Effect of Cooling Rate on the Structure of Cast Ti-20.5al-15Nb-1Mo Alloy

LiangliangLiu, Dong Liu*, Yuyou Cui, Rui Yang
Institute of Metal Research, Chinese Academy of Sciences, 72 Wenhua Road, Shenyang, Liaoning, 110016, China
*E-mail: dliu@imr.ac.con

Abstract: The structure changes of cast Ti-20.5Al-15Nb-1Mo alloy at different cooling rates heated from the B2 field were analyzed. At the cooling rates of 10, 5 and 2.5 ℃/s, the α 2colony precipitated with a subboundary morphology in the retained B2 phase through metallographic microscope observation. The subboundary morphology precipitation differed from real subboundary structure and consisted of a series of acicular α2 phase with approximately identical orientations through scanning electron observation. At decreased cooling rates of 1, 0.5 and 0.1 ℃/s, the subboundary morphology precipitation disappeared, and the α 2 changes from acicular shape to plate. Reheating the alloy with subboundary morphology precipitation at α2 + B2 field, a kind of fine microstructure with homogeneous α2/O plates and few acicular second α 2/O was obtained.

Keywords:cast microstructure, Ti3Al alloy, cooling rate, subboundary

1 Introduction

With low density, high specific strength, good flame retardancy, excellent oxidation resistance, and creep resistance，Ti3Al alloys are being considered as potential lightweight alloys for aerospace structural parts such as pressurized airplane magazines applied at 600~700 ℃. Althoughthe Ti3Al alloys have been showing excellent mechanical properties after thermomechanical processing, the poor welding property limits their application[1, 2]. The precision cast process is another way to manufacture Ti3Al components without welding, while alloys with the cast process show much weaker mechanical properties compared to thermomechanical processing.

Interestingly, a network of subboundaries characteristic of a polygonization phenomenon occurs in Ti3Al alloy during cooling[3-5]. As fine grain size contributes to both strength and plastic, the fine subboundaries may achieve the same effect. But firstly, we should know the characteristics of subboundaries. In this paper, the structure changes, especially the subboundaries phenomenon, of cast Ti-20.5Al-15Nb-1Mo alloy were identified during cooling.

2 Experimental procedure

The Ti-20.5Al-15Nb-1Mo alloy (hereafter designated as 20.5-15-1)casting rods with a diameter of about 32 mm were hot isostatically pressed (HIPed) at 1020℃ with an applied pressure of 150 MPa for 2 hours.Table 1. shows the composition of the alloy.The specimen forthe thermal simulated test had a diameter of 6mm and a length of 76mm. The specimens were first heated at a rate of 5 ℃/s to 1100 ℃, holding 10 minutes, and then cooled to room temperature at different cooling rates varying from 0.1 to 100 ℃/s inthe GLEEBLE 3800machine. The microstructure was observed on a Zeiss AXIOVERT 200MAT optical microscope (OM) and an FEI Apreo scanning electron microscope (SEM).

Table 1. Composition of Ti3Al Alloy

Al / wt. %	Nb / wt. %	Mo / wt. %	O / ppm	N / ppm	H / ppm	Ti / wt. %
10.7	27.8	1.9	720	90	9	Bal.

3 Result and discussion

3.1 HIPed microstructure

The HIPed microstructure, shown in Figure 1, consists of coarseα_2 plates and acicular second α_2/O phase in retained ordered B2 phase.

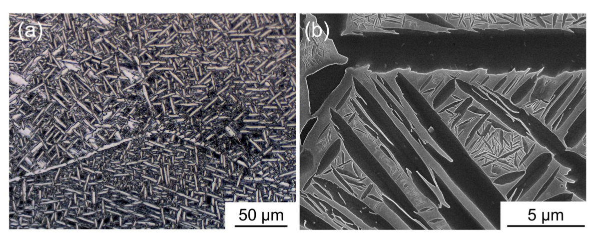

Figure 1. HIPed microstructure of Ti3Al alloy (a) Metallograph, (b) SEM image.

3.2 Effect of cooling rates on metallographic structure

The microstructure changes with different cooling rates from the B2 phase field are shown in Figure 2. The subboundaries phenomenon occurs at cooling rates of 10, 5 and 2.5 ℃/s. The main characteristic of the subboundaries phenomenon is the network precipitation with subboundary morphology in the retained B2 phase. As the cooling rate decreases, the widths of subboundaries increase and more punctiform precipitations appear in the retained B2 phase. When the cooling rate decreases further, the subboundaries phenomenon disappears and acicular α2 appears with no evidence of retained B2.

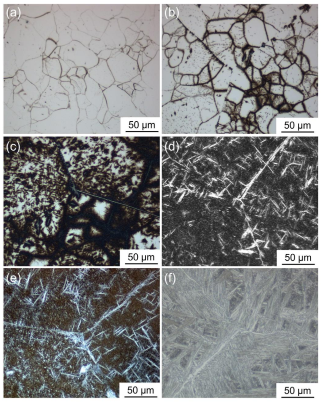

Figure 2. Metallographs of HIPed 20.5-15-1 specimens heated to 1100℃/10min, then cooled at rates of (a) 10℃/s, (b) 5℃/s, (c) 2.5℃/s, (d) 1℃/s, (e) 0.5℃/s, (f) 0.1℃/s.

3.3 Structure of subboundary morphology precipitation

As shown in Figure 3, the precipitation with subboundary morphology consists of a series of acicular α2 phase with approximately identical orientations.And the precipitation colonies are not real subboundaries. When the cooling rate decreases to 5 ℃/s, more α_2 colonies precipitate intermixedly and grow up. Although the reason for precipitation showed subboundary morphology is unclear, it indeed stimulates intragranular nucleation instead of the grain boundary.

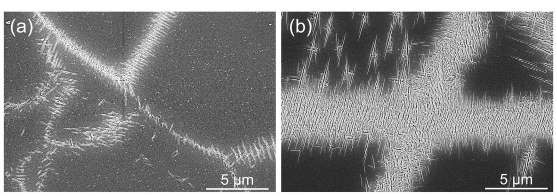

Figure 3. SEM images of HIPed 20.5-15-1 specimens heated to 1100℃/10min, then cooled at rates of (a) 10℃/s, (b) 5℃/s.

3.4 Structure of post heat treatment

Due to the intragranular nucleation of subboundary morphology precipitation, the microstructure of HIPed 20.5-15-1 alloy with 10℃/s cooling rate reheated in 1020℃ consists of fine α_2/O plates and few acicular second α_2/O phase.

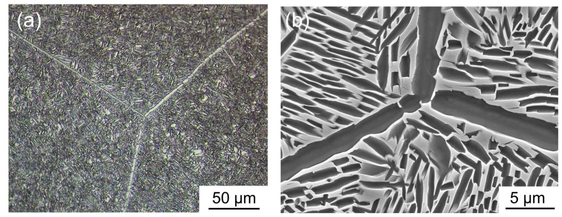

Figure 4. Microstructure of HIPed Ti3Al alloy with heat treatment: 1100℃/10min/10℃/s + 1020℃/1h/furnace cooling (a) Metallograph, (b) SEM image

4 Conclusion

The subboundary morphology precipitation occurs at Ti-20.5Al-10Nb-1Mo alloy at cooling rates of 10, 5 and 2.5 ℃/s heated at 1100℃. Consisting of a series of acicular α_2 phase with approximately identical orientations, the subboundary morphology precipitation has a different structure from the subboundary. The subboundary morphology precipitationstimulates intragranular nucleation and helps to refine the post heat treatment microstructure of Ti-20.5Al-15Nb-1Mo alloy.

References

[1] W. Baeslack, T. Mascorella, T. Kelly. Weldability of a titanium aluminide [J]. Weld. J., 1989, 68(12): 483.
[2] X. Cai, H. Li, L. Wan , et al. Microstructural characterization and mechanical properties of Ti3Al-Nb/Ni-based superalloy laser-welded joints with different type of V/Cu composite interlayers [J]. Optics and Laser Technology, 2023, 157.
[3] W. Cho, A. W. Thompson, J. C. Williams. CREEP-BEHAVIOR OF TI-25AL-10NB-3V-1MO [J]. Metallurgical Transactions a-Physical Metallurgy and Materials Science, 1990, 21(3): 641-657.
[4] S. Djanarthany, C. Servant, R. Penelle. PHASE-TRANSFORMATIONS IN TI3AL AND TI3AL + MO ALUMINIDES [J]. Journal of Materials Research, 1991, 6(5): 969-986.
[5] W. A. Baeslack,T. Broderick. Effect of cooling rate on the structure and hardness of a Ti-26 at% Al-10 at% Nb-3 at% V-1 at% Mo titanium aluminide [J]. Scripta Metallurgica et Materialia, 1990, 24(2): 319-324.