EXPERIMENTAL INVESTIGATION OF TEMPERATURE AND STRAIN-RATE BEHAVIOUR OF Ti₃Al-Nb ALLOY

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1. Introduction

High-temperature mechanical properties and low density makes the titanium aluminides attractive candidate for engine and airframe applications. Considerable efforts in research has been devoted to this class of materials, particularly to Ti₃Al-Nb alloy. This alloy typically consists of the ordered Ti₃Al α₂ phase (DO₁₉ structure, similar to h.c.p) and the b.c.c. β solid solution phase [1].

At high temperature, the alloy exhibits good ductility through thermal activated softening [2]. It was suggested that the activation barrier for DRX in the (α₂+β) field depends on the cross-slip in the α₂ phase [3].

Identification of rate controlling deformation mechanisms in two phase alloys is still not fully clear. Particularly confusing is a large scatter of activation energies[4,5] associated with deformation precedes. Creep, transition to low-temperature creep and power law breakdow behaviour is emphasis of this work. Deformation mechanisms are identified in terms of creep stress exponent and activation energy for deformation.

2. Experimental

The alloy was prepared from a Ti-6Al-4V (extra low interstitials quality), high-purity aluminium and niobium flakes. It was smelted in vacuum arc furnace under the low-pressure ‘argon blanket’. The nominal chemical composition of the alloy was as follows (at.%): 24%Al, 11%Nb and 1% V, Ti - the rest. After cleaning, the rod was hot-rolled on a laboratory two-high mill with φ-calibrated rolls, down to a diameter of 6 mm. Hot-rolling was conducted at 1050°C, in the two-phase field well below the β-transus temperature.

Compression test specimens with φ=6 mm and 12 mm in height were machined from the previously chemically cleaned rod. A series of strain-rate jump test [6] were conducted on an “Instron” testing machine in a water-cooled vacuum chamber at temperatures ranging from 800 to 1100°C. Temperature of the chamber was maintained within ±5°C. The true strain rates were calculated [7] to be in the range from 10⁻⁶ to 10⁻³ s⁻¹. True stress were normalized with shear modulus μ=5.1x10³–9T [8].

3. Results and Discussion

Results of strain-rate jump test are summarized in Fig.1. It appears that stress follow rather strong dependency of temperature and strain rate. The stress sensitivity parameter, n, can be calculated as

\[ n = \left( \frac{\partial \ln \varepsilon}{\partial \ln \sigma} \right)_\tau \]  \hspace{1cm} (1)

Least-squares fit of data suggests that overall results might be separated in two fields: low-stress regime with n=3 (3.0<n<3.2) and upper, high-stress regime, with n=5 up to 9. Contrary to low-stress field, where n is almost constant, in high-stress region n gradually increases with temperature and stress. The n=3 value correspond to alloy-type creep behavior (Class A), so-called viscous glide creep [9]. In contrast to this, metal-type creep behavior (Class M) is recognized with n=5 and usually point to dislocation climb mechanism [10]. However, stress-dependent gradual increase of n-values up to 9 suggests power law breakdown (PLB) may be more probable [11]. The apparent activation energy for creep is given by

\[ Q_{app} = -R \left( \frac{\partial \ln \varepsilon}{\partial 1/T} \right)_\sigma \]  \hspace{1cm} (2)
where \( R \) is the gas constant. For constant stress values, in the range of \( \sigma/\mu=4\times10^{-4} - 2\times10^{-3} \), application of Eq. 2 is illustrated in Fig. 2. Calculated activation energies are 280-420 kJ/mol. In low-stress region, activation energies are within the range typical of lattice self-diffusion, 280-340 kJ/mol [4-5]. In high-stress regime, Q values are higher (350-420 kJ/mol) and might be related to PLB [11]. Stress-dependent Q values involve that, apart the creep, dislocation glide mechanisms are operative. However, it is not yet clear which one is rate controlling.

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5. References