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STUDY 0F MICROSTRUCTURE AND HARDNESS OF EQUAL CHANNEL ANGULAR EXTRUDED 7075AL ALLOYS

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ABSTRACT

In the present years, there has been an increasing interest in the production of ultra-grained materials for investigative purposes. The ultra-grained materials exhibit mechanical and physical properties of great interest, in particular their remarkable strength and toughness. This paper reports a study of microstructures of the ultra-grained produced through equal channel angular processing (EACP), pressed 10 times through the 120º die angle impart a higher strain were investigated using optical microscope. The average grain size obtained from the optical microscope was 300 – 400 ηm but the microstructure of ECAP aluminium was not homogeneous. The Vickers micro-harness tester was used for measured hardness on the different location in the extruded sample with an applied load of 1N. The universal testing machine was used for measuring ultimate tensile strength and ductility of samples. Elimination of dendritic as-cast structure with reduction of porosities and deformation-induced homogenization by the effect of ECAP processing increased the ductility of the alloy. Attained experimental results indicate that multi-pass ECAE processing is very effective in improving the hardness of binary 7075Al alloy.

Keywords: *SPD, E-cap, Microstructure, TEM*

1. Introduction

Plastic deformation strongly affects the microstructure and strengthens the martial usually at expenses of their ductility. However severe plastic deformation (SPD) leads to the formation of submicron and nano-grained structures that show high strength at room temperature and significant ductility [1].Equal channel angular extrusion (ECAE) technique is a severe plastic deformation process invented by Segal V.M [2]. An important advantage of ECAE is that it imposes much higher plastic strain during pressing without reducing the cross-sectional area of working billets, resulting in unique combinations of mechanical properties and grain size. Recently, active research efforts have been made and successful applications have been reported for various materials such as pure copper [3–4], Al alloys [5], magnesium alloys [6] and Ti alloys [7], etc. Accordingly, the experiments were conducted on an Al-7075 alloy where this alloy was selected because it has an excellent strength to weight ratio, generally limited formability and yet an earlier study documented the occurrence of super plastic elongations after processing by ECAP [7-8]. The Al-7075 alloy is also of considerable current interest because of potential applications in the aerospace industry [10-11]. In this study, aluminium 7075 was chosen to determine its suitable processing temperature for ECAE, and the effect of ECAE on the microstructure and hardness was also investigated.

2. Experimental Studies

The experiments were carried out on the aluminium alloy the chemical composition of which is presented in Table 1.

Table: 1 Chemical Composition of al7075 Alloy

Zn	Cu	Mg	Al
5.6	1.6	2.5	Balance

Material in the form of extruded rods subjected to artificial ageing was used as the initial state. Prior to deformation in an ECAP die, specimens of the analysed alloy in the initial state were solution annealed at 550°C, and cooled to the ambient temperature by water quenching. The quenched specimens were then subjected to deformation in an ECAP die with the parameters: $\Phi = 90°$ a $\Psi = 37°$. Pressing of specimens of size 10 mm x 80 mm in the ECAP die was realised at ambient temperature by route up to three passes corresponding to deformation ratio □ = 3.5. After ECAP, the specimens were subjected to a solid solution

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heat treatment at 550°C for 2.5 hours and subsequently water-quenched to reproduce an equilibrium solid solution matrix without any precipitates. The ECAP quenched specimens were prepared and tested for microstructural studies using optical microscope. The influence of the applied heat treatment, severe plastic deformation by ECAP process and natural ageing on the mechanical properties of the analysed alloy was evaluated by tensile and Vickers hardness test. The tensile tests were carried out on short specimens using a deformation rate of 2.5 x 10^{-4} m/s. Subsequently, characteristics of the ultimate tensile strength, and elongation were determined. Vickers microhardness measurements were taken with loads of 50g applied for 13 s. The specimens for tensile test were machined from the as-received and the extruded billets with the gauge length of 25 mm and cross-section of 2×2 mm^2.

3. Results and Discussion

TEM images of the investigated alloy subjected to large plastic strains as shown in Fig.1. These observations have revealed that, during ECAE process, the original grains are partitioned by extended boundaries shown Fig. 1. These bound raises separate the cell-block, which deform by different slip systems. They have been termed geometrically necessary boundaries, since they take account of the difference in lattice rotation between adjacent parts of the crystal. Dislocation cells within location boundaries. This sub division of grains by well-defined dislocation boundaries leads to a refinement of the initial microstructure. In the investigated Al alloy, the microstructure after four passes of ECAE consists of elongated sub grains. Analysis of selected area electron diffraction pattern indicates low mis-orientation

Thus, for alloys subjected to deformation, It revealed the following: (i) the grain structure is refined and (ii) the (Al) supersaturated solid solution decomposes. The (Al) enriched with Zn is completely decomposed with the formation of the phases corresponding to equilibrium at room temperature. We did not reveal in our samples the Guinier–Preston zones (GPI, GPII) or the phases appearing sequentially during slow decomposition of supersaturated solid solutions [8]. The decomposition of the Zn-containing (Al) solid solution was also observed, but it was less pronounced. In other words, SPD leads to the formation of a phase state that is closer to thermodynamic equilibrium than the initial undeformed state is.

Vickers hardness, ultimate tensile strength and tensile elongation of specimens with various pass numbers are shown in Figs. 2, 3 and 4, respectively. It is seen that the hardness and the ultimate tensile strength of the specimens after ECAE are higher than that of the specimen without ECAE. The hardness and the ultimate tensile strength increases remarkably with a significant decrease in elongation after one pass of ECAE. However, the hardness, ultimate tensile strength and elongation increase with the increase of the pass number after two passes of ECAE. The improvement of the mechanical properties is attributed to the difference in microstructures between as-received and extruded aluminium bronze specimens. Grain size decreased and grain was refined during the progress of ECAE. Grain refinement can affect mechanical properties of polycrystalline materials [9]. The classical effect of grain size on hardness can be explained by the Hall–Petch model [10].

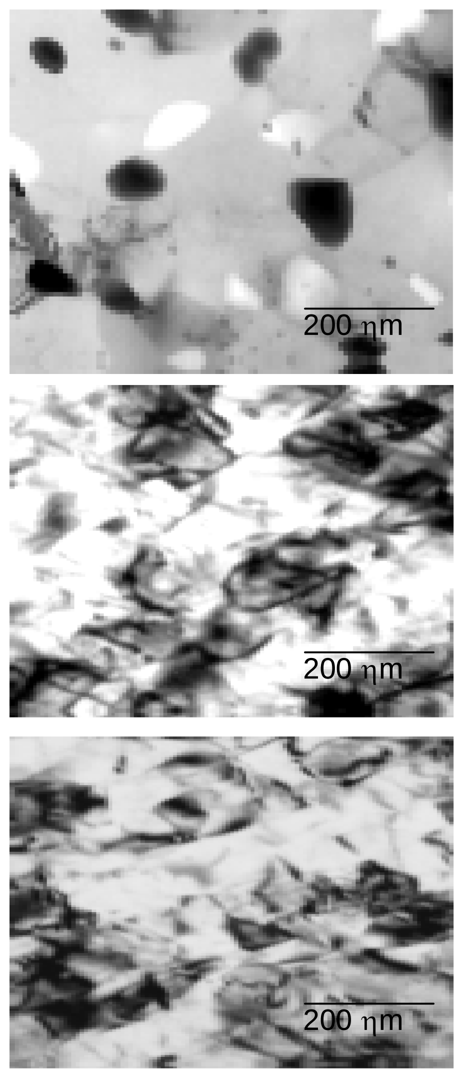

Fig. 1 TEM of SPD Specimens (a) 1 Pass (b) 3Passes and (c) 4 Passes Respectively

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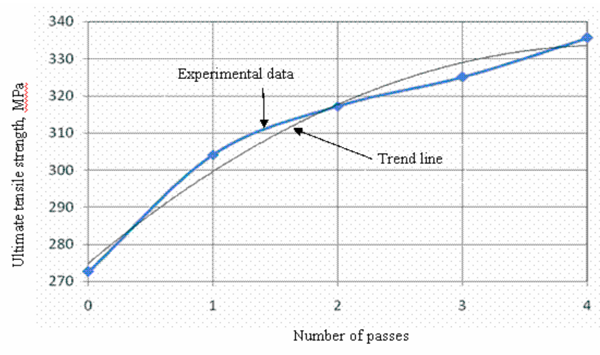

Fig. 2 Ultimate Tensile Strength of the Aluminium Specimens with Various Pass Numbers.

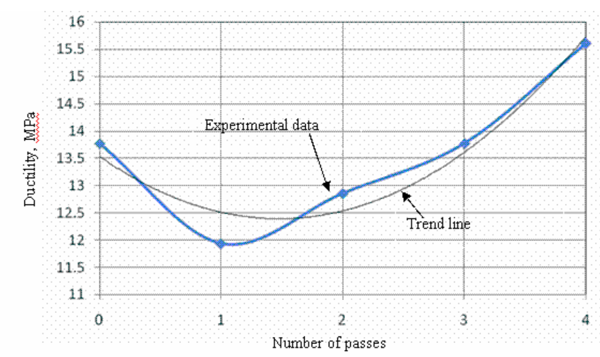

Fig. 3 Ductility of the Aluminium Specimens with Various Pass Numbers.

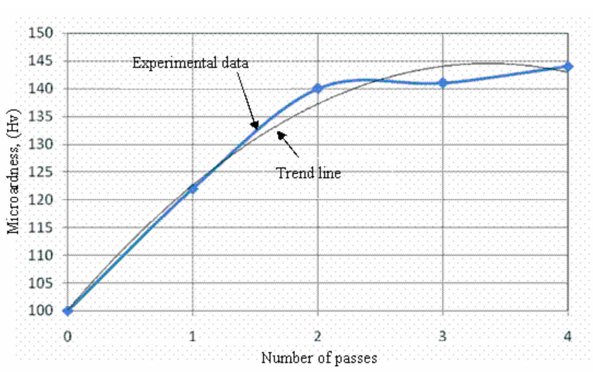

Fig. 4 Micro-Hardness of the Aluminium Specimens with Various Pass Numbers.

4. Conclusions

It is demonstrated that the number of passes of ECAE for aluminium 7075 alloy has more homogeneous fine-grained structure that as received one and some equiaxed grains occur in some areas. TEM shows ECAE deformation of Al alloys significantly decreases the Al and alloying elements grain sizes and the size of particles of intermetallide phases. As a result of deformation, the supersaturated Al solid solution decomposes and the system passes gradually into the state corresponding to the equilibrium phase diagram. With the increase the pass number of ECAE, the grain size of the alloy progressively decreases, and the hardness and strength gradually increase along with ductility of the specimens. After one pass of ECAE, the increase of hardness and strength of the specimen is due to grain refinement and the increase of the second phase, while the improvement in mechanical properties of the alloy after two passes of ECAE is a consequence of grain refinement and rearrangement of the second phase.

References

1. *Krzysztof J Kurzydlowski, Halina Garbacz and Maria Richert, (2004) "Effect of Sever Plastic Deformation on the Microstructure and Mechanical Properties of Al and Cu" Rev. Adv. Mater Science, Vol.8, 120-133.*

2. *Segal V M, Reznikov V I, Drobyshevskiy A E, and Kopylov V I (1981), "Plastic Working of Metals by Simple Shear", Russ. Metall. (Metally) Vol.1, 99–105.*

3. *GAO L L and CHENG X H (2007), "Grain Refinement and Mechanical Properties of Cu–Al 10%– Fe 4% Alloy Produced by Equal Channel Angular Extrusion", Materials Science-Poland, Vol. 25(4), 1119-1126.*

4. *Erbel S (1979), "Mechanical Properties and Structure of Extremely Strain Hardened Copper", Material Technology. Vol.12,482–486.*

5. *Korbel A and W Bochniak (2004), "Refinement and Control of the Metal Structure Elements by Plastic Deformation", Scripta Material Vol. 51,755–759.*

6. *Litwi´nski E (2004), "Method and Apparatus for Producing a Refined Grain Structure", U.S. Patent Appl. No 0004107 A1.*

7. *Lowe T C and Zhu Y T (2003), "Commercialization of Nanostructure Metals Produced by Severe Plastic Deformation Processing", Advance Engineering Materials, Vol. 5(5), 373–378.*

8. *Azushima R Kopp, Korhonen A, Yang D Y, Micari F, Lahoti G D, Groche P, Yanagimoto J Tsuji N, Rosochowski A and Yanogida A, (2008), "Server Plastid Deformation (SPD) Processes for Metals, CIRP Annals-Manufacturing Technology, Vol. 57(2),716-735.*

9. *Taolin Ren, Debin Shan, Yong Chen and Yan Lu, (2010), "Surface Plastic Deformation Distribution and Microstructural Evolution in the Compound Rolling of Ti–50Al Billet" Materials & Design, Vol. 31(7), 3457-3462.*

10. *Ashouri S, Nili-Ahmadabadi M, Moradi M, Iranpour M (2008) "Semi-Solid Microstructure Evolution During Reheating of Aluminum A356 Alloy Deformed Severely by ECAP", Journal of Alloys and Compounds, Vol. 466(1-2), 67-72.*

11. *Kashyap B P and Chaturvedi M C (2009), "Superplasticity in Aerospace Materials", Journal of Manufacturing Engineering, Vol.4 (1), 23-29.*

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12. *Cherukuri B, Nedkova T S and Srinivasan R (2005), "A Comparison of the Properties of SPD-Processed AA-6061 by Equal-Channel Angular Pressing, Multi-Axial Compressions/ Forgings and Accumulative Roll Bonding", Material Sci. Eng. A-Structural Materials Properties Microstructure and Processing. Vol. 410, 394 – 397.*

13. *Werenskiold J C and Roven H J(2007), "Microstructure and Texture Evolution During ECAP of an AIMgSi Alloy: Observations, Mechanisms and Modelling", Material Sci. Eng. A-Structural Materials Properties Micro-structure and Processing, Vol. 410 – 411, 174 – 177.*

14. *Leo P, Cerri E, De Marco P P and Roven H J (2007)," Properties and Deformation Behaviour of Severe Plastic Deformed Aluminium Alloys", Journal of Material Processing Technology, Vol. 182(1-3), 207 – 214.*

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