yield strength at room temperature increase 43.5MPa, 19.3MPa respectively; the tensile strength and yield strength at 500°C temperature increase 36.3MPa, 11.8MPa respectively; and the high temperature duration time increases 40h.

Table 3 The mechanical properties of D, E, F and C

Sample	Rm/MPa	Rp0.2/MPa	A/%	Z/%	500°C Rm /MPa	500°C Rp0.2 /MPa	High-temperature duration time/h
D	927.5	861	17	44	637	497.5	56
E	960.5	881.5	17	42	651.5	493.5	66
F	962	871.5	16.5	44	662.5	501.5	79
C	971	880.3	15.8	42.5	673.3	509.3	96

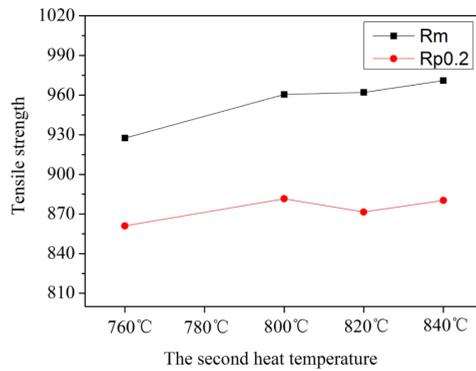


Fig.5 Tensile properties vary with temperature

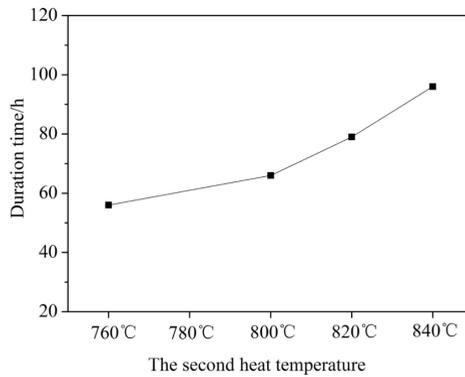


Fig.6 Duration time vary with temperature

3.3 Analysis of rupture fracture

The sample C first stage heat treatment temperature is 955 °C/2.5h AC , and the second stage heat treatment is 840 °C/2.5h AC. The tensile specimen of sample C is fractured by tensile stress at room temperature, and its elongation is 18%. The longitudinal section of the rupture fracture is shown in Fig.7. It can be seen that the primary α -phase and the β -transformed tissue is elongated along the tensile stress direction. There are some holes near the fracture surface, all of which are at the interface of primary α phase and β -transformed tissue, indicating that the holes tend to initiate and expand at the interface of primary α phase and the β -transformed tissue, and cracks are formed when the holes grow and polymerize.

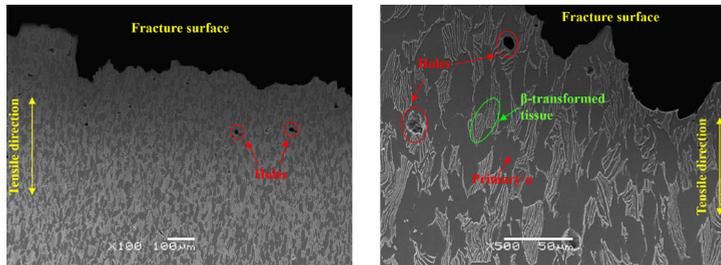


Fig.7 The longitudinal section of the rupture fracture

4. Conclusion

1. After the first stage of heat treatment at 950°C~955°C, the content of primary α phase decreases, and the thickness of the second α tends to thin.
2. After the first stage of heat treatment, the content of the β -transformed tissue increases, which results in the decreasing of the tensile strength and the prolongation of the duration time.
3. With the increasing of heating temperature in the second stage, the content of the third α phase precipitated from the residual β phase increases, the tensile strength increases, and the duration time prolongs gradually.
4. The cracks tend to initiate and propagate at the interface of primary α phase and the β -transformed tissue during tensile test.

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6. References

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