Progress in Natural Science: Materials International 2012;22(5):452–460

Chinese Materials Research Society

Progress in Natural Science: Materials International

www.elsevier.com/locate/pnsmi
www.sciencedirect.com

ORIGINAL RESEARCH

Designing of ECAP parameters based on strain distribution uniformity

F. Djavanroodi, B. Omranpour, M. Ebrahimi*, M. Sedighi

Department of Mechanical Engineering, Iran University of Science and Technology, Tehran, Iran

Received 21 May 2012; accepted 5 August 2012
Available online 30 October 2012

KEYWORDS

ECAP;
FEM;
Die design;
Strain distribution

Abstract Equal Channel Angular Pressing (ECAP) is currently one of the most popular methods for fabricating Ultra-Fine Grained (UFG) materials. In this work, ECAP process has been performed on commercial pure aluminum up to 8 passes by route *A*. After verification of FEM work, the influences of four die channel angles, three outer corner angles and pass number up to 8 have been analyzed to investigate strain distribution behavior of ECAPed material. Two methods for quantifying the strain homogeneity namely inhomogeneity index (C_i) and standard deviation (S.D.) are compared. It is shown that C_i is not a good candidate for examining the strain distribution uniformity. Moreover, it is suggested that designing of ECAP die geometry to achieve optimum strain distribution homogeneity is more suitable than the optimum effective strain magnitude. The best strain distribution uniformity in the transverse plane is obtained with $\Phi=60^\circ$ and $\Psi=15^\circ$ and for the bulk of the sample, $\Phi=120^\circ$ and $\Psi=15^\circ$ or 60°, gives the highest strain dispersal uniformity.

1. Introduction

Equal Channel Angular Pressing developed by Segal [1] is the most popular Severe Plastic Deformation (SPD) techniques for enhancement of mechanical properties and superplastic behavior with respect to the grain size reduction [2–4]. As a principle, material grain size is one of the prominent parameters influencing mechanical behavior of base metals and alloys concentrated in all of the SPD techniques like ECAP [5], High Pressure Torsion (HPT) [6], Accumulative Roll Bonding (ARB) [7], Constrained Groove Pressing (CGP) [8], Accumulative Back Extrusion (ABE) [9], Tubular Channel Angular

*Corresponding author. Tel.: +98 217 724 0203.
E-mail addresses: javanroodi@iust.ac.ir (F. Djavanroodi), omranpour@yahoo.com (B. Omranpour), mebrahimi@iust.ac.ir (M. Ebrahimi), sedighi@iust.ac.ir (M. Sedighi).

Peer review under responsibility of Chinese Materials Research Society.

Production and hosting by Elsevier

1002-0071
http://dx.doi.org/10.1016/j.pnsc.2012.08.001

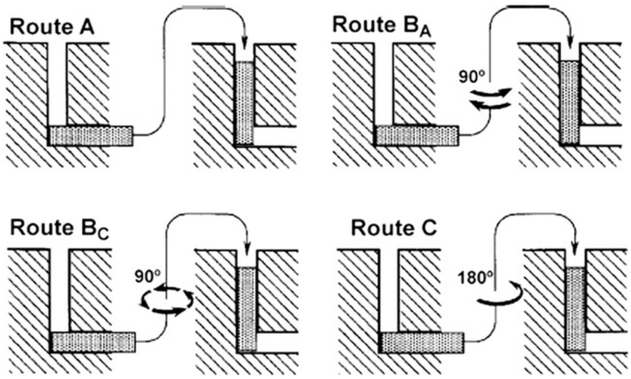

Fig. 1 Four fundamental routes in the ECAP process [12].

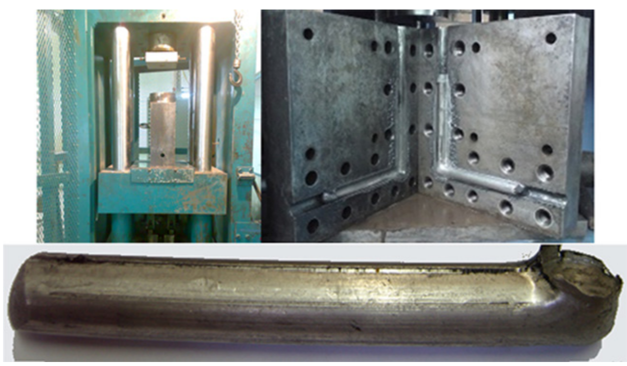

Fig. 2 Hydraulic press, ECAP die and AL billet after one pass pressing.

Pressing (TCAP) [10], etc. During ECAP, a sample is pressed through two intersecting channels having the same cross-sections with a die channel angle of Φ and an outer corner angle of Ψ. During this process, billet with high value of plastic strain can be produced because of accumulative shear strain at each pass. The magnitude of shear strain after one pass ECAP in the frictionless condition is determined with [11]:

$$\gamma = 2cot\left(\frac{\boldsymbol{\Phi}+\boldsymbol{\Psi}}{2}\right) + \boldsymbol{\Psi}cosec\left(\frac{\boldsymbol{\Phi}+\boldsymbol{\Psi}}{2}\right) \quad (1)$$

Also, the magnitude of equivalent effective plastic strain (ε_{eq}) after N passes is given by the following relationship:

$$\varepsilon_{eq} = N/\sqrt{3}\left[2cot\left(\frac{\boldsymbol{\Phi}+\boldsymbol{\Psi}}{2}\right) + \boldsymbol{\Psi}cosec\left(\frac{\boldsymbol{\Phi}+\boldsymbol{\Psi}}{2}\right)\right] \quad (2)$$

In the ECAP process, there are four fundamental routes between each repetitive pressing as shown in Fig. 1 [12]. These are as follows: route A by which the sample is repetitively pressed without any rotation, route B_A by which the sample is rotated by 90° in the alternative direction between each pass, route B_C by which the sample is rotated in the same direction by 90° and route C by which the sample is rotated by 180° between consecutive passes. These routes result in different slip systems in the specimen and so, various microstructures and mechanical properties can be obtained by them [12,13].

So far, many experimental studies have been performed to investigate the influence of different pressing routes on the microstructure, texture and so, mechanical properties of the final work-piece [14,15]. Investigations of Komura et al. [16]

Table 1 Mechanical properties of pure Al before and after ECAP process up to 8 passes by route A.

No. of passes	Pass 0	Pass 1	Pass 2	Pass 3	Pass 4	Pass 8
YS (MPa)	39	87	118	136	145	153
UTS (MPa)	83	144	165	178	186	192
EL (%)	36	19	15	14	14	12

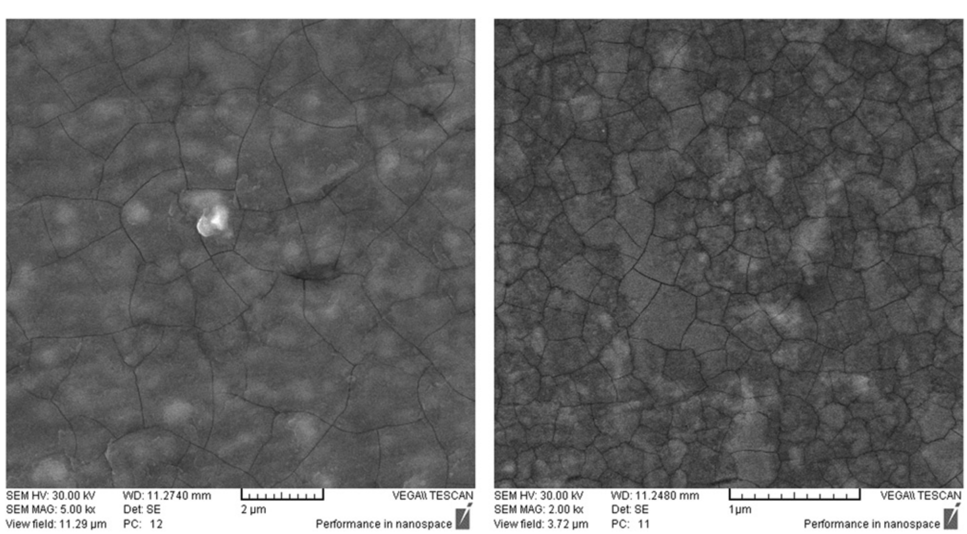

Fig. 3 Microstructure observations for initial and ECAPed Al after 8 passes by route A using SEM.