Available online at www.sciencedirect.com
SCIENCE @ DIRECT®
Scripta Materialia 52 (2005) 645–650
Scripta MATERIALIA
www.actamat-journals.com

Fatigue behavior of 7010 aluminum alloy containing scandium

Mohammed Noor Desmukh [a,*], R.K. Pandey [a], A.K. Mukhopadhyay [b]

[a] *Department of Applied Mechanics, IIT Delhi, Hauz Khas, New Delhi 110 016, India*
[b] *DMRL, Kanchanbagh, Hyderabad 500 058, India*

Received 17 September 2004; received in revised form 31 October 2004; accepted 18 November 2004
Available online 10 December 2004

Abstract

7010 Al alloys with and without scandium addition were processed in the form of plates and subsequently heat treated to the peak aged temper. The fatigue initiation thresholds, fatigue propagation threshold, and the Paris constants of these alloys were evaluated. The investigations revealed that the scandium addition refines the grain structure but results in poor fatigue crack growth resistance and fatigue thresholds.

Keywords: 7010 Aluminum alloy; Sc addition; Fatigue crack propagation; Thresholds; S–N curve

1. Introduction

The 7010 aluminum alloy with suitable temper is considered to be an important aerospace material as it possesses a good combination of strength, toughness and stress corrosion cracking resistance. Over the years attempts have been made to enhance the performance of conventional 7010 alloy with the appropriate addition of alloying elements [1,2]. The addition of scandium to this alloy has been reported to provide an improved weldability [3]. Aerospace structures are very commonly subjected to fatigue loading. No systematic work has been reported in the literature so far on the effect of Sc addition on the fatigue parameters such as the endurance strength, fatigue crack growth rate, da/dN, and the fatigue threshold stress intensity factor, ΔK_{th}. The present work is an attempt to study the effect of scandium on the fatigue behavior of the 7010 aluminum alloy.

* Corresponding author. Tel.: +911126591751; fax: +91112658 1119.
E-mail address: mdnoord@yahoo.com (M.N. Desmukh).

2. Experimental procedure

2.1. Materials and microstructural characterization

The materials used in the present investigation were a conventional 7010 Al alloy (hereafter termed base alloy) and the base alloy containing Sc. The chemical composition (in wt%) of the 7010 alloy was 6.3% Zn, 2.3% Mg, 1.55%Cu, 0.14% Zr, and balance Al and impurities such as Fe (0.06%) and Si (0.02%). In the Sc-containing alloy, 0.25% Sc was added keeping the other alloying additions the same. The materials were produced in the form of plates having a thickness of 14 mm. The materials were subsequently solution treated at 465 °C for 60 min, water quenched at room temperature and heat treated to the peak aged condition by aging at 120 °C for 24 h.

The specimens for microstructural studies were cut from the plate and polished on an automatic polishing machine. They were initially ground on 800 grit paper and then polished on micro cloth using 1 μm diamond suspension. The final polishing was carried out on a chemomet cloth with master polish suspension. The specimens were then etched in a Keller's reagent, washed in warm distilled water and finally dried with a blower.

1359-6462/$ - see front matter
doi:10.1016/j.scriptamat.2004.11.018

The microstructural features were then examined using an optical microscope in the unetched as well as in the etched conditions.

2.2. Tensile tests

The cylindrical tensile specimens having a gauge length of 45 mm and a diameter of 9 mm were prepared as per the ASTM standard. The tensile tests were conducted using an Instron machine. The yield strength and the tensile strength of the 7010 alloy were found to be 500 MPa and 566 MPa, respectively, and the elongation was 13%. The Sc-containing alloy was found to possess somewhat better strength and ductility as compared to the conventional 7010 alloy resulting in an yield strength of 537 MPa, tensile strength 588 MPa, and elongation at 14%.

2.3. Fatigue experiments

The fatigue testing was carried out on a servo hydraulic machine (MTS model 858) with a capacity of 25 kN. Sinusoidally applied load at a constant stress ratio R ($\sigma_{min}/\sigma_{max}$) = 0.1 was used for the fatigue loading. The commands and measurements of the load, crack length and the number of cycles were achieved through the controller installed with the machine.

2.4. Fatigue initiation thresholds (Endurance)

The standard 'dog bone' type fatigue specimens with circular section and continuous radius between the ends as per the ASTM standard E 466-76 [4] (Fig. 1) were machined out of the plate with the rolling directions along the tensile axis, and given a smooth surface finish. The minimum diameter of the continuously reducing cross section was kept at 8 mm, the radius of curvature 64 mm, and the length 32 mm. The diameter at the grips was 12 mm. The high cycle fatigue testing was subsequently carried out and the S–N curves were plotted for determining the endurance strength corresponding to about 10^6 cycles (Fig. 1).

2.5. Fatigue crack propagation

The crack growth measurements were carried out using the compliance technique. The compact tension (CT) type specimen geometry was used for fatigue testing. The specimens were machined from the rolled plate, maintaining an L–T orientation, i.e. the longitudinal or the rolling direction has been kept perpendicular to the notch plane and the crack propagation direction is along the long transverse direction. The specimen dimensions were kept as per the ASTM standard with the width W = 56.5 mm, thickness B = 12 mm and notch length a_n = 22 mm. The specimens were polished (for better crack visibility) and then subjected to fatigue loading to obtain a precrack length of 2 mm. The final maximum stress intensity used during pre-cracking was 8 MPa$\sqrt{m}$.

2.6. Fatigue crack propagation threshold region

The fatigue crack propagation threshold was measured by subjecting the precracked CT samples to a continuously decaying cyclic loading. The load shedding was carried out keeping the normalized stress intensity gradient, $[1/K\,(dK/dN)] = -0.08$ as per the ASTM standard [5]. This process of K decreasing was continued until the threshold was reached. The evaluation of the crack growth rate, da/dN was carried out using the ASTM recommended secant method. The da/dN value was continuously monitored and the test was continued until a value of around 10^{-9} m/cycle was reached (Figs. 2 and 3).

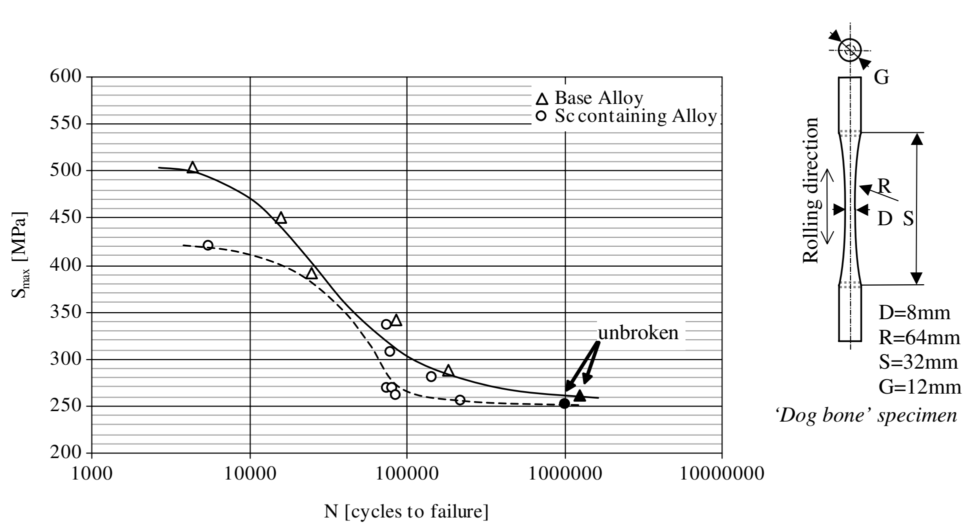

Fig. 1. The S–N curves for base alloy and Sc-containing alloy.