Available online at www.sciencedirect.com
ScienceDirect
Thin Solid Films 515 (2006) 1187 – 1191
www.elsevier.com/locate/tsf

Effect of combined shot-peening and PEO treatment on fatigue life of 2024 Al alloy

D.T. Asquith [a,*], A.L. Yerokhin [a], J.R. Yates [b], A. Matthews [a]

[a] Department of Engineering Materials, University of Sheffield, Sir Robert Hadfield Building, Mappin Street, Sheffield S1 3JD, UK
[b] Department of Mechanical Engineering, University of Sheffield, Mappin Street, Sheffield S1 3JD, UK

Available online 11 September 2006

Abstract

One of the most important objectives in the surface engineering of light-weight alloys is to enhance their fatigue properties, allowing both increased performance and an extended service life. This can be achieved by forming a hard surface layer while incorporating a favourable stress state. Single surface treatments, for example, Plasma Electrolytic Oxidation (PEO), are not always capable of creating optimal combinations of these characteristics, whereas greater durability can be achieved by applying mechanical pre-treatments prior to the coating. In this work, a combination of shot-peening pre-treatment with plasma electrolytic oxidation coating is studied as a means to improve the fatigue performance of 2024 T351 Al alloy. The shot-peening was carried out in a compressed air configuration using S110 gauge shot at 200% coverage with an intensity of 20 AlmenC. PEO coatings of 30 μm thickness were produced using pulsed bipolar current technology. Fatigue properties were evaluated by a four-point bending technique at a stress ratio of 0.1. Hardness, residual stress and microstructure of the surface layers were studied by Knoop microhardness tests, fluorescence spectroscopy and SEM analyses, respectively. The effect of the combined shot-peening and PEO treatment is an increased fatigue limit and elevated microhardness when compared to aluminium treated only with PEO.

Keywords: Plasma electrolytic oxidation (PEO); Shot-peening, fatigue; Residual stress; Aluminium; Aluminium oxide; Raman scattering

1. Introduction

Aluminium alloys are increasingly employed in a variety of applications where previously materials such as steel or even titanium would have been used. New applications of Al alloys require that weight savings are made without compromising overall strength and long term performance. This is a developmental area in which there is considerable opportunity for improvement of aluminium alloy performance. The broad spectrum of applications means that researchers from many different disciplines are contributing to the field, drawing on experiences with numerous techniques.

In the automotive and aerospace industries, where components often experience repetitive loading, materials are commonly treated with cold working processes to increase their fatigue performance. In particular aluminium alloys are shot-peened to improve these characteristics. The process of shot-peening involves bombarding a surface with hard spherical particles propelled by compressed air or a centrifugal effect. These properties inhibit short crack growth and increase the fatigue life [1]. Shot-peening tends to increase the surface roughness which can be detrimental to fatigue performance [2]. It can also increase the susceptibility to corrosion, but it does not usually affect the tribological performance of aluminium.

In particular with aluminium alloys, anodic oxidation processes are employed to improve and retain the surface finish [3], but these also have a significantly negative influence on the bulk fatigue properties [4]. The development of thicker, harder ceramic coatings on aluminium such as by plasma-electrolytic oxidation (PEO) has provided improved wear characteristics but the problem of fatigue strength deficit still remains [5,6]. This has meant that, despite the surface properties being favourable, the overall performance of anodised alloys means they are often relegated to aesthetic functions leaving structurally intensive applications to stronger and heavier materials.

The next logical step to improve the overall performance of Al alloys would be to use a combination of cold-working and

* Corresponding author.
E-mail address: d.asquith@shef.ac.uk (D.T. Asquith).

0040-6090/$ - see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.tsf.2006.07.123

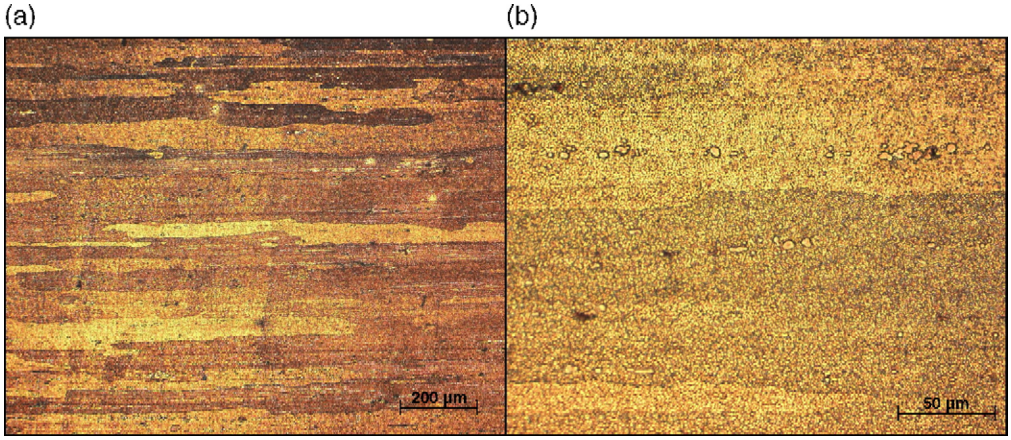

Fig. 1. Optical micrograph of (a) grain structure and (b) precipitates in AA2024-T351.

hard coating to provide synergistic enhancement of fatigue performance and wear resistance. studies of duplex treatments have been reported in earlier papers [7,8], particularly looking at anodizing as opposed to PEO: results there suggest that cold-working and hard coating will be complimentary. In this work the aerospace alloy AA2024-T351 was examined with individual and combined treatments to evaluate the possibility of fatigue-life improvements.

2. Experimental

2.1. Sample preparation

Samples were prepared in a size suitable for four point bend tests measuring 20 mm × 22 mm × 150 mm. The parent plate was 20 mm thick AA2024-T351 supplied by Apollo Metals Ltd, Birmingham, England. Specimens were cut from the parent plate using a hydraulic feed horizontal band saw; no further conventional machining was performed during preparation.

A proportion of the specimens were then shot-peened on a single face of interest, later the subject of fatigue testing. This was conducted using a Tealgate Precifeed system which is a compressed air with magnetic shot feed configuration. Peening was performed in accordance with the military guideline MIL-S-13165c to 200% coverage and further verified at 20AlmenC. An S110 mild steel shot was used.

PEO treatment was applied to a batch of both peened and unpeened samples using a 10-kW laboratory rig manufactured by Keronite Ltd. A dilute alkaline electrolyte was used with additions of 2–3 g l^{-1} of Na_2SiO_3 and $Na_3P_2O_7$ [9]. Samples were suspended fully submerged using a threaded contact insulated from the electrolyte by a plastic jacket. A Pulsed Bipolar Current (PBC) supply was used with frequency set at 2 kHz and current density ≈30 A dm^{-2} [9]. PEO treatment covered the whole surface of the specimen except for the threaded holder.

2.2. Fatigue

Fatigue testing was carried out using an Instron 8500 servo-hydraulic test frame with Instron 8501 digital controller. Loading was conducted in a typical four point bend configuration with a gauge volume length of 40 mm. Constant amplitude loading was applied with a stress ratio $R=0.1$ at a range of maximum stress values between 250 and 400 MPa. A selection of data from the literature was consulted to identify

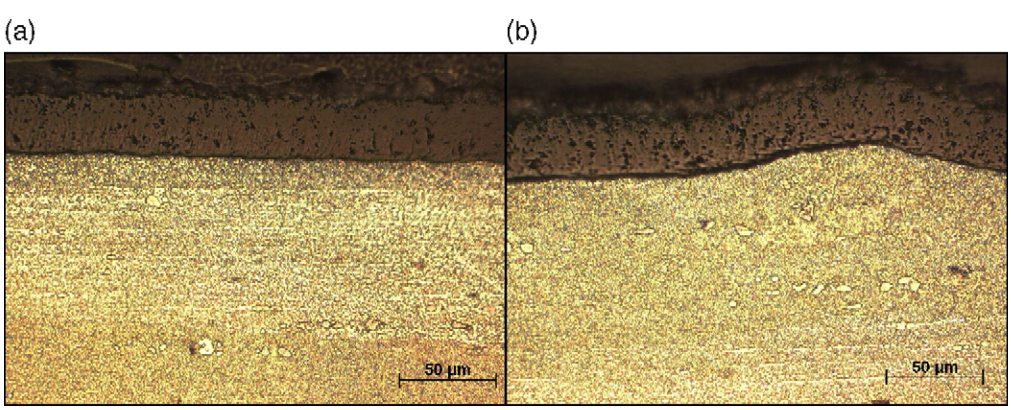

Fig. 2. Optical micrographs of PEO coatings on (a) as-received and (b) shot-peened Al alloy substrates, showing (a) Cu precipitates aligning with the rolling direction and an oxide layer consisting of ~25 μm dense alumina and 5 μm porous surface layer can be seen, (b) precipitates deviate from the horizontal to follow the peened surface contours.