Materials and Design 32 (2011) 1710–1715

Contents lists available at ScienceDirect

Materials and Design

journal homepage: www.elsevier.com/locate/matdes

Technical Report

Effects of strain waveform on low cycle fatigue behaviour of near α Timetal 834 titanium alloy

Kartik Prasad *, Rajdeep Sarkar, P. Ghosal, Vikas Kumar

Defence Metallurgical Research Laboratory, Kanchanbagh, Hyderabad 500 058, India

A R T I C L E   I N F O

Article history:
Received 8 July 2010
Accepted 24 August 2010
Available online 20 September 2010

A B S T R A C T

The low cycle fatigue (LCF) behaviour of a near α Timetal 834 titanium alloy has been studied under fast–slow and slow–fast waveforms at peak dynamic strain aging (DSA) temperature (450 °C). The alloy exhibits inferior fatigue life under slow–fast waveform as compared to fast–slow waveform. This is attributed to slow rate of straining in tensile direction under slow–fast waveform which allows more interaction between mobile dislocations with solute atoms thereby enhancing the strength of DSA. A life prediction model based on the dynamic viscosity with waiting time correction as per dislocation kinetics predicts fatigue lives reasonably well under pronounced DSA effect.

1. Introduction

In recent years, reasonable efforts have been made to study the high temperature low cycle fatigue (HTLCF) properties in near α Timetal 834 titanium alloy [1–5], primarily because of the intended application of this alloy for compressor disc in advanced gas turbine engines [6–8]. The tensile [9–11] as well as LCF tests [4,5] have already confirmed the occurrence of dynamic strain aging (DSA) in Timetal 834. In this alloy, the DSA phenomenon is related to the interaction between mobile dislocations and silicon atoms in the temperature range between 400 °C and 475 °C under monotonic deformation, displaying maximum DSA effect at 450 °C [10]. The occurrence of DSA under pure fatigue condition (symmetrical waveform) at different strain rates has already been reported in earlier investigations by the authors [4,5]. Nevertheless, the comparison between fast–slow and slow–fast cycling (asymmetrical waveforms) in LCF has attracted considerable attention in past because of significant difference in damage mechanisms operative in the ascending and descending parts of the waveform [12]. Hardt et al. [1] compared the LCF life under fast–slow and slow–fast waveforms of Timetal 834 at 600 °C. They reported that slow plastic straining in the tensile half part of the cycle increases environmental damage significantly. There is, however, no reported literature on the effect of asymmetrical waveforms on LCF behaviour of near α titanium alloy Timetal 834 in the DSA regime.

The objective of the present study is to understand the deformation mechanisms operative in this alloy under asymmetrical waveforms at peak DSA temperature. The fatigue life of the alloy is correlated to the evolution of dislocation substructures and mean stress effects. A dynamic viscosity model [13] to account the DSA effect has been applied to predict LCF life of Timetal 834 titanium alloy.

2. Experimental methods

The chemical composition of the near α Timetal 834 titanium alloy is shown in Table 1. Thick plates of 16 mm of Timetal 834 were solution treated (ST) in α + β region at 1025 °C (β-transus temperature ~1045 °C) for 2 h followed by oil quenching. The solution heat-treated plates were subjected to a stabilization treatment at 700 °C for 2 h before air cooling to room temperature. The microstructure of the heat treated alloy was metallographically examined using Kroll's reagent (6 ml HNO_3/ 3 ml HF/ 100 ml water) under scanning electron microscope (SEM; model Leo 440IL). The heat treated microstructure as observed is shown in Fig. 1. The alloy shows a bi-modal microstructure which consists of equiaxed primary α in the transformed β matrix as shown in Fig. 1. The average size of primary α and prior β grain size was found to be ~8 μm and ~70 μm, respectively. The volume fraction of primary α was determined to be ~15%.

LCF tests were performed on cylindrical specimens with a gauge length and gauge diameter of 15 mm and 6.35 mm, respectively, conforming to ASTM standard E-606 [14]. Tests were conducted in laboratory air under fully reversed loading condition employing an asymmetrical, fast–slow (6.67×10^{-3}–$6.67 \times 10^{-5}\ s^{-1}$) and slow–fast ($6.67 \times 10^{-5}$–$6.67 \times 10^{-3}\ s^{-1}$) waveforms as shown in Table 2 with an MTS servohydraulic test system equipped with three-zone resistance furnace. In order to observe the repeatability of material behaviour, four LCF tests have been performed under each asymmetrical waveform. The occurrence of DSA under monotonic deformation has already been reported [10] at

* Corresponding author. Tel.: +91 4024586407; fax: +91 4024340266.
E-mail address: kartik@dmrl.drdo.in (K. Prasad).

0261-3069/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.matdes.2010.08.044