EFFECT OF Sb ADDITION ON MICROSTRUCTURE AND MECHANICAL PROPERTIES OF TiAl INTERMETALLIC COMPOUND①

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ABSTRACT

The effect of Sb addition on the microstructures and room-temperature mechanical properties of Ti-34 wt.-% Al alloy was investigated. The experimental results showed that the microstructure of Ti-34 wt.-% Al alloy changed from as-cast coarse columnar into narrow columnar grains due to Sb addition, and that the room temperature bending strength and ductility of TiAl+Sb alloy were relatively high compared with those of the binary alloy. Fractograph analysis exhibited that the crack could propagate in single γ phase and there were more tear ridges in TiAl+Sb alloys.

Key words: Sb microstructure TiAl intermetallic compound

1 INTRODUCTION

Titanium Aluminide is a candidate material for advanced aerospace airframe because of its low density, good oxidation resistance and high mechanical strength at high temperature. However, its lower ductility and poor hot work formability[1-4] have been hindering its engineering use.

Alloying is an effective way to improve the room temperature ductility of TiAl based alloy. The effects of elemental additions, including V[5], Cr[6], Mn, Nb[7,8], Ag[9] and Er[10] etc, on the TiAl based alloy had been studied. It was reported that V, Cr, Mn could improve the ductility of TiAl based alloy, but oxidation resistance at high temperature was also deteriorated. Therefore, further research on the alloying effect of TiAl alloy is expected. In the present research the microstructure and mechanical properties of TiAl+Sb alloys were investigated and also the reasons why Sb addition can improve the mechanical properties of the alloys were discussed with micrograph and fractograph.

2 EXPERIMENTAL

The alloys studied in this work were prepared from Ti of 99.6%, Al of 99.7% and 99.0% Sb (by weight)purity by nonconsumable arc-melting technique in an argon atmosphere. The nominal composition of the studied alloys was showed in Table 1. Three point bending specimens were spark eroded from the ingots. The specimen's size was 2 mm × 4 mm × 30 mm. Three specimens of each condition were tested at room temperature. The span length was 25 mm and the cross head speed of test machine was 0.2 mm/min.

The metallographic samples were prepared in a standard fashion and etched with the kroll's solution. The microstructures and fracture morphologies were analysed by Nephot- Ⅱ type optical microscope and X650 type scanning electron microscope, respectively. Rigaku 3014 type X-ray diffractome-

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ter was used for phase constitutent and crystal structure analysis.

Table 1 Chemical composition of TiAl based alloys

Number	Chemical composition (wt. -%)
1	Ti-34Al
2	(Ti-34Al)-0.2Sb
3	(Ti-34Al)-0.4Sb
4	(Ti-34Al)-0.5Sb
5	(Ti-34Al)-1.0Sb
6	(Ti-34Al)-1.5Sb
7	(Ti-34Al)-2.0Sb
8	(Ti-34Al)-2.5Sb

3 EXPERIMENTAL RESULTS AND ANALYSIS

The effect of Sb addition on mechanical properties of TiAl based alloy is shown in Fig. 1. It can

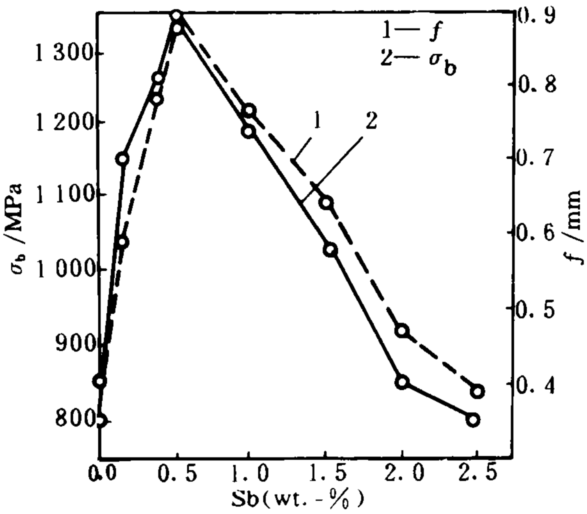

Fig. 1 The effect of Sb addition on the mechanical properties of Ti-34 wt. -% Al alloy

be seen that the room temperature bending strength and deflection of TiAl based alloy increase largely by a little Sb addition. But they don't vary monotonely with Sb content. The bending strength and deflection of (Ti-34Al)-0.5Sb alloy weight percent; same as following are maximum. Its fracture strength is 1 345 MPa and deflection is 0.90 mm. The bending strength of (Ti-34Al)-0.5Sb inceases by 68.1% and deflection by 125%, compared with the binary Ti-34 Al alloy.

Fig. 2 shows the metallographs of as-cast TiAl based alloys samples added with different Sb contents. It can be seen that the microstructure of Ti 34 Al alloy is with coarse columnar lamellar grains. Width of which is about 2 mm (as shown in Fig. 2(a)). Microstructures of as-cast TiAl+Sb alloys still belong to columnar grains, yet the columnar grain widths of the alloys become narrow, for example, the width of (Ti-34Al)-0.2 Sb alloy is only about 0.39mm, as shown in Fig. 2(b). The dependence of the columnar width of as-cast TiAl +Sb alloys on the Sb addition is given in Fig. 3. It can be seen that the columnar grains of (Ti-34Al)-0.5 Sb are the finest.

SEM was used in microstructure analysis in order to further understand the effects of Sb addition on the TiAl based alloys, and these results were shown in Fig. 4. It can be seen from Fig. 4(a) that the microstructure of (Ti-34Al)-0.2 Sb is still with lamellae which consist of α_2 and γ plates. There are few equiaxed grains which are proved to be single γ phase by TEM. The chemical compound of the equiaxed grain indicated by "A" letter is 48.9% Al and 51.3% Ti by weight percent. When 0.5 wt. -% Sb is added, as shown in Fig. 4 (b), the plates of lamellar grains are the finest. The third phase particles appear in microstructure when Sb is added up to 2.5 wt. -%. Because these particles exist inside lamellar grain (shown in Fig. 4(d)), it can be deduced that these particles are not low melt-point phase. EDAX in SEM result shows that the chemical composition of the third phase particles is 45.0% Ti, 17.5% Al and 37.5% Sb (by weight percent), as shown in Fig. 5. Moreover, EDAX area analysis shows that Sb element distributed homogeneously inside lamellar grains for the lower Sb-contained alloys.

Fig. 6 shows the morphologies of the fracture surface of TiAl based alloys with different contents of Sb. It can be seen that the fracture of Ti-34 wt. -% Al alloy is characterised by cleavage and the fracture surface is generally vertical to the direction of lamellae structure. However, there are some cracks extending into single γ phase except of cleavage cracks of lamellar structure for (Ti-34Al)

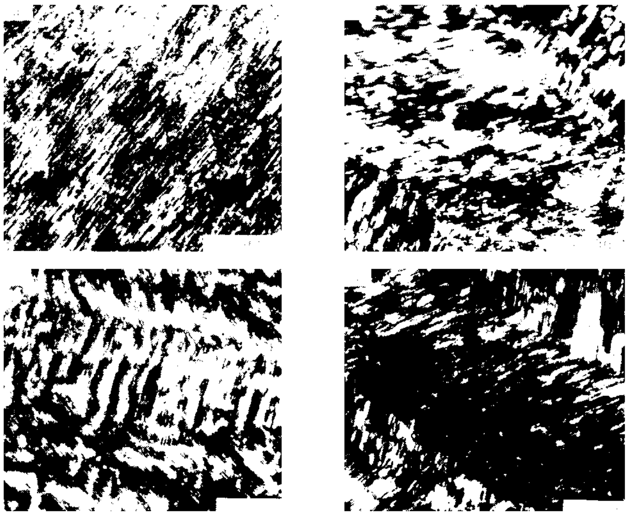

Fig. 2 Micrographs of Ti-34 Al alloys added by 0(a), 0.2(b), 0.5(c) and 1.5(d) wt.-% Sb

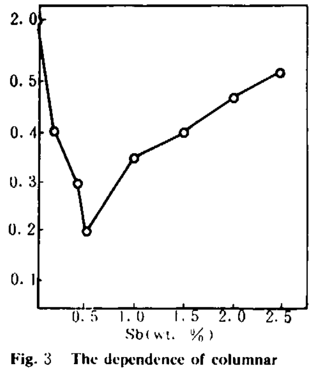

Fig. 3 The dependence of columnar width of TiAl+Sb based alloys on the amount of Sb addition

-0.5 wt.-% Sb, as shown in Fig. 6(b). The tear ridges increase and height between both next cleavage planes increases with the Sb content up to 0.5 wt.-%, the phenomena of crack extending inside single γ phase is more evident, and it is easy to see that there are some pitfall zones and curve tear ridges, which are of the characteristics of quasi-cleavage fracture, as shown in Fig. 6(c). In the fractograph of as cast (Ti-34Al)-2.5 Sb alloy, cracks both perpendecular to lamellae and extending in single γ phase can be found (shown in Fig. 6(d)). Fig. 7 shows the X-ray diffraction spectras of TiAl + Sb alloys. Because the amount of the third phase is too little, no diffraction peak of it can be detected in these TiAl+Sb alloys.

4 DISCUSSION

As mentioned above, the room-temperature mechanical properties of TiAl alloy can be improved by Sb. According to the microstructure

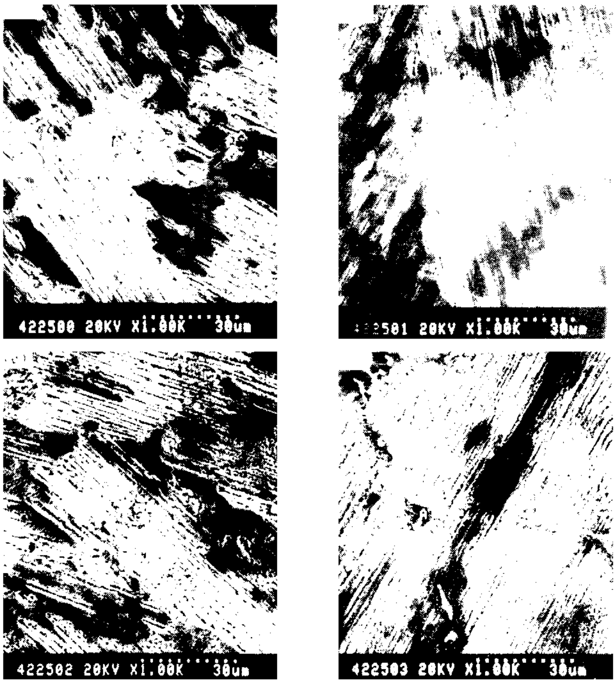

Fig. 4 SEM micrographs of TiAl based alloys added with 0. 2(a), 0. 5(b), 1. 5(c) and 2. 5(d) wt. % Sb

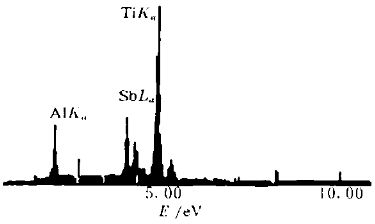

Fig. 5 EDAX analysis result of "A" area in Fig. 4(d)

analysis, the reasons are believed to be its microstructural refining effect, and in addition to solution strength. When Sb content is 0. 5 wt. -%, the columnar of lamellar structure grains of as- cast TiAl+Sb alloy is the finest so that it has the best ductility and highest strength. Binary TiAl based alloy exhibites full cleavage fracture and crack surface is vertical to the lamellar direction. When the TiAl based alloy is added with a little of Sb, the angle between crack surface and lamellar direction increases, and there are more tear ridges as shown in Fig. 6(b d), that is the fracture model changed from pure cleavage into quasi- cleavage with Sb

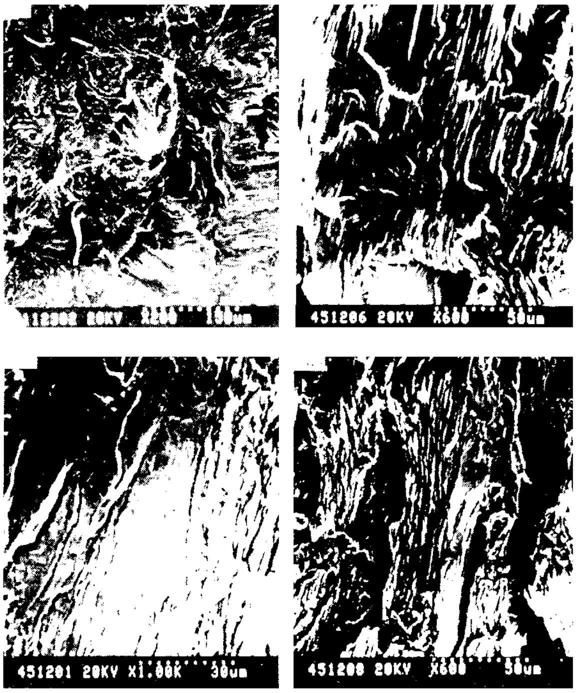

Fig. 6 SEM micrograps of fracture surface of TiAl based alloys added with 0(a), 0.5(b), 1.0(c), 2.5(d) wt. % Sb

addition, so the ductility might be improved. However, when the Sb addition is over 2.5 wt.-%, the mechanical properties debase, because of the formation of brittle third phase particles. The microstructure refining effect of Sb is thought to be due to two reasons. First, the increase of nucleation sites by Sb addition makes the grains growing along the maximum temperature gradient increase and the side direction growth of grains is depressed. On the other hand, the liquidus face of the TiAl based alloy becomes steep with Sb addition and the large composition undercooling zone forms in front of solid phase, which promotes the growth speed of grains along a direction.

5 CONCLUSION

(1) The room temperature bending strength and ductility of TiAl based alloy can be improved largely by Sb addition.

(2) Sb addition can refine the microstructure of TiAl based alloy, which is mainly responsible for the mechanical properties improvement.

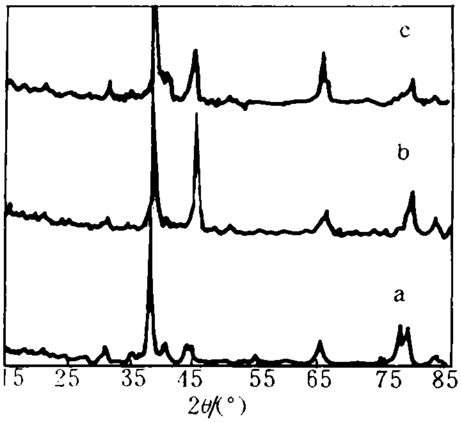

Fig. 7 X-ray diffraction diagrams of TiAl based alloys added with 0(a), 0.5(b) and 1.5(c) wt.-% Sb

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