Creep Behavior of Nonburning Ti-35V-15Cr-xC Alloys

F.S. Sun and E.J. Lavernia

(Submitted August 24, 2005)

A comparison is made between the creep behavior of the Ti-35V-15Cr and Ti-35V-15Cr-0.2C alloys at 500 to 580 °C within the stress range of 200 to 300 MPa. The creep resistance of Ti-35V-15Cr-0.2C is considerably improved by the incorporation of Ti_2C particulates into the Ti-35V-15Cr-0.2C matrix.

Keywords: dislocations, mechanical properties (creep), titanium alloys, transmission electron microscopy

1. Introduction

There is an interest in developing nonburning titanium alloys for aerospace applications. In 1985, Pratt & Whitney accelerated the development of a unique titanium alloy that would not burn under the operating condition present in an aeroengine to meet increasing demands in their industry sector. From this investigation, a commercial alloy, Ti-35V-15Cr, designated as alloy C, was developed that has high burn resistance up to 600 °C (Ref 1-3). Recently, an alloy development program was undertaken jointly by the Interdisciplinary Research Centre (IRC) at the University of Birmingham and Rolls-Royce that aimed to identify a low-cost nonburning titanium alloy by introducing Al into the Ti-V-Cr system; hence, an alloy of Ti-25V-15Cr-2Al was developed (Ref 4-6). In addition to the burn-resistant properties, there is great interest in optimizing the mechanical properties, such as creep resistance, of nonburning titanium alloys by investigating alloying effects. The objective of this research was thus to provide information on the significance of creep strengthening in carbon-bearing, nonburning titanium alloys.

2. Experimental

The alloys studied in this investigation were Ti-35wt.%V-15wt.%Cr and Ti-35wt.%V-15wt.%Cr-0.2wt.%C. Ten kilogram ingots of each alloy were melted using a consumable-electrode-arc-remelting furnace with a combination of master alloys and pure elemental materials. The ingots were forged into rods at 1000 °C and subjected to a heat treatment of 950 °C air-cooled (AC) and 1 h/700 °C AC for 4 h. Samples with a gage length of 50 mm and a diameter of 5 mm were used for creep testing. The experiments were performed on a vertical load frame with a 20:1 lever-to-arm ratio in air at 500, 540, and 580 °C, and 200 to 300 MPa. The testing temperature was measured using a thermocouple placed near the sample, and the variation of the temperature was within ±5 °C. Creep deformation was recorded across the shoulders of the samples using a dial gage and a linear variable differential transducer. Engineering creep strain versus time curve was developed for each test, and the minimum creep rates were calculated from these curves. Microstructural characterization was conducted on the creep samples using an optical microscope. The deformation behavior was characterized using a transmission electron microscope (TEM).

This paper was presented at the Beta Titanium Alloys of the 00’s Symposium sponsored by the Titanium Committee of TMS, held during the 2005 TMS Annual Meeting & Exhibition, February 13-16, 2005 in San Francisco, CA.

F.S. Sun and E.J. Lavernia, Department of Chemical Engineering and Materials Science, University of California, Davis, CA 95616. Contact e-mail: lavernia@ucdavis.edu.
3. Results and Discussion

Optical micrographs of the heat-treated microstructures of the Ti-35V-15Cr and Ti-35V-15Cr-0.2C alloys are shown in Fig. 1. The microstructure of the Ti-35V-15Cr alloy consisted of a coarse β phase equiaxed structure with a grain size of approximately 108 μm, with some α phase in the matrix and the grain boundaries (Fig. 1a). The microstructure of the Ti-35V-15Cr-0.2C alloy consisted of a coarse β-phase matrix with Ti2C particles randomly distributed in the matrix and the grain boundaries (Fig. 1b). The grain size was about 112 μm, and the average particulate size was determined to be 9.8 μm. Energy dispersive spectrometry (EDS) revealed that these Ti2C particles consisted of 24.9 at.% C, 16.5 at.% O, and 58.6 at.% Ti.

Figures 2 and 3 show typical creep strain versus time curves for the Ti-35V-15Cr-xC (x = 0, 0.2%) alloys, which were obtained at temperatures of 500, 540, and 580 °C, and applied stresses of 200, 250, and 280 MPa, demonstrating the three stages of the creep behavior: primary, secondary, and tertiary creep. It is clear that higher temperatures or higher stresses lead to a shorter secondary creep stage. The creep test results are presented in Table 1, which includes the creep deformation, the minimum creep rate, and the corresponding testing conditions for the heat-treated Ti-35V-15Cr-xC (x = 0, 0.2%) creep specimens. The data indicate that adding 0.2% C to the non-burning titanium alloys leads to greater creep resistance. For example, the creep deformation and minimum creep rate were more than three times greater for the Ti-35V-15Cr alloy than for the Ti-35V-15Cr-0.2C alloy at 540 °C/250 MPa.

The creep resistance is increased by incorporating Ti2C par-