EFFECT OF Pb ADDITION ON TiAl BASED ALLOYS①

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ABSTRACT

The effects of Pb addition on the mechanical properties, microstructure, crystal structure and fracture characters were investigated. It has been found that the room-temperature mechanical properties of TiAl based alloy can be improved by Pb addition, the reasons for which have been explained based on the changes in microstructure and fracture characters with Pb addition.

Key words: TiAl intermetallic compound alloying room temperature mechanical properties

1 INTRODUCTION

Titanium aluminide (TiAl) is under investigation as candidate material for advantageous aerospace airframe because of its low density and relatively good mechanical properties at high temperature. The major obstacles for engineering use are its low tensile ductility at ambient temperature and poor formability by hot working. The previous studies for the alloy are mainly on the alloying[1-3], microstructure[4-6], heat treatment[7], crystal structure[8-10], fracture morphology, hot working[13]. The research of alloying for TiAl based alloys focused on the addition of V[14], Cr[15], Mn, Nb[3,9], Ag[2] and Er[16,17] elements in order to raise their room temperature ductility. But in the present work, the effect of Pb addition on TiAl based alloy was studied.

2 EXPERIMENTAL

The alloys used in this work were prepared from Ti of 99.9%, Al of 99.7%, Pb of 99.0% (by weight) purity by non-consumable electrode arc-melting in an argon atmosphere. The nominal composition of the studied alloys are shown in Table 1.

Table 1 Nominal composition of studied alloys

Alloys Number	Nominal Composition /wt.-%
1	(Ti-34.1Al)-0.5 Pb
2	(Ti-34.1Al)-1.0 Pb
3	(Ti-34.1Al)-1.5 Pb
4	(Ti-34.1Al)-2.0 Pb
5	(Ti-34.1Al)-0 Pb

Three-point bending specimens were spark eroded from the ingots. The specimens size was 2 mm × 4 mm × 30 mm. Three specimens of each series were tested at room temperature. The span length was 25 mm and the cross head speed of the testing machine was 0.2 mm/min. The metallographic samples were prepared in a standard fashion and

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etched with the kroll solution. The microstructures and fracture morphologies were analysed by means of a scanning electron microscope.

3 RESULTS

Fig. 1 shows the results of bending test at room temperature for as-cast TiAl based alloys added with Pb. It can be found that the bending strength of the Pb-added TiAl specimens increases by 15 percent when the Pb content is 0. 5 wt. -% compared with the binary TiAl specimens. However, strength decreases with the further increase of Pb addition, but is still higher than that of the binary TiAl alloy. Fig. 1 also shows that the bending deflection and ductility of as-cast TiAl based alloys at room-temperature are improved by the Pb addition. Therefore, it can be concluded that the combined mechanical properties of TiAl based alloy are increased by the Pb addition.

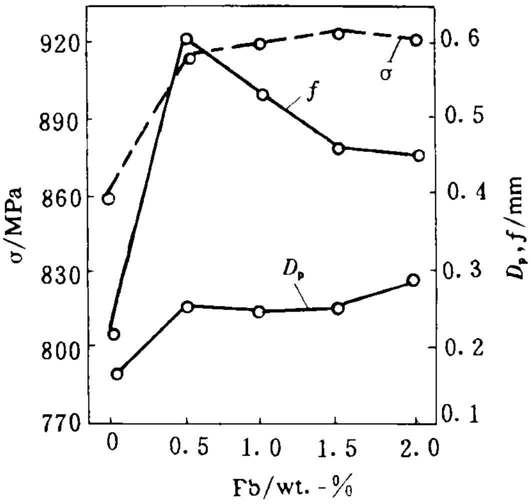

Fig. 1 Effect of Pb addition on bending strength σ, deflection *f* and bending ductility D_p of as-cast Ti-34 wt. -%Al alloys added with Pb

Fig. 2 shows the metallographs of as-cast TiAl based alloys samples with different Pb contents. It can be seen that the microstructure of Ti-34 wt. -% Al is the coarse columnar grains, which accedes to ref. [18]. However, the microstructure of the as-cast (Ti-34 wt. -% Al)-0. 5 wt. -% Pb alloy consists of fine equiaxed full lamellar grains, the average diameter of which is 50 μm, as shown in Fig. 2(b), without third phase being. The size of grains of the lamellar structure does not change with the further increase of Pb content when the Pb content is over 1. 0 wt. -%, but the lamellar thickness increases, as shown in Fig. 2(c). A little of the third phase shaped as triangle blocks can be found in this photograph. The thick lamellae can be seen as the amount of Pb addition increases to 1. 5 wt. -%, and it is observed that this lamellar structure branches, as shown in Fig. 2 (d). The amount of third phase increases with increasing Pb content and it exists along the grain boundary.

SEM was used in microstructure analysis in order to further understand the effects of Pb addition on the TiAl based alloys, and these results were shown in Fig. 3. It can be seen from Fig. 3(a) that(Ti-34 wt. -% Al)-0. 5 wt. -% Pb is with an intact lamellar structure. But Widmanstattan structure, which is doliphinlip-like, is seen in the alloy added with 1. 0 wt. -% Pb, as shown in Fig. 3(b). The Widmanstatten structure consists of α_2 phase (Ti_3Al) and γ phase matrix.

In (Ti-34 wt. -% Al)-1. 5 wt. -% Pb alloy, the α_2 phase in the form of thin stripe distributes in the γ matrix. As the amount of Pb addition increases to 1. 5 wt. -%, the length of α_2 phase decreases further.

In this research, the phase constitution and crystal structures were analysed by X-ray diffraction spectra. The results were shown in Fig. 4.

Almost no diffraction peak of the third phase can be detected in the TiAl based al-

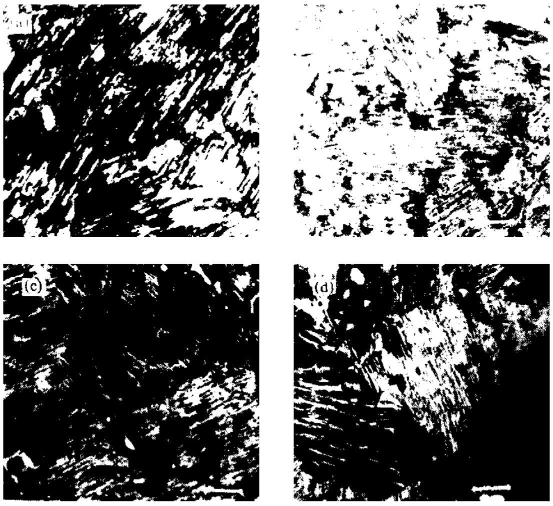

Fig. 2 Optical micrographs of as cast microstructure of alloys added with
(a)—None Pb, ×200; (b)—0.5 wt.-%Pb, ×100;
(c)—1.0 wt.-%Pb, ×100; (d)—1.5 wt.-%Pb, ×100

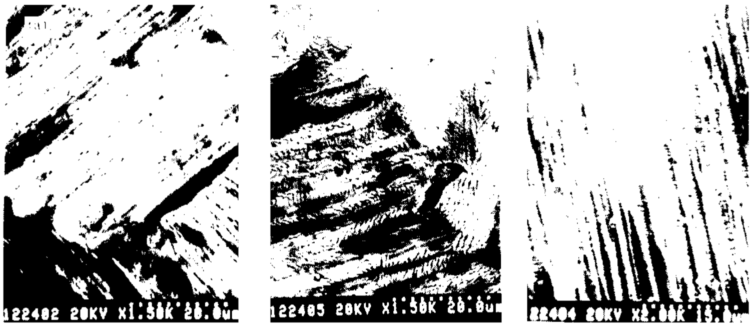

Fig. 3 Scanning electron microscope images of Ti-34 wt.-% Al alloys added with
(a)—0.5 wt.-%Pb; (b)—1.0 wt.-%Pb; (c)—1.5 wt.-%Pb

loys added with 1.0 and 2.0 wt.-% Pb, which indicates that the amount of the third phase is very little. But the third phase has been dectected with EDAX of SEM. The re-

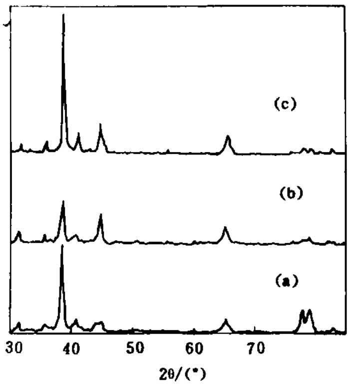

Fig. 4 X-ray diffraction spectra for samples of Ti-34 wt. -% Al alloys added with 0(a), 1. 0(b) and 2. 0(c)wt. -% Pb

sults show that its composition is Ti∶Pb = 1∶1 (by weight) without Al element, from which it is deduced that the third phase is Pb-Ti_4. It can also be seen from the test results that the distance between diffraction peaks of γ (002) and γ (200) of (Ti-34 wt. -% Al)-1. 0 wt. -% Pb alloy becomes shorter compared with that of the Ti-34 wt. -% Al alloy. When the amount of Pb increases to 2. 0 wt. -%, the distance decreases further. This means that Pb addition results in the reduction of the c/a ratio of γ phase, and the ratio decreases with the increase of Pb content. Fig. 5 shows the morphologies of the fracture surface of TiAl based alloys with different contents of Pb. It can be seen that the crack of Ti-34 wt. -% Al-alloy is of cleavage and the crack surface is generally vertical to the direction of lamellar structure. However, the angle between crack surface and the direction of lamellar structure for (Ti-34 wt. -% Al)-0. 5 wt. -% Pb is not 90 C. There are some tear ridges in fracture surface of this alloy, as shown in Fig. 5 (b). As the amount of Pb addition increases to 1. 5 wt. -%, a part of the crack surface is perpendicular to the direction of the lamellar structure, and the other part shows some short and curve tear ridges, radioactive-ray-like pattern and pitfall zones, with the characteristics of quasi-cleavage fracture.

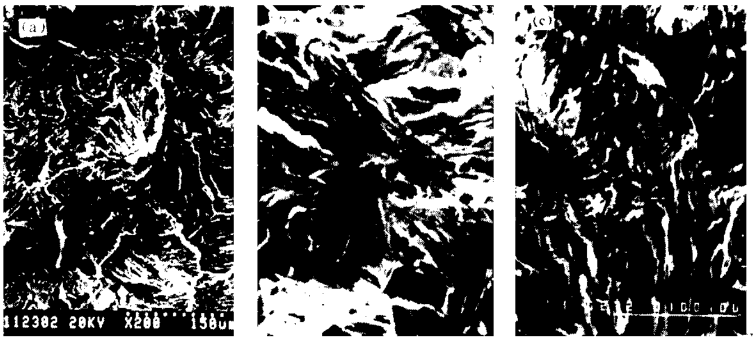

Fig. 5 SEM fractographs of Ti-34 wt. -%Al alloys with
(a)— No Pb; (b)—0. 5 wt. -%Pb; (c)—1. 5 wt. -% Pb

4 DISCUSSION

It is known that the room-temperature mechanical strength and ductility of TiAl+Pb ternary alloys are higher than those of TiAl binary alloy from Fig. 1. The reasons are believed to be that their microstructure changes into fine equiaxed grains from coarse columnar grains in TiAl binary alloy and the c/a ratio of γ phase decreases with Pb addition. It can be seen from Fig. 5(a) that the TiAl based binary alloy shows full cleavage fracture and the crack surface is vertical to the lamellar direction. When the TiAl based alloy is added with a little Pb, the angle between crack surface and lamellar direction increases and there are some tear ridges, as shown in Fig. 5(b). When the amount of Pb addition increases to 1.5 wt.-%, the fracture surface shows the characteristics of quasi-cleavage crack.

5 CONCLUSIONS

(1) The combined mechanical properties of TiAl based alloy at room temperature can be improved by Pb addition.

(2) The microstructure of as-cast TiAl+Pb alloys shows fine equaxied grains.

(3) Almost no third phase except γ and α_2 is detected in the TiAl based alloys with 0.5 wt.-%~2.0 wt.-%Pb by means of X-ray diffraction.

(4) TiAl+Pb alloys exhibit the characteristics of quasi-cleavage fracture.

(5) The c/a ratio of γ phase decreases with Pb addition.

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