EFFECTS OF TWO-STEP HEAT-TREATMENT ON MICROSTRUCTURE AND PROPERTIES OF TiAl INTERMETALLICS①

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ABSTRACT Special heat-treatment was used to improve the mechanical properties at room temperature of TiAl-based alloys which were isothermal forged (1 050 ℃, 82%). The results showed that proper two-step heat treatment could decrease or eliminate large-grained lamellar structure produced by inhomogeneous deformation, and gain fine, homogeneous duplex microstructure. And the volume ratio of $\gamma:\alpha_2/\gamma$ was about 1:1. The room temperature ductility of the TiAl alloys reached 3. 3% with high strengths.

Key words: interme-allics heat treatment tensile properties

1 INTRODUCTION

Titanium aluminides based on TiAl are of interest as potential aerospace structural materials because of their light weight, relatively good high-temperature mechanical properties and oxidation resistance[1-3]. But their brittleness and poor formability at ambient temperature prevent these alloys being fully utilized in aerospace application. The experimental results showed that the deformation structure of TiAl alloys were not homogeneous even through large ratio (82%) isothermal forging[4]. Original large-grained lamellar microstructure, which causes poor room temperature ductility, was still remained after normal one-step heat treatment. A new two-step heat treatment, however, could gain fine, homogeneous duplex microstructure. One of the reasons was that increasing treatment temperature could promote recrystallization ratio and improve homogeneity. On the other hand, the second treatment, whose heating temperature was lower than the first one, could restrain grains growing rapidly, control α and γ phase volume ratios, thus improve the room-temperature properties of the TiAl alloys.

2 EXPERIMENTAL

The nominal compositions (wt. -%) of experimental alloy were (Ti-33Al-3Cr)-0. 5Mo and Ti-33Al-3Cr. The alloys ingots which were homogeneous-treated and isothermal-forged were heat treated as shown in Fig. 1. The size of tensile test samples was d3 mm × 18 mm. Room temperature tensile test was carried out on a css-112 electronic tensile instrument. And the microstructures were observed and analyzed by optical microscope and X-650 scanning electron microscope (SEM).

3 RESULTS

3. 1 *Room Temperature Mechanical Properties*

The room temperature tensile test results are listed in Table 1.

It can be seen from Table 1 that two-step

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heat treatment, as compared with single step heat treatment, could apparently improve the room-temperature ductility of the TiAl alloys. The tensile elongation rate increases from 1.15% to 3.3%. Meanwhile, the yield strength and the fracture strength were also increased to some degree.

3.2 *Microstructure*

Optical microstructure morphologies of (Ti-33Al-3Cr)-0.5Mo alloy heat treated under single or two-step processes are shown in Fig. 2. The microstructure of Ti-33Al-3Cr alloy is the same as that of the Ti-Al-Cr-Mo alloy. Fig. 2(a) shows that the microstructure of TiAl alloy corresponding to single step heat treatment state is inhomogeneous with regional large-grained unrecrystallized lamellar microstructure. These original large-grained lamellar microstructure were decreased or eliminated by two-step heat treatment. Fig. 2(b) illustrates that the recrystallization microstructure is composed of large-grained equiaxed lath-like lamellar structure and a few of equiaxed γ phase grains. The volume ratio was about 9∶1. The sizes of lamellar grain colony and γ grains were 100～300 μm and 10～25 μm respectively. Changing cooling method, i.e. using Ⅱ scheme, not only large-grained lamellar microstructure was eliminated, but also fine grains were gained. And the volume ratio of α_2/γ lamellar sructure and γ phase grains with the same size about 20～40 μm decreased to 6∶4 (Fig. 2(c)). The similar fine homogeneous duplex microstructure sized 15～20 μm could obtain if decreasing frist heat treatment temperature to 1 280 ℃, i.e. Ⅲ scheme (Fig. 2(d)).

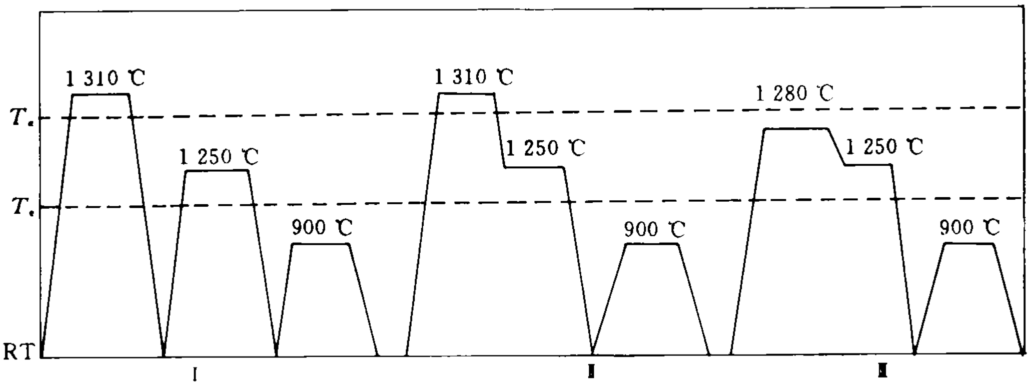

Fig. 1 Two-step heat treatment schemes

T_a—α transus temperature; T_e—eutectoid temperature; RT—room temperature

Table 1 Room temperature tensile properties under different heat treatment state

Sample No.	Composition(wt.-%)	Heat treament	$\sigma_{0.2}$ /MPa	σ_f /MPa	ε_f %
1	(Ti-33Al-3Cr)-0.5Mo	two steps (Ⅰ)	521	583	2.1
2	(Ti-33Al-3Cr)-0.5Mo	two steps (Ⅱ)	590	673	2.4
3	(Ti-33Al-3Cr)-0.5Mo	two steps (Ⅲ)	481	580	3.3
4	(Ti-33Al-3Cr)-0.5Mo	single step (1 250 ℃, 4 h +950 ℃, 6 h)	491	519	1.15
5	Ti-33Al-3Cr	two steps (Ⅰ)	558	605	2.1

4 DISCUSION

Two-step heat treatment could effectively decrease or eliminate original large-grained lamellar grain colony, obtain homogeneous microstructure. Thus, alloys' room-temperature ductility were improved remarkably. But the size of recrystallization grains and the volume ratio of lamellar grains to γ phase grains were controlled by the first heating temperature and subsequent cooling rate.

Fig. 3 schematically illustrated the microstructure evolution under three kinds of two-step heat treatment. If using I and II kinds of heat treatment processings, the samples were first heated to 1 310 ℃, which was in α single phase field ($T_\alpha \approx 1\,300$ ℃), formed α phase solid solution (Fig. 3 I (a), II (a)). Air-cooled to room temperatuer (I), α phase transformed into $\alpha_2 + \gamma$ phases. During this transformation process, α_2 phase was transformed directly from α phase ordering transition. The γ phase precipitated on the {0001} habit plane of α phase, thus forming α_2/γ full lamellar colony structure (Fig. 3 I (b)). These full lamellar structures took place uncontinuously coarsed[5] during the second heating (1 250 ℃), colony size was increased and lamellar distance was thicken with a few of γ

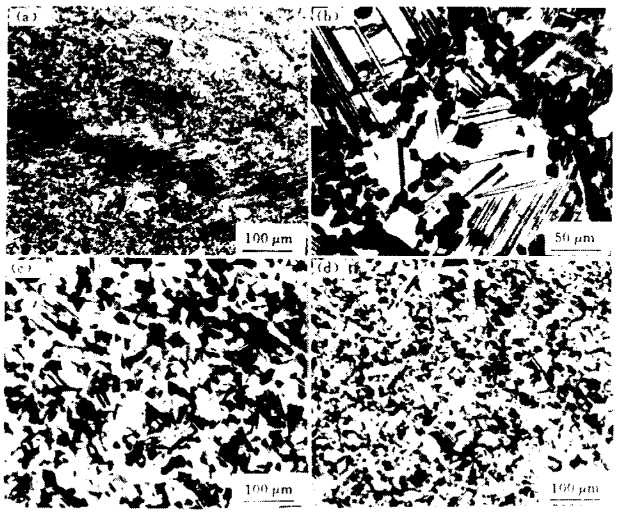

Fig. 2 OM morphologies of (Ti-33Al-3Cr)-0.5Mo alloy under different heat treatment states

AC—Air—cooling; FC—Furnace—cooling

(a) 1 250 ℃, 4 h, FC+950 ℃, 6 h, AC;

(b)—1 310 ℃, 4 h, AC+1 250 ℃, 6 h, AC+950 ℃, 6 h, AC;

(c)—1 310 ℃, 4 h, FC→1 250 ℃, 10 h, AC+900 ℃, 6 h, AC;

(d)—1 280 ℃, 4 h, FC→1 250 ℃, 6 h, AC+900 ℃, 6 h, AC;

phase equiaxed grains precipitating (Fig. 3 I (c)). Adopting Ⅱ processing, the alloys were furnace cooled from 1 310 ℃ to 1 250 ℃, then retained at 1 250 ℃ for several hours. There were two kinds of morphologies of γ phase precipitating from α solid solution. One formed lamellar structure with α phase, another of γ equiaxed grains. The existence of γ equiaxed grains could effectively prevent the coarsening of lamellar grains colony (Fig. 3 Ⅱ (b)). During subsequent cooling process, α phase remained transformed to $\alpha_2 + \gamma$ phase. Finally gained duplex microstructure composed of α_2/γ lamellar grains colony plus γ equiaxed grains. And the size of colony was remarkably finer than that of the I processing (Fig. 3 Ⅱ (c)). Adopting the third (Ⅲ) heat treatment method, the first heating temperature was slightly lower than T_α. The equilibrium phases of TiAl alloy were about 85% α phase and 15% γ phase at this temperature. These two phase nucleated and growed in deformation structure respectively. But the growth of α phase was faster, and its amount as compared with γ was larger. All these were due to the fact that α phase was disordered phase (Fig. 3 Ⅲ (a)). When furnace cooled to 1 250 ℃, α phase percent decreased to about 50 percent. At this time, original γ phase grew as the leading phase of new precipiated γ phase. Since the existence of equiaxed phase γ grains, the rapid growth of α phase was restrained. During sebsequent cooling process, α phase left took place $\alpha \rightarrow \alpha_2 + \gamma$ dissociated reaction,

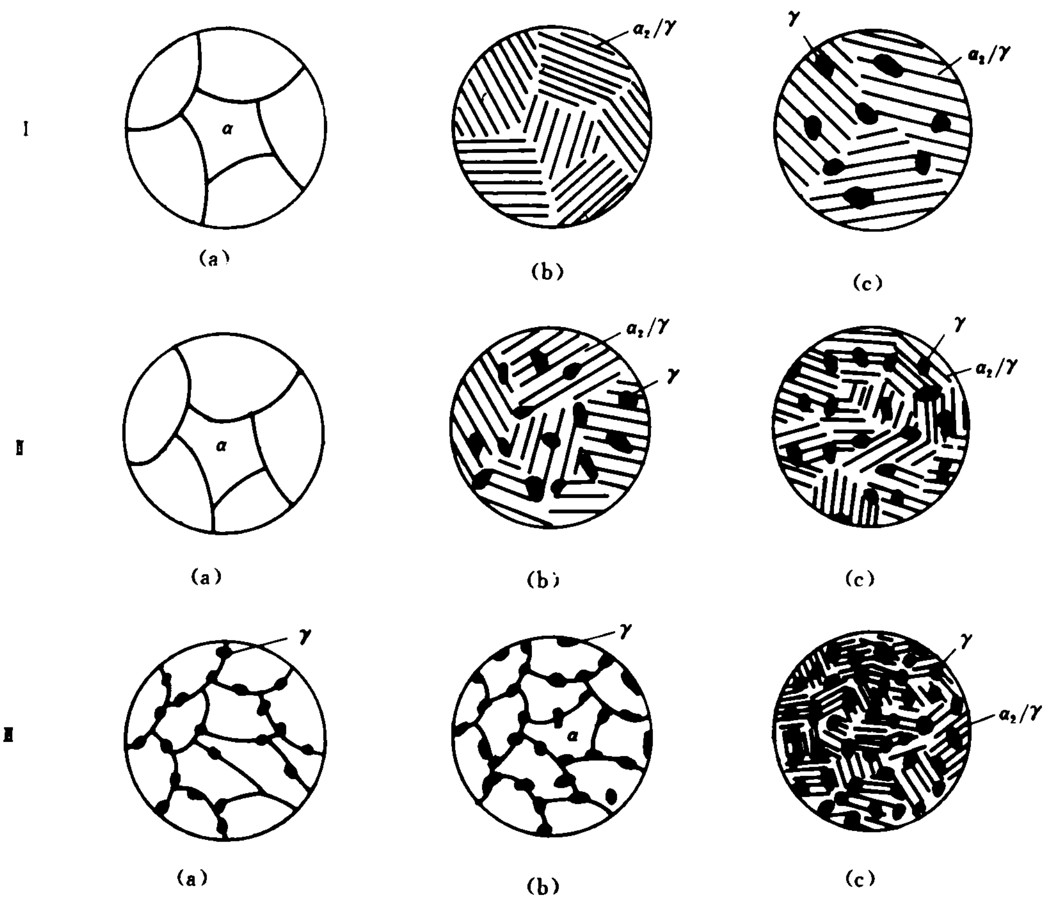

Fig. 3 Schematic drawing of microstructure formation under different two-steps heat treatment

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nism (1), microcracks initiate along the TA2/A3 interface and link up under tensile load. The final cleavage fracture of the specimen takes places mainly in the recrystallized and grain abnormal growth regions on the A3 side in the vicinity of TA2/A3 interface. Localized fracture takes place along the interface molten layer.

(b) No cracks nucleation and propagation inside the adiabatic structure and ASB, on the TA2 side of TA2/A3 interface are observed under tensile load at room temeprature.

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formed α_2/γ grains. Thus fine duplex microstructure composed of α_2/γ lamellar strucutre and equiaxed γ phase grain with same volume fraction was obtained (Fig. 3 Ⅲ (c)).

5 CONCLUSIONS

(1) Two-step heat treatment can decrease or eliminate large untransformed lamellar structure. Suitable first heaing temperature and cooling rate can gain homogeneous, fine duplex microstructure with the same volume fraction of equiaxed γ grains and α_2/γ lamellar structure.

(2) TiAl alloy room-temperature tensile properties can be remarkably improved by two-step heat treatment, and room-temperature ductility reached 3.3%.

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