Available online at www.sciencedirect.com
ScienceDirect

RARE METALS

RARE METALS, Vol. 27, No. 2, Apr 2008, p. 181

Homogenization treatment of high Nb containing TiAl alloys with as-cast and as-forged microstructures

XU Zhengfang, XU Xiangjun, LIN Junpin, ZHANG Yong, WANG Yanli, LIN Zhi, and CHEN Guoliang

State Key Laboratory for Advanced Metals and Materials, University of Science and Technology Beijing, Beijing 100083, China

Received 27 February 2007; received in revised form 17 April 2007; accepted 25 April 2007

Abstract

The effect of heat treatment on the microstructure evolution of a high Nb containing TiAl alloy has been studied. The results indicate that β-segregation, α-segregation and S-segregation in the as-cast and as-forged alloys can be effectively eliminated at the temperature above T_α (1350-1400°C) for long holding time (12-24 h) and the full lamellar (FL) microstructure is gained. For the two alloys, the lamellar colony sizes are 120 μm and 2000 μm, respectively after heat treatment at 1400°C for 12 h. Meanwhile, the sizes are 210 μm and 3000 μm, respectively at 1350°C for 24 h. To get a fine homogenous microstructure, the primary as-cast alloy is first subjected to preheat treatment for eliminating the segregations. After the preheat treatment, the alloy is processed by the multi-step canned forging to attain the microstructure with fine grain size.

Keywords: TiAl-based alloy; Nb-containing; FL microstructure; heat treatment; microsegregation

1. Introduction

The alloy used in the study is a high performance and high Nb containing TiAl-based alloy developed by Chen [1-2]. The alloy exhibits very high strength at both room temperature and high temperature, and has excellent high temperature oxidation resistance [2-5]. The service temperature is 60-100°C higher than that of conventional TiAl alloys [6]. The effects of microstructure on the properties of the alloy is similar to that of the ordinary TiAl alloys, but the abnormal relationship between the room temperature ductility and fracture toughness found in the conventional TiAl alloys is absent [3]. Full lamellar (FL) microstructure exhibits excellent strength with the best fracture toughness and ductility [5]. However, the addition of high Nb containing exacerbates the severe microsegregation problems facing conventional binary TiAl as-cast alloys, which even fail to be eliminated by the multi-step canned forging [7-9].

Three types of microsegregations were observed in as-cast alloy of a large ingot according to the previous studies. The first is solidification segregation (S-segregation) at interdendritic area. The composition of the area is higher Al, B (boride), and Y (oxide) and lower Nb and W. The second is β-segregation at the boundary and triple junctions amongst α grains due to the phase transformation of β → α. The composition of the area is higher Nb and W that leads to form β particles and γ phase. The third is α-segregation that forms local lamellar structure composed of β, γ, and α plates due to the phase transformation of $\alpha \rightarrow \alpha_2 + \beta + \gamma$ [8]. These microsegregations are harmful for the low temperature ductility and fracture toughness of the alloy [3, 8-9] and homogenization of the microstructure. It is necessary to study how to eliminate these microsegregations to obtain homogeneous FL microstructure; however, very few information was reported. The objective of the present study is to first eliminate the microsegregations of as-cast and as-forged alloys and then discuss the heat-treatment process of attaining the fine homogenous microstructure.

2. Experimental

A high Nb containing TiAl-based dual-phase alloy with the nominal composition of Ti-45Al-(8-9)Nb-(W, B, Y) (at.%) was used in the present investigation, and was prepared by consumable electrode arc melting technique in argon atmosphere and remelted in a vacuum-skill melting furnace to reduce composition heterogeneity. This was then followed by hot isostatic pressing (HIPing) at 1250°C for 4 h

Corresponding author: LIN Junpin **E-mail:** linjunpin@skl.ustb.edu.cn

under an argon pressure of 150 MPa to eliminate the casting flows. After HIPing treatment, one of the as-cast materials was subjected to three-step isothermally canned forging. The first step canned hot forging deformed the specimen by 52.8% at 1200°C and a deformation rate of 7.1 × 10^{-3} s^{-1}. After heat treatment at 1250°C for 4 h, the specimen was deformed once again by 57.3% at 1250°C and a deformation rate of 1.1 × 10^{-3} s^{-1}. The final step forging process is 42.9% at 1250°C using a deformation rate of 1.4 × 10^{-3} s^{-1} with the forging direction perpendicular to the previous two steps.

The objects for the current study are the as-cast and as-forged alloys. The samples for heat treatment with a dimension of 10 mm × 10 mm ×10 mm were spark-machined from the mid section of the as-cast and as-forged alloys using an electrical discharge machine (EDM). Then the specimens were heat-treated. The α transus temperature of the two alloys was estimated on the basis of differential scanning calorimetry data as T_{α} = 1335°C. This temperature has been used as a basis for defining the heat treatment capable of modifying the microstructure of the two alloys. According to the temperature, the specific heat-treatment processes are listed in Table 1. For the as-cast, the forged, and their heat-treated specimens, respectively, the microstructures were studied using optical microscope (OM) and scanning electron microscope (SEM) with back scattering electron imaging (BSI). The compositions of the constitutive phases were determined by energy dispersive spectrum (EDS) of SEM. Phase determination was conducted by X-ray diffraction technique (XRD).

Table 1. Teat treatment process for the specimens of the as-cast and as-forged alloys

No.	Heat treatment
HT1	1300°C × 24 h + 900°C × 30 min/air cooling (AC)
HT2	1350°C × 24 h + 900°C × 30 min/AC
HT3	1400°C × 6, 12 h + 900°C × 30 min/AC
HT4	1345°C × 30 min + 900°C × 30 min/AC
HT5	1400°C × 6 h + 900°C × 30 min + HT4

3. Results and discussion

3.1. Microstructure of as-cast and as-forged alloys

Fig. 1(a) shows the microstructure of the as-cast alloy. Three kinds of contrasts can be seen in the image. The black contrast area is the so-called S-segregation that appears patchy or vermicular distributing across the grey matrix. A higher magnification SEM-BSI image (at the right corner in Fig. 1(a))

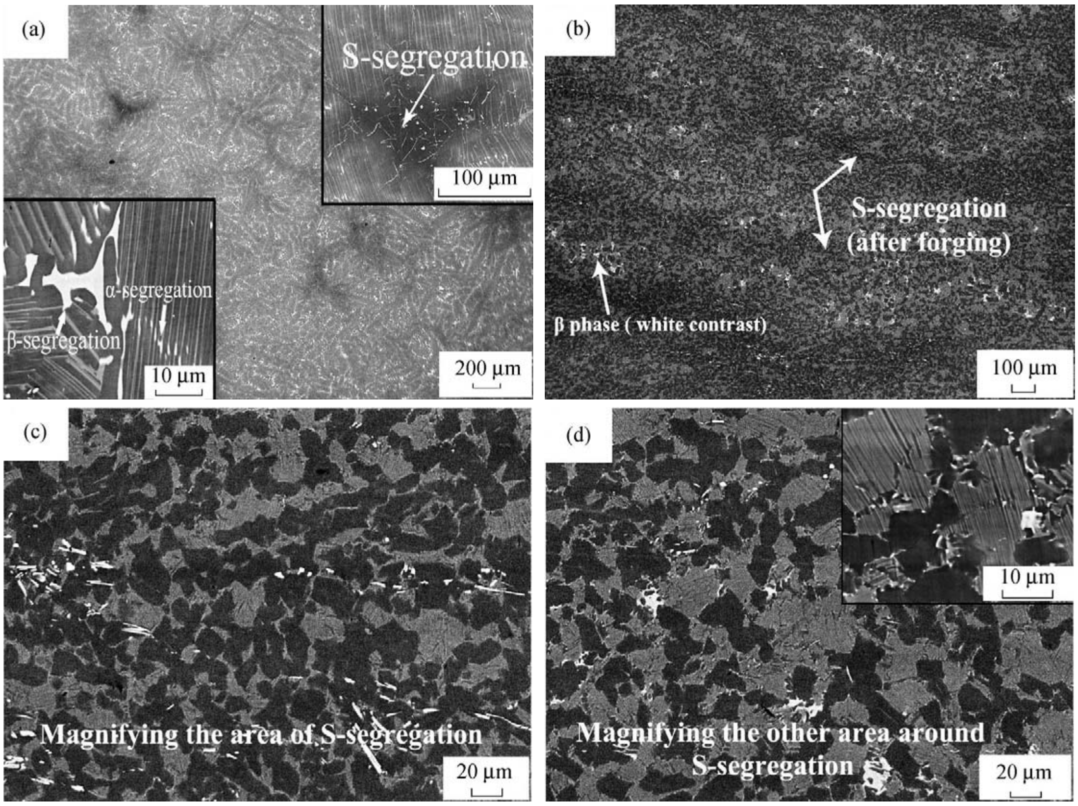

Fig. 1. Microstructures of the two alloys: (a) as-cast alloy; (b), (c) and (d) as-forged alloy.