PLASTIC DEFORMATION OF TiAl INTERMETALLICS WITH Mn ADDITION①

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ABSTRACT

The dislocation structures of arc-melted, near-equiatomic TiAl alloys containing 1.5–2.0 wt.–% manganese were analysed and compared with those of binary TiAl alloy processed in a similar fashion. It was found that the pinning effect of a / 6 [112] partial dislocations was eliminated by Mn addition, as a result, the movement of a[101] and a / 2[112] superdislocations and twinning and played an important role in the plastic deformation and increased the ductility of TiAl alloys. In addition, the workability of the Mn–ductilized TiAl alloy was evaluated with hot extrusion and forging.

Key words: TiAl alloys, Plastic deformation, dislocation structure

1 INTRODUCRION

In recent years there has been an interest in intermetallic phases with respect to materials developments for high-temperature applications[1]. Titanium aluminide (TiAl) is under investigation as candidate materials for advanced aerospace airframe and propulsion components[2]. Like other intermetallics, TiAl exhibits high modulus retention with temperature and enhanced creep resistance. The low density of TiAl makes it particularly attractive when compared to superalloys on a strength / weight basis of if its low-temperature ductility can be improved[3,4].

It has been reported[5] that a small Mn addition can improve the ductility of TiAl alloys at room-temperature. This paper discusses the effects of Mn–addition on the plastic deformation of TiAl based on the comparison of the dislocation structure of TiAl and TiAl+Mn alloys. Several possibilities were proposed to explain the improvement of ductility of TiAl by Mn addition at room-temperature. In addition, the workability of TiAl+Mn alloys was evaluated by hot extrusion and forging.

2 EXPERIMENT

The alloys of TiAl and TiAl+Mn were prepared by nonconsumable arc-melting in an argon atmosphere. The TEM specimens of dia. 2.9 mm × 0.4 mm were sliced off from the annealed ingots by electrodischarge machining and mechanically prethinned to about 0.1 mm thick. The final thinning was conducted by the twin-jet technique. All thin foils were examined in a Hitachi H–800 electron microscope operated at 200 kV.

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The TiAl+2.0 wt.−% Mn specimens of dia.25 and dia.6 mm were cut from the ingots and put in steel cans for hot extrusion and forging respectively.

3 RESULTS AND DISCUSSION

3.1 *Deformed Substructures*

The ordinary dislocations with Burgers vector of a / 2[110] were commonly observed in slightly deformed TiAl. With the increase of deformation these ordinary dislocations appeared in the form of networks and cell structure (Fig.1) which had little role in the plastic deformation. A lot of faulted dipoles were found on deformed TiAl and their density increased rapidly with plastic deformation (Fig.2). Under the same conditions, the deformation substructures of the ductilized ternary TiAl+Mn alloy had three different characteristics from the binary TiAl alloy. Firstly, the faulted dipoles were no longer observed; and secondly, much more stacking fault bands formed (Fig.3) and finally , a lot of twins ocurred (Fig.4). Hug et al[6] studied the details of the dissociation of superdislocations, including [101] and a / 2 [112] types, in Ti−54Al alloys. They reported that these superdislocations formed faulted dipoles which were extrinsic

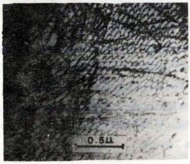


Fig.1 Dislocation networks in slightly deformed TiAl alloy

and bordered by a / 6[112] type partial dislocations. However, our observation and analysis indicated that the faulted dipoles observed in Ti−50Al alloy were intrinsic and were also bordered by a / 6[112] type partial dislocations[7]. All observed faulted dipoles unexclusively formed on the slip planes of {111} .

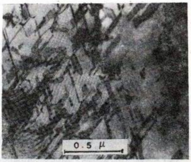


Fig.2 Faulted dipoles in deformed binary TiAl alloy

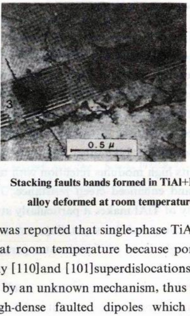


Fig.3 Stacking faults bands formed in TiAl+Mn alloy deformed at room temperature

It was reported that single-phase TiAl was brittle at room temperature because portions of many [110]and [101]superdislocations were pinned by an unknown mechanism, thus forming high-dense faulted dipoles which were boredered by a / 6[112] type partial dislocations[3]. It was shown later that the pinned superdislocations overcame their barriers and the faulted dipoles disappeared at about 700 ℃. And at higher temperatures TiAl was well-behaved and exhibited considerable plasticity[4]. It can be seen that the faulted dipoles are closely related to the plastic deformation behaviours of TiAl intermetallic compound. In this study, as mentioned above, a small Mn addition seemed to eliminate much of the pinning effect of a / 6[112] partial dislocations at room temperature and enhanced the mobility of superdislocations. As a result, the ductility was improved.

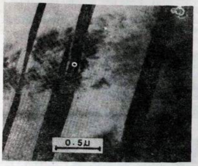


Fig.4 TEM image of the deformation twins in TiAl+Mn alloys

The stacking fault bands have been identified as the overlapping stacking faults from their contrast characteristics[8]. The closely spaced overlapping faults on parallel {111} planes cause the fringes to shift because the phase angle gap is $\pm 2/3\pi$ when one more stacking fault overlaps, (see Fig.3 at 3)and every third set of fringes show zero contrast since $\alpha = 3n \times 2/3\pi = 2n\pi$, (see Fig.3 at 3). These overlapping stacking faults are actually the embryos of deformation twins and are thought to be produced by a spiral source of twinning dislocation[9].

Mn-addition not only decreased the stacking fault energy of TiAl[5], but also, as mentioned above, enhanced the mobility of a / 6[112] partial dislocations which are also twinning dislocations. Therefore, twinning increased importance as a deformation mode and made a significant contribution to the increase of ductility.

3.2 *Workability Evaluation of the* Mn *Ductilized* TiAl *Alloys*

Since the ductility of TiAl alloys has been improved by the addition of a suitable amount of Mn, The TiAl+ 2.0 wt.−% Mn specimens are extruded and forged at elevated temperatures in order to test their workability. Fig.5a shows the rods with different extrusion ratios. It has been found that at a suitable extrusion rate, almost no-crack products can be obtained with the extrusion ratio smaller than 6 at about 1,250 ℃. The typical optical micrograph of the extruded alloy is shown on Fig.6a.

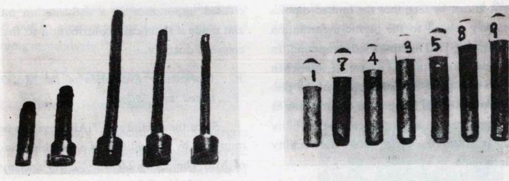
Fig.5b is a picture of the hot forged specimens. A forging elongation of 28% was obtained at 1,100 ℃ without any cracks on the surface of specimens. Fig.6b shows the microstructures of the specimen on the longitudinal section.

From Fig.6 it can be seen that TiAl grains were evidently elongated after extrusion or forging.

4 CONCLUSIONS

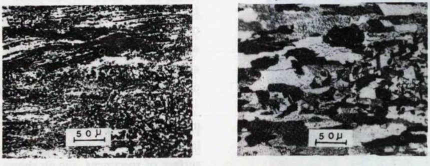
a. In view of deformation substructures, the ductility improvement of TiAl by Mn−addition is associated with enhancement of the movement of a / 6[112] partial dislocations and superdislocations as well as the twinning process.

b. TiAl+2.0 wt.−% Mn alloy can be processed by hot extrusion or forging with selected processing parameters.



a——Extruded b——Forged

Fig.5 Pictures of the hot extruded and forged TiAl+Mn alloy rods



a——Extruded b——Forged

Fig.6 Optical micrographs of the longitudinal section of the hot extruded and forged TiAl+Mn specimens

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