Available online at www.sciencedirect.com

ScienceDirect

Trans. Nonferrous Met. Soc. China 25(2015) 1367−1375

Transactions of Nonferrous Metals Society of China

www.tnmsc.cn

Microstructure and texture evolution of Al-7075 alloy processed by equal channel angular pressing

M. H. SHAERI[1], M. SHAERI[2], M. T. SALEHI[3], S. H. SEYYEDEIN[3], F. DJAVANROODI[4,5]

1. Department of Metallurgy and Materials Engineering, Engineering Faculty, Imam Khomeini International University, Qazvin 34149−16818, Iran;
2. Department of Materials Science and Engineering, Sharif University of Technology, Tehran, Iran;
3. Department of Metallurgy and Materials Engineering, Iran University of Science and Technology, Tehran, Iran;
4. Department of Mechanical Engineering, Iran University of Science and Technology, Tehran, Iran;
5. Department of Mechanical Engineering, Prince Mohammad Bin Fahd University, Al Khobar 31952, Saudi Arabia

Received 4 July 2014; accepted 25 October 2014

Abstract: Equal channel angular pressing is an effective technique to control the texture and microstructure of metals and alloys. Texture and microstructure of an Al-7075 alloy subjected to repetitive equal channel angular pressing through a 90° die were evaluated by X-ray diffractometer and orientation imaging microscopy. It is observed that processing through different routes leads to different types of textures, in both qualitative and quantitative senses. The texture calculation by Labotex software reveals that texture strengthens after the first pass and weakens by progressing ECAP process up to 4 passes. Microstructure investigations show that after 4 passes of equal channel angular pressing via routes B_C and A, very fine grains with average grain size of about 700 nm and 1 μm appear, respectively, and most of the grains evolve into arrays of high angle boundaries. The effects of covering the Al-7075 billets with copper tube on texture and microstructure were also studied.
Key words: equal channel angular pressing; crystallographic texture; aluminum alloy; ultra-fine grain

1 Introduction

Equal channel angular pressing (ECAP) or extrusion (ECAE) is known as the most promising technology among the potential severe plastic deformation (SPD) processing techniques, which can be applied to producing ultra-fine grained materials in bulk metallic alloys [1]. In equal channel angular pressing process, a billet is extruded repetitively through a die with two channels of equal cross section intersecting at an abrupt angle, Φ, and with a corner curvature angle, Ψ, [2,3]. Since the cross sectional shape of the billet remains nearly the same during the process, it is now well recognized as a promising method to enhance the strength of various metallic alloys through the occurrence of grain refinement in severe plastic deformation. In multi-pass ECAP, the evolution of crystallographic texture is quite complex due to the various strain path changes instigated by the prescribed processing route. The most common routes are termed A, C, B_A and B_C according to the rotation of the billet around the specimen's longitudinal axis between successive passes: A, no bar axis rotation; C, 180° rotation after each pass; B_A, clockwise 90° rotation after even numbered passes and counter clockwise 90° after odd numbered passes; and B_C, 90° rotation after each pass [3−8].

Investigation of texture evolution is essential to understand the mechanisms of plastic deformation and grain refinement during ECAP [9]. The large plastic deformation and strain-path changes involved in the process result in significant and complex changes of crystallographic texture [10]. In the literature, many studies have been conducted to evaluate the effects of material properties and processing variables on ECAP texture evolution [7−26]. For a given material, the texture development mainly depends on the die angle (Φ), processing route, number of passes (N) and initial texture [7,9,22−26]. On the characteristics of ECAP textures, most of the studies have shown that textures developed during ECAP deformation are often compared

Corresponding author: M. H. SHAERI; Tel: +98-2833901190; Fax: +98-2833780073; E-mail: shaeri@ENG.ikiu.ac.ir
DOI: 10.1016/S1003-6326(15)63735-9

with those after simple shear tests, such as torsion. This kind of comparison is a natural consequence of simple shear that has been accepted as the dominant deformation mode in ECAP [27−29].

The objective of the present work is to study the effect of equal channel angular pressing on texture and microstructure of Al-7075 alloy processed by routes A and B_C. For this purpose, conventional aluminum specimens and aluminum specimens covered with copper tube casing were analyzed by X-ray diffractometer (XRD) and orientation imaging microscopy (OIM) after 4 passes of ECAP, and then texture and microstructure of these specimens were compared.

2 Experimental

The experiments were conducted using Al-7075 alloy as the main ECAP material and commercial pure copper as covering tube. The chemical composition of Al-7075 alloy determined by the GNR Italy metallab−7580J spectrometer set is shown in Table 1. Extruded aluminum rods were machined into billets with diameter of 19.1 mm and length of 140 mm and then pressed through an ECAP solid die having a channel angle of Φ=90° and an outer curvature angle of Ψ=20°. The outer diameter and thickness of copper tube were 19.1 mm and 1 mm, respectively, so diameter of aluminum rod was decreased to 17.1 mm by lathing for specimens covered with copper tube. The copper tube and the rod were press fitted prior to the ECAP process. As reported in our previous work [30], covering the specimens with copper tube leads to a notable decrease in pressing load of ECAP process and a slight increase in homogenity and mechanical properties of ECAP processed specimens. The Al-7075 alloy and copper tubes were annealed at 415°C and 800 °C for 1 h followed by furnace cooling, respectively. Billets were pressed at room temperature for either 1 or 4 passes, equivalent to imposed strains of about 1 and 4, respectively [31], using processing routes A and B_C.

Table 1 Chemical composition of Al-7075 alloy (mass fraction, %)

Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
0.07	0.09	1.50	0.04	2.65	0.21	5.70	0.02	Bal.

Measurements of crystallographic texture were performed employing a RIGAKU, D/MAX−2500 X-ray diffractometer (Cu K_α radiation, λ=1.5406 Å) on the flow or Y plane equivalent to the side plane at the point of exit from the ECAP die (Fig. 1[32]). The measurements were taken at approximately the mid-point on each longitudinal section by preparing a flat surface through mechanical polishing and grinding. The textures recorded over an area having dimensions of 19 mm × 19 mm. X-ray pole figures (PF) measurements were carried out using Schulz back reflection method. The Labotex 2.1 software was used to process the raw data, calculate the orientation distribution function (ODF) from three partial pole figures (111), (200) and (220), and calculate volume fraction of the texture components. After definition of the main ideal ECAP texture components by the Euler angles or Miller indices in the Labotex software, the volume fractions of the texture components were measured by integration method. The volume fractions were computed by integrating the ODF within a 10° distance in Euler space from the ideal component orientation. It might result in some limited overlapping of the volume fractions of neighboring components, nevertheless, the relative strengths of the components were well represented by this technique.

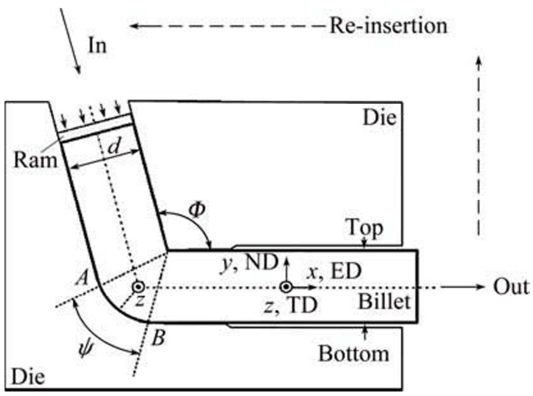

Fig. 1 ECAP die geometry and coordinate system employed

The microstructural examination was carried out using a Quanta 3D FEI field emission scanning electron microscope (FE-SEM) with electron back scatter diffractometer (EBSD) attachment at an accelerating voltage of 15 kV and a beam current of 10 nA. The orientation image microscopy (OIM) images were obtained on the area of 80 μm ×150 μm with the step size of 500 nm for annealed specimen, whereas for ECAP processed specimens the OIM images were obtained on the area of 7 μm × 12 μm with the step size of 50 nm. The results were analyzed using the TSL software. The collected data were subjected to a clean-up procedure consisting of: 1) grain dilation with grain tolerance angle of 5° and a minimum grain size of 2 pixels; 2) grain confidence index (CI) standardization with grain tolerance angle of 5° and minimum grain size equal to 2 pixels; 3) neighbor orientation correlation (level 4) with a minimum CI of 0.02. For specimen preparation, the surface of cross-section (X-plane in Fig. 1) was first mechanically ground up to 4000-grit SiC paper, then electropolishing was employed in a 30% nitric acid and