Available online at www.sciencedirect.com
ScienceDirect
Procedia Engineering 00 (2009) 000–000
Procedia Engineering
www.elsevier.com/locate/procedia

ICM11

Differing microstructural properties of 7075-T6 sheet and 7075-T651 extruded aluminium alloy

Timothy J Harrison[a*], Bruce R Crawford[b], Madabhushi Janardhana[c], Graham Clark[a]

[a]RMIT University, Plenty Rd, Bundoora 3083, Australia
[b]Defence Science and Technology Organisation, 506 Lorimer St, Fishermans Bend 3207, Australia
cDGTA, Royal Australian Air Force, Maher St, Laverton 3208, Australia

Elsevier use only: Received date here; revised date here; accepted date here

Abstract

This paper details an initial study of the differences, if any, in corrosion behaviour between 7075-T6 sheet and 7075-T651 extruded aluminium alloy. The study involved a visual inspection of the grain structure of each material and an analysis of the grain sizes. It was found that there is a significant difference in the grain sizes of the two materials; the extruded material had grains that were approximately 15-20% of the size of the sheet grains. Also, the grains in the sheet material were wider, with a length-to-width aspect ratio of 1.5 (compared with 1.3 for the extruded material). Finally, the grains in the extruded material appeared to form a semi-continuous line of grain boundaries, possibly facilitating the growth of laminar intergranular corrosion; the sheet material contained higher-angle grain boundary junctions which should limit the amount of laminar intergranular corrosion produced and promote networked intergranular corrosion. Further testing will involve corroding specimens and investigating the size, shape and depth of the corrosion produced.

Keywords: Microstructure; 7075 Aluminium; Corrosion behaviour; Grain size

1. Introduction

7075 aluminium alloy is a primary alloy in many aerospace applications due to its specific strength (strength to density ratio) and high fracture tolerance toughness[1]. However it is susceptible to several forms of corrosion, especially in the peak-aged T6 temper [2, 3]. One of the key corrosion threats is intergranular corrosion (IG), which can show little indication on the surface while penetrating deeply within the material; the severity of the damage is often masked. This form of corrosion is particularly difficult to assess in terms of its impact on structural integrity, and the variety of corrosion morphologies can also make complete removal of the affected region difficult if not impossible [4].

* Corresponding author. Tel.: +61 4 3700 1720.
E-mail address: timothy.harrison@student.rmit.edu.au.

This paper is part of a larger program that aims to address the impact of different types of IG corrosion on 7075 alloys with a specific focus on the P-3C Orion in service with the Royal Australian Air Force (RAAF). This program involves, amongst other things, fatigue testing corroded coupons of 7075-T6 to develop a predictive fatigue life model that can be applied to components in-service. One immediate problem is that it can be difficult to match the coupon test material with the actual aircraft component material. In this particular application the problem is that the P-3C wing skin is an integrated stringer/skin machined from an extrusion, resulting in an extruded skin section approximately 2 mm thick. It is difficult to obtain 2 mm thick extrusion without resorting to machining down a thicker section; for example, in Australia the thinnest commonly-available extruded section is ¾" (~20 mm) [5], and machining this down to the required thickness would lead to the risk of the coupon material not being fully representative of the thicker extrusion. The usefulness of any investigation (for example developing a fatigue life prediction model) relies on a close match between the corrosion behaviours of the test material and the aircraft skin material. One solution to this problem is to attempt to find a material with the same behaviours and characteristics as the aircraft component material. It is possible to obtain 7075 aluminium alloy in a number of thicknesses (from 0.5 mm to 3.2 mm from [5]), however it is rolled sheet rather than an extrusion. A key issue with using sheet material is that the different grain boundary structure is likely to affect the corrosion behaviour.

It is known that the grain boundary structure influences other forms of localised corrosion. For example, exfoliation requires a highly directional grain structure, which results in an available corrosion path through the material [6-9].

This paper describes a preliminary investigation of the microstructure to give an indication as to whether the two manufacturing processes are likely to have an influence on the form of corrosion produced. This work underpins the larger fatigue and structural integrity program.

2. Microstructure

A material's microstructure can give a valuable insight into its properties and corrosion resistance. The volume fraction of inclusions and grain size are important characteristics that can affect several different material properties. A greater number of inclusions within a material can increase its strength as they can cause dislocation pile-ups [2, 10]. These inclusions can also have an effect on the pitting resistance of the material; some literature has suggested that inclusions and constituent particles can be initiation points for pitting corrosion [11-13].

The grain size and general microstructural texture were investigated through optical microscopy of cold-mounted 7075-T6 and 7075-T651 samples. A qualitative comparison of inclusion shape, size and density was conducted – no measurements were taken so this comparison is based on the optical images. Each mounted sample contained three specimens to show each face (as shown in Fig. 1(b) – Fig. 1(a) shows a schematic of the face labelling and faces shown in the grain maps, Fig. 2). Cold mounting was used to avoid the thermal effects (such as grain boundary changes) that can occur during hot mounting, where the sample is held at 180ºC for approximately 8 minutes.

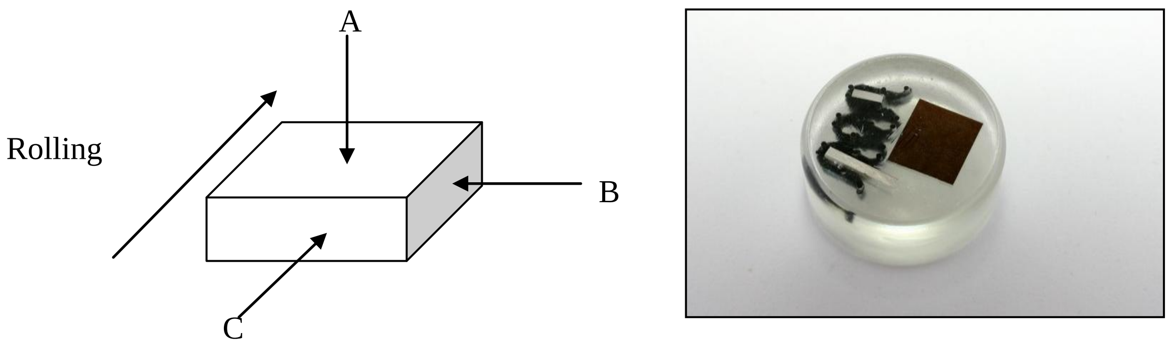

Fig. 1. (a) Schematic of the faces shown in the cold mount (b). Example of a cold-mounted specimen

The samples were polished to a 1µm finish. The samples were then etched using the swab method and Keller's Etchant; the etchant was applied using a cotton ball for 15-20 seconds per sample, thoroughly washed with water then rinsed with ethanol and dried.

Digital micrographs were then taken of the samples at 20x, 50x or 100x magnifications. These images were then analysed using Image J, a public domain image analysis program. The line intercept method was used to determine the average size of the grains. It was found that the length and width of the grains can be measured from face a, length and thickness from face b and face c shows the width and thickness.

3. Results

3.1. Grain analysis

Three samples of each material were cold-mounted for microstructural analysis with each cold mount contained three faces (as in Figure 1 (b)). The samples of 7075-T651 were designated A1 to A3 while the 7075-T6 samples were designated D1 to D3. Two grain maps are shown in Fig. 2. The scale bars on these represent 100 µm.

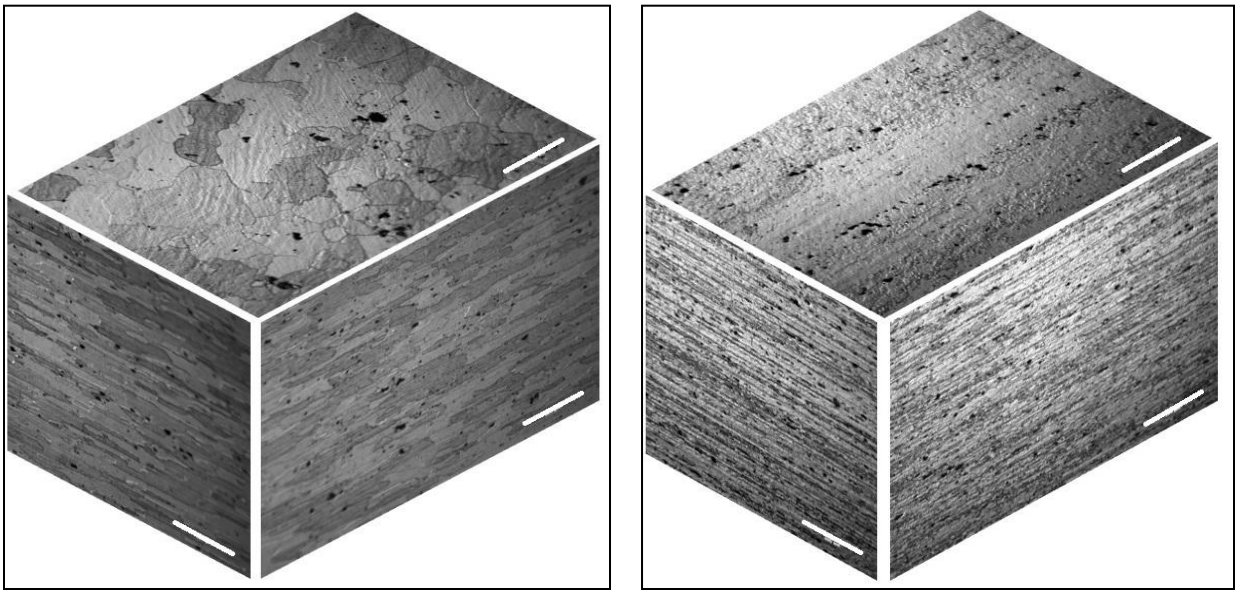

Fig. 2.(a) Grain map of sample A2 (b) Grain map of sample D2. Scale bar indicates a length of 100 µm,

Table 1 shows the mean grain sizes (and 95 percent confidence interval) of the samples of 7075-T6 and 7075-T651. The data in Table 1 indicate that there were significant differences in the grain sizes of the two materials.

Table 1. Mean grain sizes and confidence intervals

		Mean (μm)	Std Error (μm)	95% Confidence Interval (μm)
Length	7075-T651	13.0	3.0	7.1 - 18.9
	7075-T6	79.9	12.3	55.9 - 104.0
Width	7075-T651	8.3	1.9	4.6 - 12.1
	7075-T6	59.7	9.2	41.5 - 77.8
Thickness	7075-T651	2.8	0.6	1.5 - 4.0
	7075-T6	12.5	2.0	8.7 - 16.3

The comparison between 7075-T6 sheet and 7075-T651 extrusion reported here found a significant difference in the grain structures of each. It was found that, while both the sheet and extrusion had pancake-shaped grains (much thinner than their length and width); the sheet material had larger, more well-defined grains than the extrusion. It appeared that the extrusion had broken up grains that appear to have not recrystallised following the extruding process; the grains were significantly smaller than the grains in the sheet. However the grains in the extrusion lined up to form a semi-continuous series of grain boundaries (as can be seen in Fig. 5(a)), whereas the larger grains in the sheet had a more equiaxed appearance with a number of high-angle junctions between the grain boundaries (as shown in Fig. 5(b)).

Further, the dimensions of the grains in the extrusion were approximately 15-20% of the size of those in the sheet material. The grains in the extrusion also had a less consistent grain size – the difference between the mean and standard error for the extrusion was 23% and the sheet was 15%.

3.2. Inclusions

A simple comparison of the amount, size and density of inclusions in both materials was made based on visual inspection only. By comparing the images of the extruded and rolled samples it appears that the inclusions on both materials are very similar. The only main difference is that the inclusions in the extruded section are more structured and form into lines compared with the sheet; the sheet has a more random distribution of inclusions.

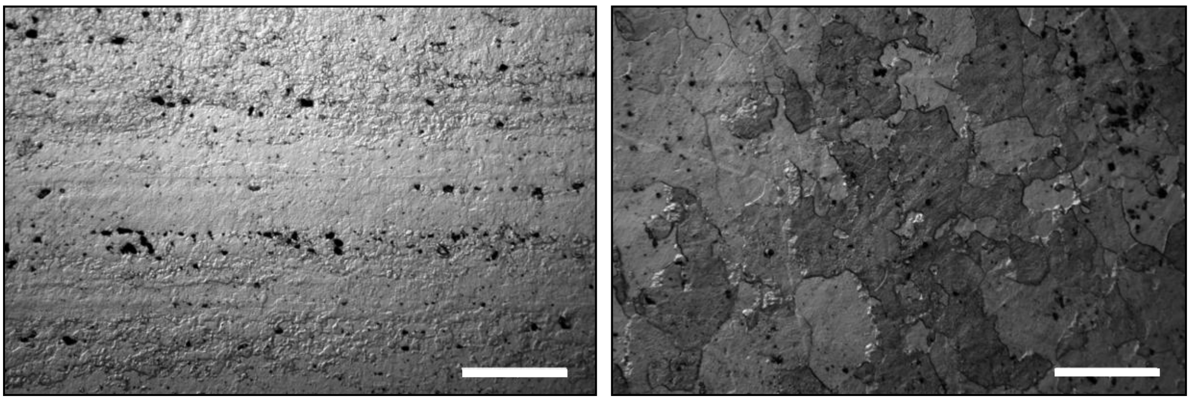

Fig. 6. (a) Face a of Sample A2 showing inclusions (black spots). Scale bar = 100μm (b) Face a of Sample showing inclusions (black spots). Scale bar = 100μm

4. Discussion and Conclusions

The aim of this paper was to assess the possibility of differences in the corrosion behaviour of 7075-T6 sheet and 7075-T651 extrusion, through an analysis of the grain structure. Important differences between the two materials were found; the extruded material had very small grains that formed a structured, semi-continuous line of grain boundaries. The authors hypothesise that this may have the ability to facilitate laminar intergranular corrosion. The sheet section had larger grain boundaries that did not form a semi-continuous line due to a larger amount of high-angle grain boundary junctions; again, the authors hypothesise that this is less likely to lead to laminar intergranular corrosion, however is more likely to create networked intergranular corrosion.

It is therefore concluded that there may be differences in the corrosion behaviour of the two materials, which will have consequences for selecting the best material to assist in modelling corrosion behaviour in the current research program. It will be necessary to investigate the actual differences in corrosion behaviour between the two materials before proceeding to develop a model that will help to predict fatigue-related issues in aircraft components. Such a comparison will provide additional robustness to the modelling. The continuing program will involve corroding specimens of both 7075-T6 sheet and 7075-T651 extrusion and investigating the corrosion found using methods such as optical microscopy, SEM, ultrasound, eddy current, tomography and further microhardness testing.

Acknowledgements

The authors would like to thank Stephan Toman, Charles Brady, Cathy Smith and Noel Goldsmith (all from DSTO) for their help and guidance in using the various laboratories at DSTO.

References

[1] MatWeb. http://www.matweb.com/search/DataSheet.aspx?MatGUID=4f19a42be94546b686bbf43f79c51b7d&ckck=1 Cited: 08/03/2011.

[2] Jin-Feng L, Peng ZW, Chao-Xing L, Zhi-Qiang J, Wen-Fing C, Zi-Quao Z. Mechanical properties, corrosion behaviors and microsctructures of 7075 aluminium alloy with various aging treatments. Trans Nonferrou Met. Soc. China 2008;**18**:755-62.

[3] Prevey PS, Cammett J. Low cost corrosion mitigation and improved fatigue performance of low plasticity burnished 7075-T6. JMEPEG 2001;**10**:548-55.

[4] Cole GK, Clark G, Sharp PK. The implications of corrosion with respect to structural integrity. DSTO Technical Report DSTO-RR-0102 1997.

[5] Airport Metals. http://www.airportmetals.com/index.htm Cited: 27/02/2011.

[6] Liao M. Modelling the effects of prior exfoliation corrosion on fatigue life of aircraft wing skins, Int J Fatigue 2003;**25**:1059-67

[7] Lian M. Fatigue modelling for aircraft structures containing natural exfoliation corrosion. Int J Fatigue 2007;**29**:677-86.

[8] Zhao X, Frankel GS. Quantitative study of exfoliation corrosion; exfoliation of slices in humidity technique. Corrosion Science 2007;**49**:920-38.

[9] Posada M, Murr LE, Niou CS, Roberson D, Little D, Arrowood R et al. Exfoliation and related microstructures in 2024 aluminium body skins on aging aircraft. Materials Characterization 1997;**38**:259-72.

[10] Askeland DR, Phule PP. *The science and engineering of materials*. 5th ed. Toronto: Nelson, 2006.

[11] Jones K, Hoeppner DW. The interaction between pitting corrosion, grain boundaries and constituent particles during corrosion fatigue of 7075-T6 aluminium alloy. Int J Fatigue 2009;**31**:686-92.

[12] Harlow DG, Wei RP. A probability model for the growth of corrosion pits in aluminium alloys indicated by constituent particles. Eng Fracture Mechanics 1998;**59**:305-25.

[13] Birbilis N, C avanaugh MK, Buchheit G. Electrochemical behaviour and localized corrosion associated with Al_7Cu_2Fe particles in aluminium alloy 7075-T651. Corrosion Science 2006;**48**:4202-15.