Abstract

IMI 834 is a near-α Ti alloy used in high temperature applications such as compressor discs and blades of aero engines. Titanium alloys including IMI 834 are known to exhibit dynamic strain aging (DSA) over the temperature range of 623-773K. However, the interplay between DSA and creep has not been previously studied in detail in titanium alloys. The objective of the present study is to probe creep mechanisms and phenomenology at intermediate temperatures in IMI 834 where DSA is expected to play a prominent role.

Coupons of IMI834, cut from a hot rolled rod, were heat treated to obtain a microstructure of 80% equiaxed α, 15% of lamellar α and 5% β. The heat treatment was optimized to ensure Si retention in the solution as it is known to affect DSA in titanium alloys. Constant strain rate tests carried out in tension over a range of temperatures and strain rates identified the DSA regime in the temperature range of 623-823K as determined by serrated behavior in stress-strain curves and negative strain rate sensitivity. The dislocation structure in this domain is dominated by jogged screw dislocations in slip bands. Strain accumulation is shown to depend on conservative jog glide along the length of screw dislocations due to line tension forces.

We have tried to predict this domain of DSA using Friedel's model for breakaway stress, i.e. the stress required to break free the dislocations from solute atmosphere, using estimates of solute concentration accumulating at the edge jogs on arrest during thermally activated glide of the jogs at static solute obstacles. There is a good agreement between model and experimental data showing a DSA peak in the temperature range of 673-723K. The solute species responsible for DSA is estimated to be Si and C, but dominated by C in this temperature and strain rate regime.

Creep behavior of the alloy was explored over similar temperature regime in tension. Over this temperature range, especially at lower temperatures, very low strain rates below the resolution limits of the strain gauge were reached before the onset of steady state and

therefore current work is primarily focused on primary creep behavior. Different types of primary creep behavior were observed with temperature and stress. Anomalous primary creep behavior has been observed in the form of an abrupt decrease in strain rate beyond certain critical strains, as well as in a stress insensitivity of instantaneous strain rates on loading at 673K. At higher temperatures of 773K, conventional behavior showed strain rates approaching a steady state value. Dislocation structure in primary creep was again dominated by jogged screw dislocations. At the strain rates associated with creep, our model shows that transitions occur in jog glide from solute breakaway controlled glide to solute drag controlled glide and then again to thermally activated glide over static solutes with increasing temperature. However, in contrast to high strain rate behavior, Si solutes dominates the mechanisms of jog glide in creep.

The work of this thesis has established that a continuum of dislocation mechanisms based on jogged screw dislocation glide determine mechanical behavior over a wide range of strain rates ranging from 10^{-2} to 10^{-9} s^{-1} and temperatures from 623-773K in engineering titanium alloys.