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Investigating the Mechanical Properties of FCC Structured Material Processed by Equal Channel Angular Extrusion

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Abstract

Severe plastic deformation (SPD) process like Equal Channel Angular Extrusion (ECAE) has involved a large amount of interest, because of its capability to make ultrafine grained microstructures. Equal Channel Angular Extrusion is an inventive method capable of producing homogeneous plastic deformation for a variety of materials with no major changes in geometrical shape and cross section. In the present work pure aluminum has been investigated for ECAE processing. Single pass Pressings were conducted on Al at the room temperature. Experiments were performed by means of ECAE die with channel angle of 120^0 attached to hydraulic press, moreover Mechanical and micro-structural characterization of the ECA pressed Aluminum is carried out.

Keywords: ECAE; Aluminum; SEM; Tensile Test; Hardness Test

INTRODUCTION

Equal channel angular extrusion (ECAE) is a method of obtaining ultra fine grain structures by imparting a huge amount of shear strain on to the materials with no altering the billet shape or size.

In ECAE different die angles was used to consider the effect of strain homogeneity and deformation behavior of the processed material. The result accomplished that the best strain homogeneity of the sample with lower dead zone formation can be achieved with a channel angle of 90° and outer corner angle of 10° [1]. Proper microstructure and mechanical properties and their effective strains were achieved with a die channel angle of 90° [2]. Magnesium alloy AZ31 was processed by ECAE to know the effect of deformation behavior and fracture toughness. The result originate that the deformation behavior was improved by the ECAE process [3]. The effect ECAE process on grain refinement was investigated numerically and experimentally using different die angles [4]. The effects of multi-pass processing was investigated and found that the much more improvement in grain refinement and strength on the specimens was observed [5]. The effects of friction conditions was investigated between workpiece and die during ECAE process and found that forming loads varied very sensitively depending on the friction conditions [6]. The present study aims at the investigation of micro-structural improvements during the ECAE processing along with the tensile and hardness tests.

METHODOLOGY

The equal channel angular extrusion (ECAE) process consists of die, punch and billet. In ECAE process the die is made of two channels of same cross section (symmetrical), the punch is placed on the die. Before processing the workpiece and the walls of the die were coated with lubricant in order to minimize the friction during the ECAE process. This was done by forcing the material through a die consisting of two channels of equal cross sectional area that intersect at an angle of Φ-120°. There is also an additional angle Ψ-30° which defines the arc of curvature at the outer point of the two intersecting channels. Fig.1 shows the ECAE die used for the present study.

Figure.1: Experimental Setup of ECAE process

Die Design Details

The dimensions considered for developing the ECAE process setup in below Table 1. The ECAE die contains two channels, equal in cross-section, intersecting at an angle near the center of the die. The test sample is machined to fit within these channels and it is pressed through the die using a punch. Die material used were mild steel and the plunger were tool steel (hardened).

Table 1: Tool Dimensions And Processing Parameters

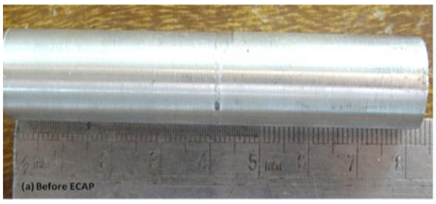
Process Parameters	Value
Billet Diameter and height	16mm and 85mm
Die channel angles (Φ)	120°
Die outer Radii (Ψ)	30°

Experimental Procedure for ECAE

Before starting the test the die, punch and inside face of extrusion chamber were cleaned. The full assembly of ECAE die was placed in between the base plate and centre table of Hydraulic press. For carrying out an ECAE test the aluminum specimen was placed inside the die. Pure aluminum rods with above mentioned dimensions were taken. The punch was then inserted into its position. Machine was started and ECAE process was continued. The application of the load was continued, the work piece till reaches out of the die. At this position machine was stopped and test was terminated. Experiments were conducted for a die angle of 120°.

RESULTS AND DISCUSSION

In this section all the results of Experimental investigation are discussed. After completion of experimental work, the specimens are to be used for multipurpose testing such as micro structural characterization and mechanical testing. The specimen must have the fine structure by polishing for characterization and for check hardness. Also part of the specimen is to be used to prepare the standard tensile specimens to observe the strength and elongation of the material. As illustrated in Fig. 2, sample was prepared it to 15.5 mm diameter and 80 mm length from round aluminum bar of 16mm diameter and 85 mm length as shown in Fig.2 (a). Another specimen was prepared from ECAP after 1st pass at room temperature as in Fig.2 (b).



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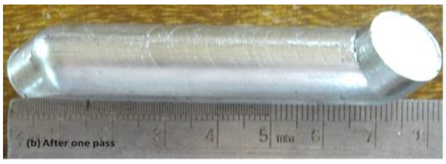

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Figure.2: (a) Before ECAP (b) After ECAP

Mechanical Testing

The test specimens are tested for the tensile test for evaluation of strength and elongation, hardness test for measuring the hardness of the material. ASTM E8M Standard is followed for the tensile testing. The details of the specimen tested for the test is shown in Fig.3. Vicker's micro hardness tester is used to test for the hardness of the billet. From Table 2, it is observed that the strength of the material was greatly improved from 237.13 Mpa to 284.56 Mpa for Non-processed and Processed specimens respectively; this is due to the change in the plastic anisotropic properties.

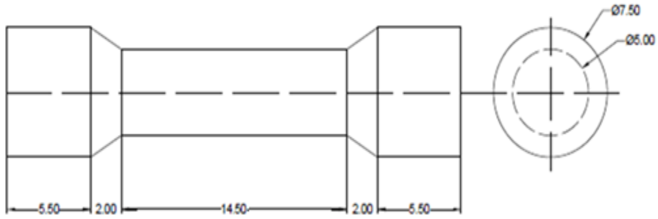


Figure.3: Test Specimen geometry

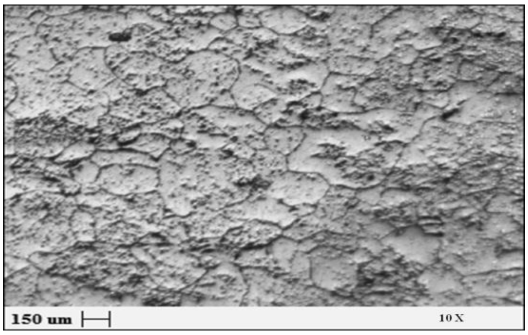
Table 2. Comparison of non-processed and processed test results

S. No	Test Name	Max. Stress (MPa)
1	Non-processed	237.13
2	Processed	284.56

Microstructural characterization

This technique is used for observing the microstructures and for evolution of size of the grains in the specimen. Scanning Electron Microscope (SEM) of JSM-6380LA, JEOL made is used in the current study and is shown in Fig.4. The SEM images at 10x magnification of 150um of the billets before and after processing are shown in Fig.5.

Figure.4: scanning electron microscopy used in the present study



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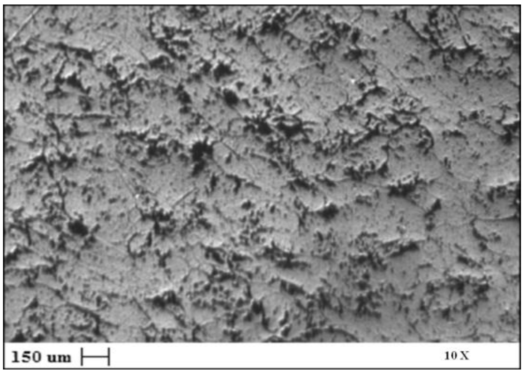

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Figure.5: (a) Grains before ECAE (b) Grains after ECAE

CONCLUSION

The grain refinement of the aluminum material was carried out successfully by ECAE process at room temperature with a speed of 2.2 mm/sec. The important conclusions were summarized as follows.

- The average size of the grains was greatly decreased by increasing number of passess. Thus the material deformation was observed in the entire material from top surface to center of the specimen
- However the strength of the material was greatly improved from 237.13 Mpa to 284.56 Mpa for non-processed and processed specimens respectively.
- Hardness of the aluminum material increased ECAE processing because of the strain hardening. Hence, the severe plastic deformation of the material was increased by ECAP.

REFERENCES

[1] Nagasekhar, A., & Tick-Hon, Y. (2004). Optimal tool angles for equal channel angular extrusion of strain hardening materials by finite element analysis. *Computational Materials Science, 30*(3-4), 489-495. doi:10.1016/j.commatsci.2004.02.041

[2] Nagarajan, D., Chakkingal, U., & Venugopal, P. (2006). Microstructure and Mechanical Properties Resulting from Conventional Cold Extrusion of Equal Channel Angular Extruded Aluminium Alloy AA6101. *Materials Science Forum Nanomaterials by Severe Plastic Deformation,* 287-292. doi:10.4028/0-87849-985-7.287

[3] Wang, X., Jin, L., Li, Y., & Guo, X. (2008). Effect of equal channel angular extrusion process on deformation behaviors of Mg-3Al-Zn alloy. *Materials Letters, 62*(12-13), 1856-1858. doi:10.1016/j.matlet.2007.10.019

[4] Xu, S., Ren, G. C., Wang, G. Q., & Liu, P. (2010). Numerical Simulation and Experimental Investigation of Grain Refinement Behavior in Equal Channel Angular Pressing/Extrusion Process. *Materials Science Forum, 667-669*, 367-372. doi:10.4028/www.scientific.net/msf.667-669.367

[5] Krishnaiah, A., Kumaran, K., & Chakkingal, U. (2010). Finite Element Analysis of Multi-Pass Equal Channel Angular Extrusion/Pressing Process. *Materials Science Forum, 654-656*, 1574-1577. doi:10.4028/www.scientific.net/msf.654-656.1574

[6] Quang, P., Nghiep, D. M., & Kim, H. S. (2015). Simulation of the Effective of Friction on the Deformation in Equal Channel Angular Pressing (ECAP). *Key Engineering Materials, 656-657*, 526-531. doi:10.4028/www.scientific.net/kem.656-657.526