MATERIALS CHARACTERIZATION 64 (2012) 107–117

Available online at www.sciencedirect.com

SciVerse ScienceDirect

www.elsevier.com/locate/matchar

Microstructure, crystallographic texture and mechanical properties of friction stir welded AA2017A

M.M.Z. Ahmed[a, b,*], B.P. Wynne[a], W.M. Rainforth[a], P.L. Threadgill[c]

[a]Institute for Microstructural and Mechanical Processing Engineering, The University of Sheffield (IMMPETUS), Mappin Street, Sheffield S1 3JD, UK
[b]Department of Metallurgical and Materials Engineering, Suez Canal University, Suez 43721,Egypt
[c]TWI LTD, Granta Park, Great Abington, Cambridge CB21 6AL, UK

ARTICLE DATA

Article history:
Received 30 July 2011
Received in revised form
10 December 2011
Accepted 13 December 2011

Keywords:
Friction stir welding
Electron back scattering diffraction
Microstructure
Crystallographic texture
Aluminium alloy

ABSTRACT

In this study a thick section (20 mm) friction stir welded AA2017A-T451 has been characterized in terms of microstructure, crystallographic texture and mechanical properties. For microstructural analysis both optical and scanning electron microscopes have been used. A detailed crystallographic texture analysis has been carried out using the electron back scattering diffraction technique. Crystallographic texture has been examined in both shoulder and probe affected regions of the weld NG. An entirely weak texture is observed at the shoulder affected region which is mainly explained by the effect of the sequential multi pass deformation experienced by both tool probe and tool shoulder. The texture in the probe dominated region at the AS side of the weld is relatively weak but still assembles the simple shear texture of FCC metals with $B/\bar{B}$ and C components existing across the whole map. However, the texture is stronger at the RS than at the AS of the weld, mainly dominated by$B/\bar{B}$ components and with C component almost absent across the map. An alternating bands between (B) components and ($\bar{B}$) component are observed only at the AS side of the weld.

1. Introduction

Friction stir welding (FSW) is a solid state joining process developed by TWI [1,2] that has rapidly progressed into a viable joining technology for a variety of metals and alloys, in particular aluminium alloys[3]. As FSW takes place the material forming the joint is subjected to a complex thermomechanical process which has a significant bearing on the microstructure and texture produced. Horizontally across the transverse section four microstructural zones were defined 1) unaffected material, 2) the heat affected zone (HAZ), 3) the thermomechanically affected zone (TMAZ), and 4) the nugget zone (NG) [4]. Vertically the NG has been divided in some cases into three or two distinct regions [5,6]. Three distinct regions have been defined in a 75 mm thickness FS welded AA6082, a) shoulder influenced deformation down to a depth of approximately 5 mm, b) probe and shoulder dominated deformation down to a further depth of 8 mm, and c) probe dominated region for the rest of the weld NG[5]. Two regions have been observed in a 32 mm thickness FS welded AA6082, shoulder affected region from the top surface down to a depth of 8 mm and then the rest of the NG influenced by the probe[6]. Crystallographic texture studies of thick section friction stir welded aluminium were mainly concentrating on the probe affected region [6–9] for limited number of heat treatable aluminium alloys such as AA6082[6] and AA2195[7–9]. In this study the microstructure and crystallographic texture of additional friction stir welded heat treatable aluminium alloy AA2017 have been investigated. Also in this work crystallographic texture investigation has been carried out at both the shoulder affected region and the probe affected region. Thus the aim of the current study was to present a

* *Corresponding author at:* Department of Metallurgical and Materials Engineering, Suez Canal University, Suez 43721, Egypt. Tel.: +20 623360252.
E-mail address: mohamed_ahmed4@s-petrol.suez.edu.eg (M.M.Z. Ahmed).

1044-5803/$ – see front matter © 2011 Elsevier Inc. All rights reserved.
doi:10.1016/j.matchar.2011.12.005

detailed investigation of microstructure and crystallographic texture of thick section friction stir welded AA2017.

2. Material and Methods

2.1. Friction Stir Welding

A 20 mm thickness plate of AA2017A- T451 was friction stir welded at the TWI Ltd (South Yorkshire) at a rotation rate of 300 rpm and traverse speed of 120 mm/min with a tool tilt angle of 2° normal to the plate surface. Details of the tool and the machine used to produce the weld were given elsewhere [10].

2.2. Metallography and Mechanical Testing

The weld was then sectioned normal to the welding direction (WD) and metallographically prepared according to the standard preparation technique using grinding and polishing followed by etching with a diluted Keller's reagent of composition; 100 ml distilled water, 10 ml HNO_3, 10 ml HCL, and 2 ml HF to reveal the microstructure using POLYVAR optical microscope. Vickers hardness was measured with 5 kg load in a two dimensional grid of 4 mm spacing such that sketched in Fig. 1a, this is mainly to construct a hardness map which could then be correlated with microstructural observations. The tensile properties of the weld were examined across the transverse cross section with the NG region in the centre of the gauge length of the tensile test sample; the dimensions and geometry of the tensile test specimen are illustrated in Fig. 1b.

2.3. EBSD Data Acquisition and Processing

For the EBSD analysis samples from the top and bottom of the weld were cut. These samples were then mechanically polished and subsequently electropolished with a solution of 30% Nitric acid in methanol for 60 s at 14 V and −15 °C. After electropolishing the samples were then mechanically polished again very gently for very short time just to remove the second phase particles coming up from the surface which causes a shadowing effect during EBSD data acquisition.

Table 1 – Parameters used in the Sirion FEGSEM for EBSD data acquisition.

Parameter	Values used
Magnification	200×
Beam spot size	3
Beam voltage	20 keV
No of background frames	64
No of averaged frames	6–8
Timing per frame	12–14 ms
Step size	2 μm
Mapping rate	0.115–0.2 s^{-1}
Camera binning	8×8 pixels

Sirion Field Emission Gun Scanning Electron Microscope (FEGSEM) equipped with a Nordlys CCD camera controlled by HKL Channel 5 software has been used for EBSD data acquisition. In the software used there is a possibility to run automatically the required area using beam controlled job and/or stage controlled job depending on the area that will be analysed. If the area that will be analysed is small and can be included in one job so in this case beam controlled job can be used. However if the area that will be analysed is large and a number of jobs are required so a combination of both beam and stage controlled jobs is needed. In the present work mainly large areas were analysed so both beam and stage control were used, the beam control was for every single job (200×200 μm^2) and the stage control was to move the sample between the jobs. The Parameters used for EBSD pattern acquisition are given in Table 1.

EBSD data were collected and saved as data files for further analysis. The first step in the data processing was to stitch the several jobs that were collected for the large area scans and this was done using map stitcher software within channel5 to get the data in one file. Then the EBSD data file was ready for the further analysis. When the data processed for the first time it was observed that during EBSD data acquisition there were some regions within the area investigated were difficult to be indexed by the EBSD software such as the grain boundaries, inclusions and/or the unknown phase particles. So to get a clear EBSD map those non-indexed points were removed using what is called noise reduction in the software and were filled in using copies of neighbouring points. In this work the indexing was between 85 and 90%.

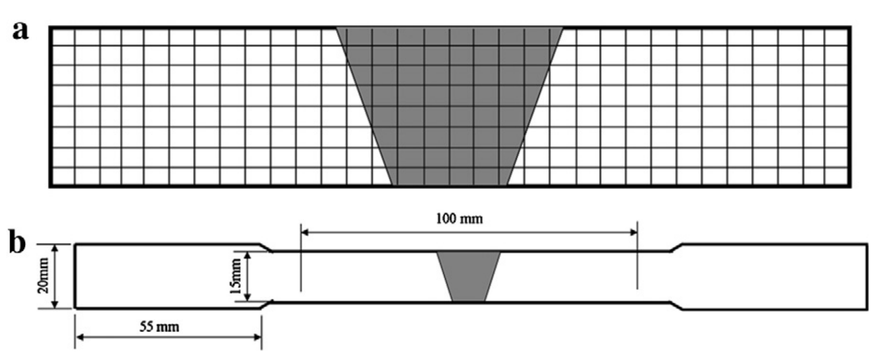

Fig. 1 – a) Schematic of the grid used for hardness measurements, and b) Schematic of the tensile test sample used with the dimensions illustrated and the NG region was kept at the centre of the gauge length.