International Journal of Fatigue 103 (2017) 419–425

Contents lists available at ScienceDirect

International Journal of Fatigue

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

Enhancement of fatigue life of aluminum alloy affected by the density of pulsed electric current

J. Jung [a], Y. Ju [b,*], Y. Morita [b], Y. Toku [b]

[a] Mechanical Science and Engineering, Graduate School of Engineering, Nagoya University, Furo-cho, Chikusa-ku, Nagoya 464-8603, Japan
[b] Department of Mechanical Science and Engineering, Nagoya University, Furo-cho, Chikusa-ku, Nagoya 464-8603, Japan

ARTICLE INFO

Article history:
Received 1 March 2017
Received in revised form 16 June 2017
Accepted 16 June 2017
Available online 17 June 2017

Keywords:
Fatigue strength
Aluminum alloys
Crack shield
Fatigue crack growth

ABSTRACT

We investigate the effect of pulsed electric current on fatigue-crack growth and the fatigue properties of aluminum alloy (A6061-T6) at current densities of 0–150 A/mm^2. The fatigue life of most of the treated specimens increases substantially when compared with that of untreated specimens. SEM imaging of the treated specimens shows local melting on the fracture surfaces. To clarify the effect of local melting on fatigue-crack propagation, we examine crack propagation utilizing the plastic replication method. We find that the delay of crack propagation is attributable to the crack-shielding effect arising from current-induced local melting.

1. Introduction

The fatigue properties of mechanical components are of crucial research interest since fatigue fracture accounts for more than 80% of all mechanical failures [1]. In this regard, certain studies have used methods such as spot heating, shot peening, and conventional/laser-annealing to improve the fatigue strength of mechanical components [2–4]; however, these approaches are currently expensive. On the other hand, the application of pulsed electric current to mechanical components has been considered to be an alternative fatigue-improvement method. Kim et al. [5] have reported that the elongation of an aluminum alloy could be improved through joule heating induced by electric current. Further, Karpenko et al. [6] demonstrated that the low-cycle fatigue life of steel could be extended through pulsed electric current under fatigue loading. Conrad et al. [7] determined that the fatigue life of copper alloy could be increased through pulsed-electric-current application. Such improvement arises because the applied electric current induces slip homogenization and thus increases dislocation mobility in the alloy. Along similar lines, crack healing through pulsed electric current has recently been investigated for increasing the fatigue life of carbon and stainless steels. For example, Zhou et al. [8] reported that pre-cracks in carbon steel could be partly healed through the application of pulsed electric current, while Hosoi et al. [9] healed cracks in austenite stainless steel using pulsed electric current. Despite such studies, the mechanisms underlying the relationship between fatigue life and pulsed electric current have not been fully understood.

In the present work, we studied the effect of pulsed electric current on the fatigue properties of aluminum alloy using the crack healing technique. Aluminum alloys are widely used for fabricating lightweight structural components in numerous engineering fields, particularly in the automobile industry [10,11]. The proposed technique could be useful for prolonging the fatigue life of such mechanical components and structures made from aluminum alloy. In the study, we investigated the fatigue lives of aluminum-alloy A6061-T6 specimens via fatigue tests at electric current densities ranging from 0- to 150-A/mm^2. The fatigue crack behavior of the treated and untreated aluminum alloy specimens was also examined. Further, in order to analyze the fracture mechanism, we examined the fracture surfaces with scanning electron microscopy (SEM), and we quantitatively evaluated fatigue crack propagation using the plastic replication method.

2. Material and methods

2.1. Material and specimen configuration

Rolled sheet of aluminum alloy (A6061-T6) was used as the experimental material. Tables 1 and 2 list the mechanical properties and chemical composition of A6061-T6, respectively. The fatigue specimens were machined to a shallow notched-dumbbell shape (Fig. 1) with thickness and width of 4.5 and

* Corresponding author.
E-mail address: ju@mech.nagoya-u.ac.jp (Y. Ju).

http://dx.doi.org/10.1016/j.ijfatigue.2017.06.021
0142-1123/