Abstract

Tensile creep behavior of the Zr-2.5Nb alloy has been studied through tests under constant load (stress range ~ 68-371 MPa) in the temperature range of 275-450°C. The minimum creep rate of the alloy is found to vary with applied stress following a power-law relation. The values of stress exponent (n) are obtained in the range of 4.0-6.8 in the interval of 300-375°C; whereas it is calculated as 1.2 and 7.0 for low and high stresses, respectively at 275°C. The apparent activation energy for creep (Q_C) has been determined by analyzing experimental data are (~ 198.5 kJ/mol) and (~ 231-264 kJ/mol) for the temperature range of 275-375°C and 350-450°C, respectively, which is found to be higher than the lattice self-diffusion activation energy of pure zirconium (113 kJ/mol). Furthermore, the stress exponent obtained by the temperature-compensated power law is in the range of 3.9-5.6. Microstructural characterization by transmission electron microscopy (TEM) with energy dispersive spectroscopy analysis has confirmed coarsening of β-Zr(Nb) precipitates with compositional changes during creep. As observed by TEM, planar arrays of (c+a) type dislocations appear to interact profusely with the β-Zr(Nb) precipitates, leading to high threshold stress, which has decreased with temperature. On considering the presence of threshold stress, true activation energy of creep (Q_t) and true stress exponent (n_t) are found as ~ 160.4 kJ/mol and ~ 4.8, respectively for the temperature range of 275-375°C. On the other hand, the calculated Q_t and n_t values are reduced to ~ 116-132 kJ/mol and ~ 3.6-4.9, respectively for the temperature range of 350-450°C. Evidence for coarsening of precipitates in the size range of 34-40 µm and 41-50 µm has been observed for samples creep-tested at 450°C with stress-axis along longitudinal and transverse directions, respectively. The orientation relationship of α-Zr [0001]//β-Zr(Nb) [001] has been observed. Analysis of creep data has confirmed the role of dislocation climb as the rate-controlling mechanism, along with validity of Monkman-Grant and modified Monkman-Grant relations. Scanning electron microscopy of creep fracture surfaces has revealed predominance of ductile fracture. The creep damage tolerance factor is found to be in the range of 1.5-2.5, indicating the predominance of cavity growth mechanism according to the Ashby-Dyson map. The Larson-Miller Parameter can be used to predict the stress-rupture data. Further, reliable creep life has been estimated at 425°C at different stresses.

Keywords: *Zr-Nb alloy, tensile creep, stress exponent, activation energy, microstructure, threshold stress, creep rupture, β-Zr(Nb) precipitates*