International Journal of Modern Engineering Research (IJMER)
www.ijmer.com Vol. 3, Issue. 5, Sep - Oct. 2013 pp-2713-2716 ISSN: 2249-6645

Improving Mechanical Properties of AL 7075 alloy by Equal Channel Angular Extrusion process

Mohan Reddy[1], Santhosh Kumar M[1], Venkata Ajay Kumar G[2]

1(Department of Mechanical Engineering,KSRM College of Engineering / JNT University, Annatapur, India)
2 (Department of Mechanical Engineering,Sri Venkateswara Institute of Science and Technology / JNT University, Annatapur, India)

ABSTRACT: *The influence of the microstructure and the tensile properties is investigated in specimens of ultrafine-grained materials processed by equal channel angular extrusion (ECAE) through route A, to refine grain size of 7075 AL alloy this was attempted at room temperature. Sub-grains/cells increases and the width of boundaries decrease while the cell/sub-grain size remains approximately constant as the number of passes increases. Yield stress and ultimate tensile stress reach a maximum after four passes. This study shows that severe plastic deformation has potential to significantly improve the mechanical properties of Al alloys. Static annealing experiments demonstrated that the extensive grain growth occurs at can be achieved after the age hardened treatment before that solution heat treatment at 480°C for 1 hour followed by age hardening at 177°C for 8 hours. Microstructure evolution during repetitive equal-channel angular extrusion (ECAE) of Al 7075 alloy with Φ=120◦ die and the outer arc ψ=50◦ was evaluated by optical microscopy.*

Keywords: *Aluminum alloy, Equal channel angular extrusion, Mechanical Properties, Microstructure analysis, Severe plastic deformation*

I. INTRODUCTION

Nanostructured (NC) and ultrafine grained (UFG) materials, defined, respectively, as polycrystalline materials with a grain size below ~100 nm and ~1µm, have been extensively studied over the past two decades because of their enhanced properties [1–3]. Generally, these materials exhibit a high strength but only limited ductility [4]. Recently, different approaches have been considered in an attempt to overcome this limitation [4, 5]. The grain size produced by conventional methods is greater than 1µm.The deformation mechanism of UFG metals is often considered to be governed not only by the activity of lattice dislocations, but also by mechanisms such as grain rotation and grain boundary sliding, especially in equiaxed microstructures [6]. There are also some methods for producing ultrafine-grained structure even to the size of nanometer, such as gas condensation and high-energy ball milling. These methods are difficult to produce in bulk form, which then limits the application in industries. Many researchers have shown that sub-micrometer grained (SMG) materials can be obtained after ECAP deformation. Although SMG materials can be produced by ECAP, the deformation mechanism and microstructure evolution in ECAP is still not clear. The SMG structure formed by SPD is characterized by mixture of both high angle boundaries (HABs) and low angle boundaries (LABs) (Bay et al. 1992a). The boundaries formed by SPD have been described as non-equilibrium boundaries. Which are associated with high internal stresses (Furukawa et at 1996a). The SMG structure of aluminum alloy formed by SPD has been suggested as a result of extended recovery (Humphrevs et al. 1995). In general, the microstructure developed by SPD is not well-defined ultrafine-grained structure for it doesn't consist of grains enclosed by HABs. Thus further annealing is required to construct a microstructure consists of fine grains enclosed by HABs. The present study deals with ECAE were used to deform the material and obtain ultrafine-grained structure. One important goal of this research is to advance our understanding of the deformation mechanism in ECAE, and to identify the key parameters that affect the microstructure evolution. The material is extruded up to two passes by route A. The detailed microscopic characterization was carried out to obtain comprehensive and quantitative information about the structure developed by various ECAP processes to achieve the goal.

II. EXPERIMENTAL MATERIAL AND PROCEDURES

2.1 Experimental Material

All the experiments were conducted using AL 7075 alloy. The material was produced in the form of ingot with a diameter of 14.9mm and a length of 50mm. The ECAE process uses a die, material for extrusion and plunger attached to the universal testing machine for the extrusion process.

2.2 Methodology

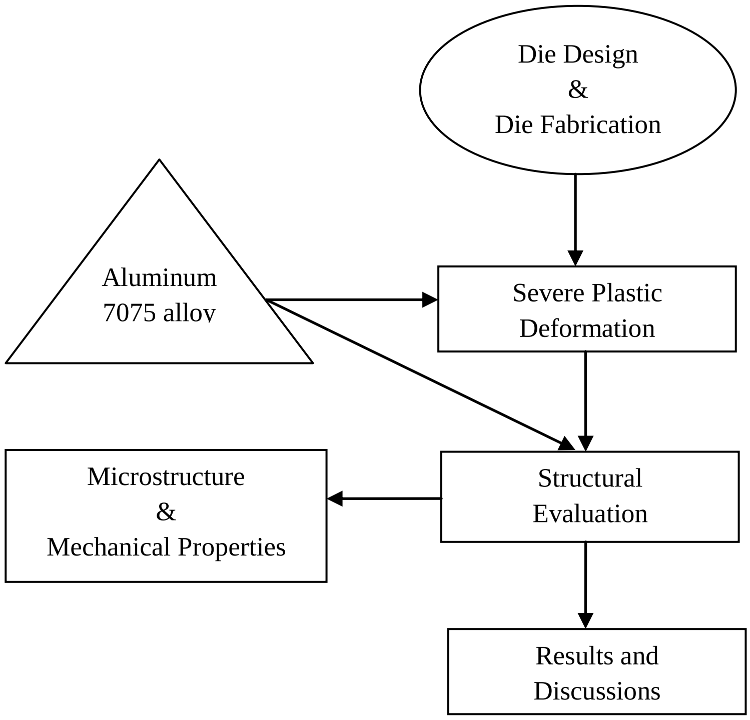

Fig. 1 Methodology

2.3 ECAE Die

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 plunger. Die material was mild steel and the plunger was EN8 steel (normalized condition), the normalizing of EN8 steel was carried out by heating above the upper-critical-temperature line followed by cooling in still air to room temperature. The purpose of normalizing is to produce harder and stronger steel than annealing, so that for some applications normalizing may be a final heat treatment. Normalizing may also be used to improve mach inability, modify and refine cast dendritic structures, and refine the grain and homogenize the microstructure in order to improve the response in hardening operations. The geometry of this die provides that the material is deformed by simple shear at ideal, frictionless, conditions. The cross section of the specimen remains about equal before and after a processing step, thus it is possible to subject one specimen several times to ECAP in order to reach highest degrees of plastic deformation.

Fig. 2.1 ECAE Die

A circular cross section of the channel provides the possibility of a materials processing at different routes that are distinguished by their different combinations of sample rotation around the channel axes between consecutive processing steps. Here route A is used for the extrusion of the material and four billets are prepared for four experiments i.e., basic material, one pass, two and three passes. The die angle 120° was used in this study. The outer arc (Ψ) of the 120° die is 50°. The dimension of the channel cross section in ECAE die is 120x120mm. According to equation (1), the strain per pass of the 120° die is 0.67. In considering both Φ and ψ, the equivalent strain of ECAE can be calculated by (Iahashi et al. 1996).

$$\epsilon_N = N \frac{\{2\cot(\Phi/2+\psi/2)+\psi\,\mathrm{cosec}(\Phi/2+\psi/2)\}}{\sqrt{3}} \quad \text{------ (1)}$$

III. EXPERIMENTAL RESULTS

3.1 Microstructural Characteristics

Al 7075 was solution treated at 480°C for 1 hour and then followed by water quenching.

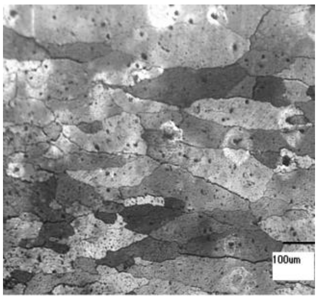

Fig 3.1.a

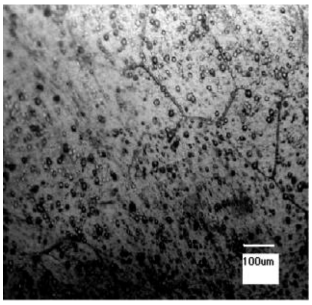

Fig 3.1.b

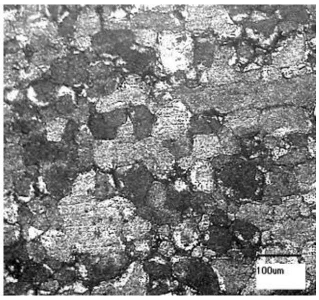

Fig 3.1.c

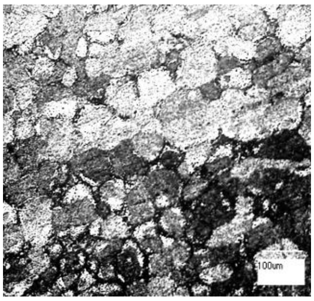

Fig 3.1.d

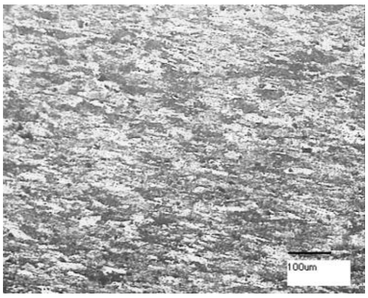

Fig 3.1.e

Fig 3.1a, optical micrograph of Al 7075, 100X, Keller's reagent. After solution heat treated at 480°C for 1 hour quenched with water, fusion voids, (black area) and agglomeration of insoluble phases (dark gray). Fig 3.1b, Al 7075 was solution heat treated at 480°C, and then artificial aging at 177°C for 8 hours, optical micrograph of Al 7075, 400X, solution treated at 480°C quenched to the water, eutectic melting temperature was exceeded during solution heat treatment, fine voids (black areas), and Keller's reagent. Al 7075 solution treated at 480°C for 1 hour and then aged at 177°C for 8 hours, which was processed through ECAP route A. Fig 3.1c, optical micrograph of Al 7075 extruded, solution heat treated, and artificially aged, fine particles of MgZn2 (dark), 100X, ECAP 1st pass, Keller's reagent. Fig 3.1d, optical micrograph of Al 7075 under ECAP processing, particles are insoluble (Fe, Mn) Al_6 (dark gray), 100X, ECAP 2nd pass Keller's reagent. Fig 3.1e, optical micrograph of Al 7075, under route A for ECAP processing 3rd pass, the fine particles of $MgZn_2$ (dark), the insoluble particles of $FeAl_3$ (light gray) 100X, ECAP 3rd pass Keller's reagent.

3.2 Tensile properties

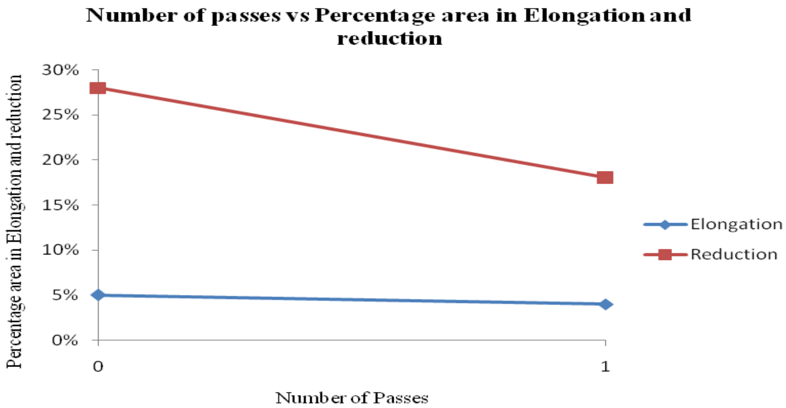

Fig. 3.2 Number of Passes Vs Percentage area in Elongation and reduction

For the Al 7075 alloy as received condition Elongation to failure occurs at 5% and it decrease to 4% after single pass, the area of reduction of 7075 alloy as received condition 28% and it reduced to 18% after single pass. It shows that percentage of area of reduction decreases drastically, while we increasing number of ECAP passes. The ultimate tensile strenth increases from 329 MPa as received condition for ultrafine grained Al 7075 alloy, it reaches about 487 MPa after single pass.

3.3 Hardness test

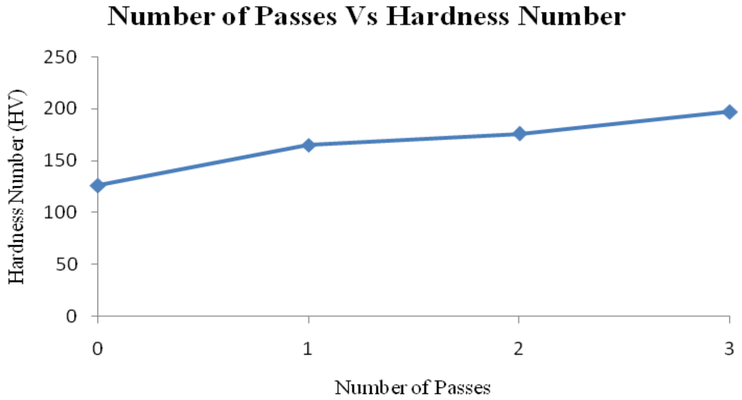

Fig 3.3 Number of passes vs Hardness number

The Al 7075 alloy hardness is tremendously increased while we increasing the number of ECAE passes, Al 7075 alloy has achieved high hardness after the third pass is about 197 HV.

IV. CONCLUSION

It was found two passes of ECAE are required for the formation of ultra fine grained structure in Al 7075 alloy. The resulting microstructure has been widely investigated by optical microscopy, putting in evidence the grain structure and precipitates distribution differences originated by the process. Tensile tests show the increase of strength from one pass to another pass of the material. Hardness is also increased by increasing the number of passes due to the fine grain structure; this survey gives clear prediction that tremendous increase of hardness has achieved compare to base metal.

REFERENCES

Journal Papers:

[1] Segal V. M., Reznikov V. I., Drobyshevskiy A. E., Kopylov V. I.,Plastic working of metals by simple shear, *Russian Metallurgy (Metally), 1, 1981, 99-105.*

[2] Iwanishi Y, Horita Z, Nemoto M, Langdon T, *Acta Mater., 46, 1998, 3317.*

[3] Aida T., Matsuki K., Horita Z. and Langdon T. G, Estimating the equivalent strain in equal-channel angular pressing. *Scripta Mater.,2001, 44, 575.*

[4] Valiev RZ, Alexandrov IV, Zhu YT, Lowe TC. J *Mater Res 2002; 17, 5.*

[5] Wang YM, Ma E., *Acta Mater 2004; 52, 1699.*

Theses:

[6] Dalla Torre FH, *Microstructure and deformation mechanism of nanocrystalline Ni synthesized by three different methods*.doctoral diss., Switzerland; 2003