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Dynamic recrystallization behavior of an as-cast TiAl alloy during hot compression

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ABSTRACT

High temperature compressive deformation behaviors of as-cast Ti–43Al–4Nb–1.4W–0.6B alloy were investigated at temperatures ranging from 1050 °C to 1200 °C, and strain rates from 0.001 s^{-1} to 1 s^{-1}. Electron back scattered diffraction technique, scanning electron microscopy and transmission electron microscopy were employed to investigate the microstructural evolutions and nucleation mechanisms of the dynamic recrystallization. The results indicated that the true stress–true strain curves show a dynamic flow softening behavior. The dependence of the peak stress on the deformation temperature and the strain rate can well be expressed by a hyperbolic-sine type equation. The activation energy decreases with increasing the strain. The size of the dynamically recrystallized β grains decreases with increasing the value of the Zener–Hollomon parameter (Z). When the flow stress reaches a steady state, the size of β grains almost remains constant with increasing the deformation strain. The continuous dynamic recrystallization plays a dominant role in the deformation. In order to characterize the evolution of dynamic recrystallization volume fraction, the dynamic recrystallization kinetics was studied by Avrami-type equation. Besides, the role of β phase and the softening mechanism during the hot deformation was also discussed in details.

1. Introduction

Titanium aluminides have become promising in replacing nickel-based superalloys used in gas turbine engines, due to their low density, high strength, good creep and oxidation resistance [1–3]. The replacement of Ni-based superalloy parts with titanium aluminides is expected to reduce the structural weight of high performance gas turbine engines by 20–30% [4]. However, low room temperature ductility and poor workability limit extensive applications of titanium aluminides. Recently, β phase containing TiAl alloys have been widely developed, since the disordered β phase is regarded as a ductile phase at elevated temperature and may therefore improve the hot deformability [5]. As a beta (β) phase stabilizing element, Nb can change the solidification path of as-cast γ-TiAl, and refine the microstructure. Much attention has been focused on the high Nb containing TiAl alloys with a base composition of Ti-(42-45)Al-(5-10)Nb-X [6,7]. However, coarse lamellar colonies form during the solidification of high Nb containing TiAl-based alloys, and lead to inhomogeneous microstructures [8], which may give rise to low room temperature ductility and a large scattering in mechanical properties.

The grain refinement by hot working has been proved to be an effective approach to enhance the mechanical properties of TiAl alloys [9]. The deformation behavior of metals during the hot deformation process can be significantly influenced by several metallurgical phenomena, such as work hardening, dynamic recrystallization (DRX) and dynamic recovery (DRV). DRX always leads to the formation of fine microstructures and improves the mechanical properties [10]. Therefore, it is important to study the dynamic recrystallization kinetics for TiAl alloys during the hot deformation. Cheng [11] found that the DRX of as-cast Ti–42Al–8Nb–0.2W–0.1Y alloy occurs at the initial stage of the hot deformation, and results in much sharper peak stress in the flow curve than that of ordinary alloys. Niu [12] found that the DRX of as-deformed Ti–43Al–6Nb–1B alloy preferentially proceeds at lamellar colony boundaries, resulting in hard-orientated lamellar structures and recrystallized γ grains. Liu [13] found that the deformation and the recrystallization occur preferentially in the grain boundary β phases in as-cast Ti–45Al–7Nb–0.4W–0.15B alloy. In our previous work [14], we found that DRX becomes the dominant softening mechanism at low Zener–Hollomon parameter (Z) condition. However, there are still uncertainties on the evolution of the DRX in beta (β) phases. Besides, most investigations have concentrated on the relationship between the Zener–Hollomon parameter (Z) and the DRX grain size after the hot deformation, few have been paid on the relationship between Z parameter and DRX grain size during the deformation.

In this work, the hot deformation behavior and the DRX of a cast Ti–43Al–4Nb–1.4W–0.6B (at.%) alloy were studied. The deformation and

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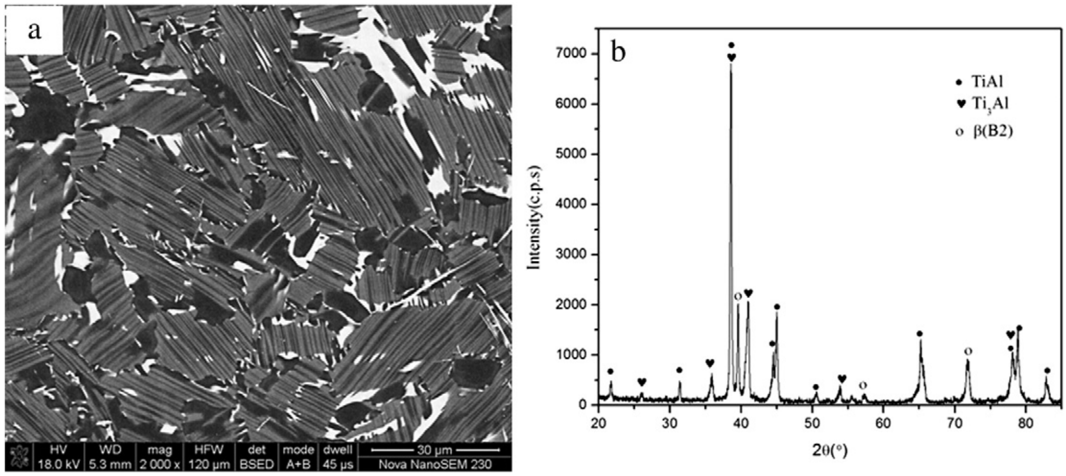

Fig. 1. Microstructures and phase constitution of as-cast Ti–43Al–4Nb–1.4W–0.6B alloy: (a) SEM backscattered electron image and (b) XRD pattern.

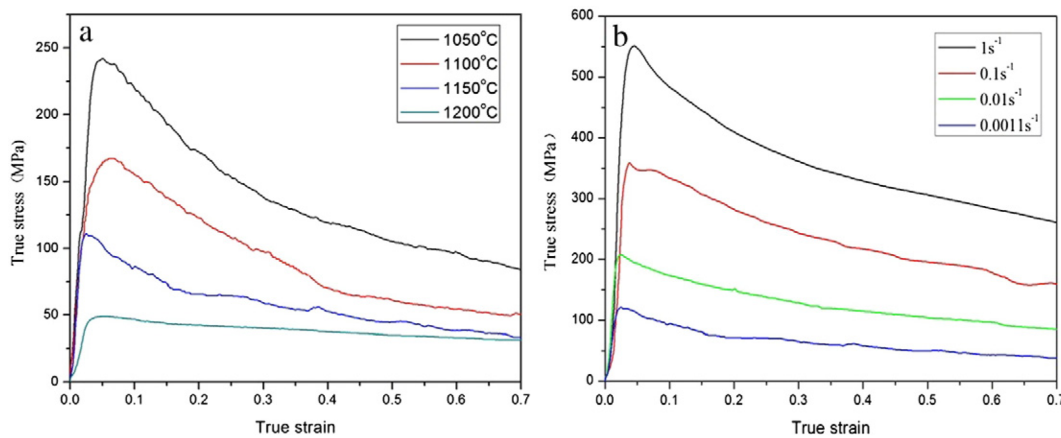

Fig. 2. Flow curves of the Ti–43Al–4Nb–1.4W–0.6B alloy at: (a) 0.001 s^{-1} and different temperatures and (b) different strain rates and 1150 °C.

the DRX mechanisms of the alloy at various Zener–Holloman (Z) parameters were discussed. The kinetic model for DRX including the relationship between Z parameter and β grain size during the compression was developed.

2. Experimental

The material with a nominal composition of Ti–43Al–4Nb–1.4W–0.6B (at. %) was prepared by a non-consumable electrode arc-melting

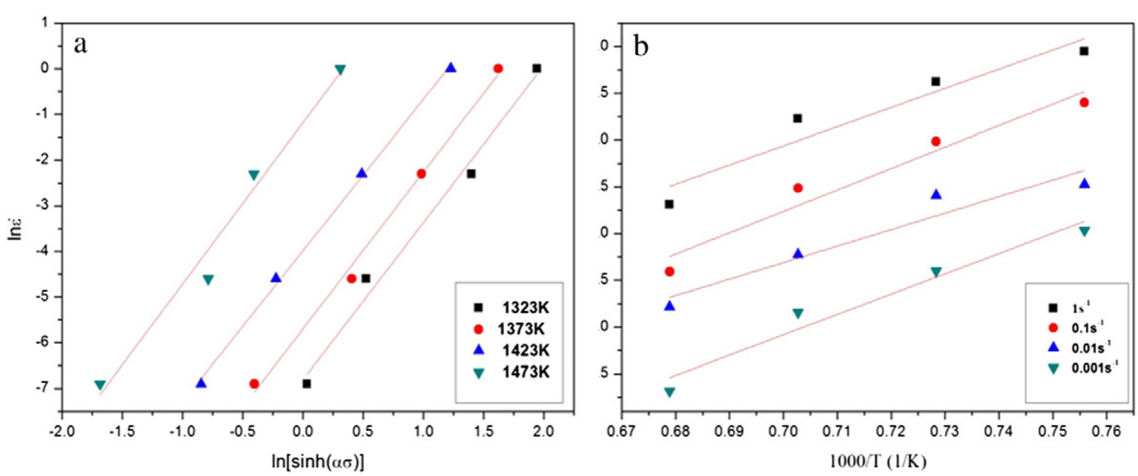

Fig. 3. Relationships for the Ti–43Al–4Nb–1.4W–0.6B alloy between the peak stresses: (a) $\ln\dot{\varepsilon} - \ln[\sinh(\alpha\sigma)]$ and (b) $\ln[\sinh(\alpha\sigma)] - 1/T$.