DYNAMIC RECRYSTALLIZATION IN SUPERPLASTIC DEFORMATION OF TiAl BASED ALLOY①

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ABSTRACT Dynamic recrystallization has great effect on the superplastic deformation and hot working of TiAl based alloys. Through TEM analyses, the dynamic recrystallization in Ti-33Al-3Cr-0.5Mo alloy after superplastic deformation was studied. The results show that, dynamic recrystallization which occurs not only in grain boundaries but also inside grains can remarkably refine grains. It is deduced that, dynamic recrystallization can be resulted from grain boundary sliding, and which can be enhanced by dynamic recrystallization.

Key words TiAl based alloy dynamic recrystallization superplastic deformation

1 INTRODUCTION

Superplasticity of TiAl based alloy has attracted more and more attention[1-3]. It has been found that, dynamic recrystallization is a common phenomenon in the superplastic deformation of TiAl based alloys[1,4,5], which also occurs in other high temperature deformation of this material[6,7]. Therefore, a detailed study on the dynamic recrystallization of TiAl based alloy will help to clarify the microstructure evolution and superplasic deformation mechanism during superplastic deformation of this material, and will have importance in hot working such as hot rolling, hot forging of TiAl based alloys. Through optical microscopy and TEM, the microstructures of TiAl based alloy after superplastically tensile deformation were studied in detail; the nucleation and growth mechanism of dynamic recrystallization and the relationship between dynamic recrystallization and superplastic deformation had also been discussed.

2 EXPERIMENTAL

The nominal composition of the experimental alloy is Ti-33Al-3Cr-0.5Mo (mass fraction, %), which was prepared with consumable arc melting technique. After homogenization annealing at 1 050 ℃ for 48 h in vaccum and HIPping, the ingot underwent a new thermomechanical treatment —rapid canned forging[8], and the final heat treatment temperature was 1 250 ℃. The gauge dimension of superplastic test samples was d 5 mm × 20 mm. The samples were superplastically tested under following conditions: equal tensile rate of attachment, initial strain rate of $3.59 \times 10^{-4} s^{-1}$, deformation temperature of 1 000 ℃.

The specimen for optical micrograph observation was prepared by standard method, and was etched in Kroll's solution. The microstructure of the specimen was then observed with Neophot-II type optical microscope. The foils for TEM observation were twin-jetted under condition of −40 ℃, 7~10 mA, 45 V in an electrolyte of 70 mL alcohol+ 120 mL methanol+ 100 mL butane-1-01 and 80 mL perchloricacid. The foils were observed with H800 transmission electron microscope operated at 175 kV.

3 RESULTS AND DISCUSSION

After thermomechanical treatment and sub-

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sequent heat treatment, TiAl based alloy shows duplex microstructure with a mean grain size of 9.8 μm, as shown in Fig. 1. At 1 000 ℃ and a strain rate of $3.59 \times 10^{-4} s^{-1}$, the sample fractured at an elongation of 305%, microstructure of homogeneously deformed part is shown in Fig. 2. Obviously, the microstructure has been refined in comparison with the initial microstructure, and the mean grain size is about 7.0 μm. The refining of grain occured due to dynamic recrystallization in superplastic deformation of TiAl based alloy.

TEM analyses show that, dynamic recrystallization occurs not only in grain boundaries,

Fig. 1 Microstructure of TiAl based alloy before superplastic deformation

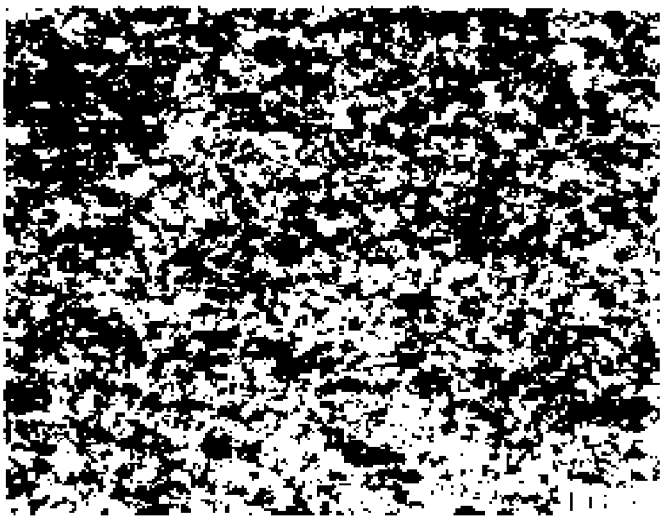

Fig. 2 Microstructure of superplastically deformed TiAl based alloy

but also inside γ grains and α_2/γ lathes. Fig. 3 shows dynamically recrystallized grains arround γ grains. As shown in Fig. 3(a), a circle of fine recrystallized grains adhere to a large γ grain, which contains high density of dislocations. Fig 3(b) shows a recrystallized grain at the boundary among three γ grains (triple point). Fig. 4 shows a dynamically recrystallized grain inside a γ grain, which contains a large amount of dislocation networks. Dynamically recrystallized grain grew at the expense of area of high density dislocations. It is note worthy that, dislocations appeared in the recrystallized grain, because the recrystallized grain was also being deformed. It is possible that when dislocation density in the new grain reached certain degree, next recrystallization would begin. Therefore, the growth of recrystallized grain is limited, as shown in Fig. 2.

Some lamellar colonies showed bended lathes, and dynamically recrystallized grains formed arround bended lathes in lamellar colonies, as shown in Fig. 5. As deformation occurred in α_2 + γ two phase field, lamellar colony transformed to γ and α_2 grains due to recrystallization.

The easiness of dynamic recrystallization of TiAl based alloys is due to its low planar fault energy and poor glissibility of dislocations[9]. As we known, grain boundary sliding is a main mechanism in superplastic deformation of TiAl based alloys[2, 5, 10]. However, grain boundary sliding will lead to strain hardening in surrounding grains, which can be accommodated by dislocation movement. Because of the low planar fault energy and poor glissibility of dislocation, the cross gliding and climbing of dislocation to other planes are difficult. Therefore, the density of dislocation will increase to such a high degree that the dynamic recrystallization occurs. As the degree of strain hardening due to grain boundary sliding is different in grains, grain boundary and at triple point, the nucleation mechanism and possibility of dynamic recrystallizaion are different. Lee[6] found that, in near γ microstructure, dynamic recrystallization is apt to nucleate at triple point, while in lamellar microstructure, it is apt to nucleate in grain boundaries. However, in duplex microstructure, dynamic recrystallization occurs not only in grain boundaries and at triple points, but also within grains as shown in Figs. 3~ 5.

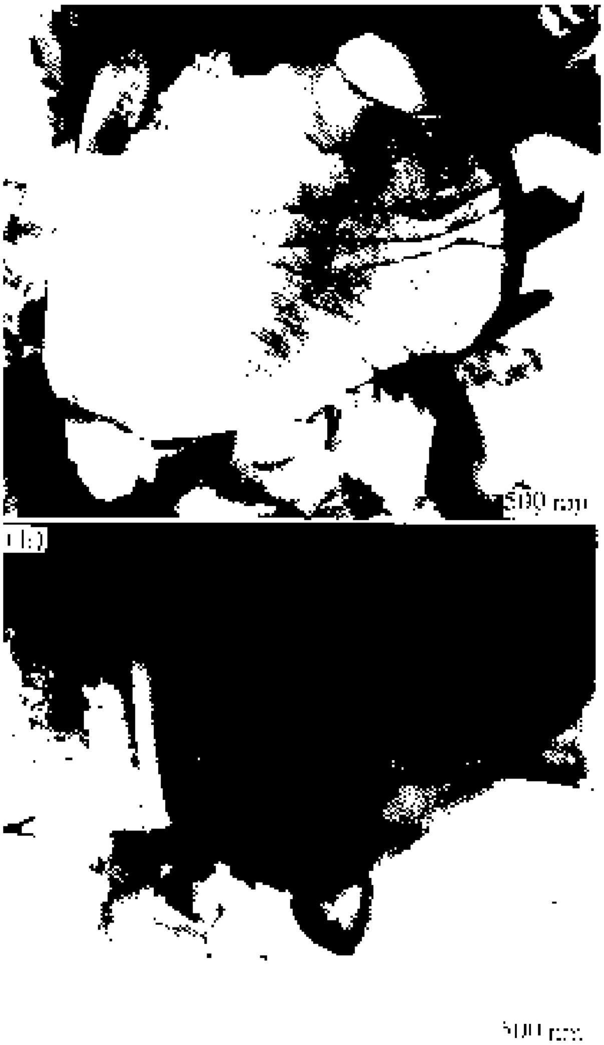

Fig. 3 Dynamically recrystallized grains
(a) —Around a gamma grain; (b) —At a triple junction

In TiAl based alloys, the nucleation of dynamic recrystallization occurs through subgrain growth and grain boundary stretching out. In Fig. 4, it is found that dynamic recrystallization in γ grains occurs through subgrain growth. As has been found by Ramanujan *et al*[11], in γ lath of lamellar colony exists subgrain boundary, whose movement will lead to formation of recrystallized γ grain during annealing. It is deduced that, during superplastic deformation, the dislocation caused by lath bending moves into the subgrain boundary in γ lath; the subgrain boundary then develops into large angle grain boundary, which could be the nuclei of recrystallization. Because of inhomogeneous deformation in grains, dislocation density difference between two sides of certain large angle grain boundary will be so large that this grain boundary will stretch out to the side with high dislocation density, leading to the decrease of dislocation densi-

Fig. 4 Dynamically recrystallized nuclei within a gamma grain

Fig. 5 Dynamically recrystallization occurring around and within lamellar colony

ty and release of storing energy; this side would be nuclei of dynamic recrystallization[12]. Therefore, the mechanism of dynamic recrystallization in grain boundaries and at triple points will belong to grain boundary stretching out.

It is possible that dynamic recrystallization can be an accomodating mechanism of superplastic deformation in γ TiAl based alloys. Dynamic recrystallization is a dynamic, continuous recovery process, grain boundary sliding would result in strain hardening, which could be relaxed by softening through recrystallization. High elongation can be obtained only when the hardening and softening was in a state of equilibrium. In addition, dynamic recrystallization refines coarser grains, and leading to the formation of finer grains around big primary grains, which will benefit grain boundary sliding. However, in the final period of superplastic deformation, because grain boundary sliding becomes difficult, the rate of dynamic recrystallization is higher than grain boundary sliding, i e, the dynamic equilibrium between them is destroyed, the irregular migration of grain boundary caused by dynamic recrystallization decreases the stability of the position of grain boundary, preventing grain boundary sliding. At that time, dynamic recrystallization will lead to the formation of finer grains in some region, where will occur neck growth and fracture because of low strength and strain concentration.

4 CONCLUSIONS

(1) Dynamic recrystallization occurs in the superplastic deformation of TiAl based alloy, and can refine grains remarkably.

(2) Dynamic recrystallization nucleates not only around γ grains and lamellar colonies, but also inside them.

(3) Dynamic recrystallization can be one of the accomodating mechanisms in superplastic deformation of TiAl based alloy.

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