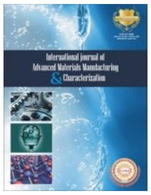

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Analysis of Mechanical properties and Micro structure formation in Al 6082 alloy during ECAP process

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A R T I C L E I N F O

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A B S T R A C T

The possibility of including a new methods into classical technologies is one of the reasons which for writing this paper. ECAP is unique because significant cold work can be accomplished without reduction in the cross sectional area of the deformed work piece. In conventional deformation processes like rolling, forging, extrusion, and drawing, strain is introduced by reduction in the cross sectional area. ECAP produces significant deformation strain without reducing the cross sectional area. This is accomplished by extruding the work piece around a corner. For example, a circular cross section rod of metal is forced through a channel with a 90 degree angle. The cross section of the channel is equal on entry and exit. The complex deformation of the metal as it flows around the corner produces very high strain. Because the cross section remains the same, a work piece can be extruded multiple times with each pass introducing additional strain. This paper describes about micro structural development in Aluminum during ECAP process. Also, Mechanical properties are improved by Severe Plastic Deformation (SPD) process such as Equal Channel Angular Pressing (ECAP). This procedure makes it possible to obtain after 4 passes the grain size of approx. 2μm. Achieved quality level of mechanical properties is a function of no. of passes as well as used technological route.

Introduction

Severe Plastic Deformation (SPD) techniques are generally applied for obtaining Ultrafine grained (UFG) microstructure in bulk metals & Alloys [1]. Processing by SPD refers to various experimental procedures of metal forming that may be used to improve very high strains to materials leading to exceptional grain refinement [2]. Equal Channel angular Pressing (ECAP) is the most often used method among SPD procedures since it results in homogenous microstructure without changing the dimensions of the bulk specimen [3, 4]. The UFG materials produced by ECAP have an attractive combination of high strength and good ductility due to their low contamination and unique structures [5]. For understanding the mechanical behavior of materials produced by ECAP it is necessary to characterize their microstructure. From the point of view of industrial application, the investigation of ECAP induced evolution of microstructure in commercial alloys is very important. X-ray diffraction analysis is an effective tool for studying the microstructure of UFG materials. Products made by this technique are characterized by high strength properties and they can be potentially used at subsequent Super-Plastic forming.

Ecap overview:

There are no. of reports describing the fundamental process of metal flow during ECAP [6]. For nano structured materials produced by ECAP technique, the workability parameters depend on the no. of passes, type of passes and the direction of the specimen axis [1].

Ecap setup:

The principle of ECAP is illustrated in fig 1. The ultimate aim of ECAP processing is to bring about grain refinement in materials and that brings about an improvement in properties of alloys. There are various forms of ECAP that have been developed recently and applied for grain refinement [9]. For the die showed as illustration in fig 1, the internal channel is bent through an abrupt angle ϕ, equal to 90˚ and there is an additional angle Ψ, equal to 0˚, which represents the outer arc of curvature where the two channels intersect. The sample is in the form of a rod, is machined to fit within the channel and the die is placed in some form of press so that the sample can be pressed through the die using a plunger.

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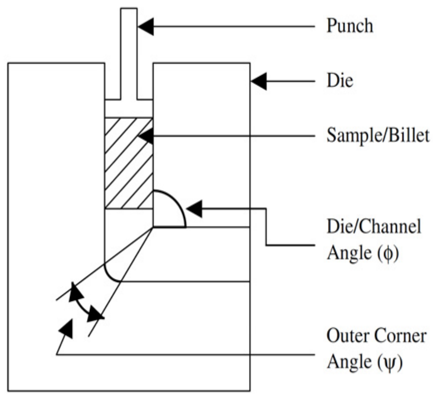
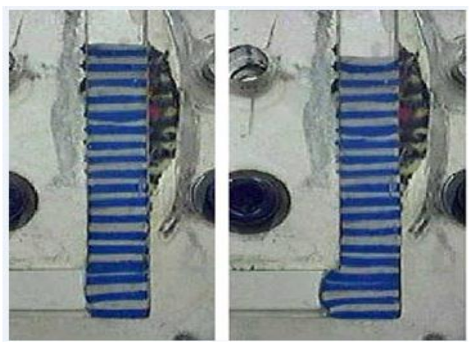
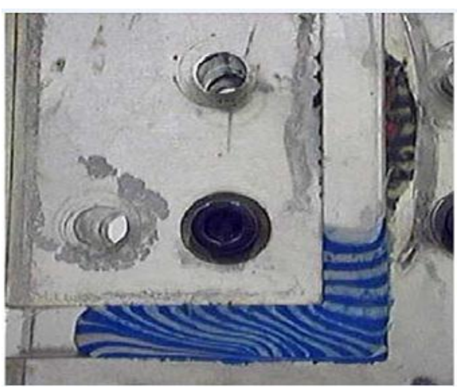


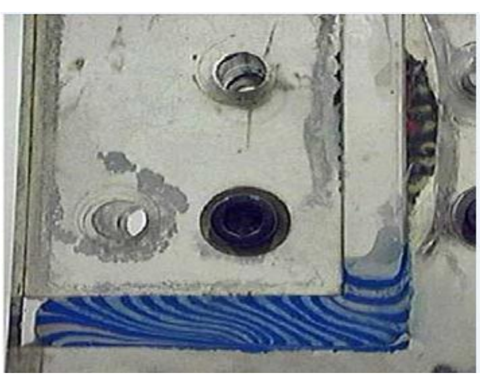
Fig 1. Schematic Illustration of ECAP



1. Step one



2. Step Two



3. Step Three

Fig 2. Nature of ECAP process

The nature of the imposed deformation is simple shear which occurs as the sample passes through the die as shown in fig 2. It can be seen from the fig 2 that when pressure is applied through plunger to the specimen the material deforms without causing any changes in the cross – sectional area of the specimen. After 5 passes of the specimen through the die it brings about significant changes in the material leading to improvement in the material properties [10].

Mechanical properties:

Materials produced by ECAP are reported to have excellent mechanical properties [1, 9]. The improvement in mechanical property is due dislocation density. Significant strengthening is observed due to the presence of high dislocation density in passes. The improvement of mechanical properties such as Hardness, Tensile strength etc…can be observed in materials subjected to ECAP. This is due to the mobility of dislocation density in materials, by adopting different processing routes will not result in significant increase in strength. But by adopting processing route such as 0˚-90˚-180˚-270˚-360˚-0˚ (i.e.) rotating the specimen in longitudinal direction will increase the strength and further no.of passes through this processing route will bring about a significant change in strength of the material [10]. This is due to the rotation of specimen in different crystallographic planes results in cross-hardening by mobile dislocations in different directions so that the accumulation of dislocation in the same direction is avoided and annihilation of dislocation is reduced.

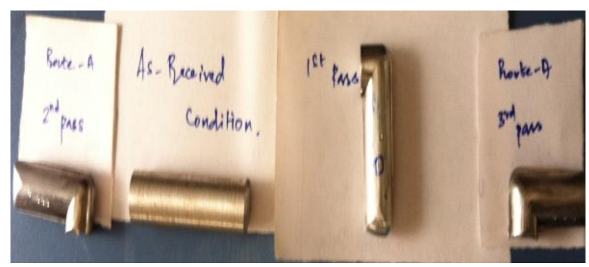


Fig 3.Route A output

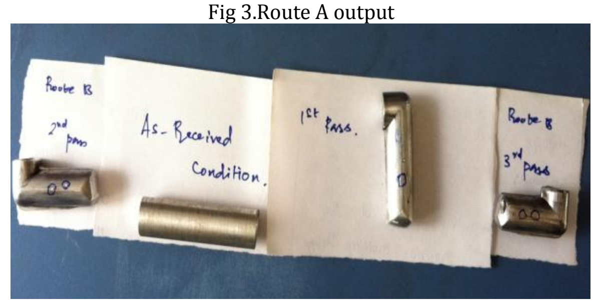


Fig 4.Route B output

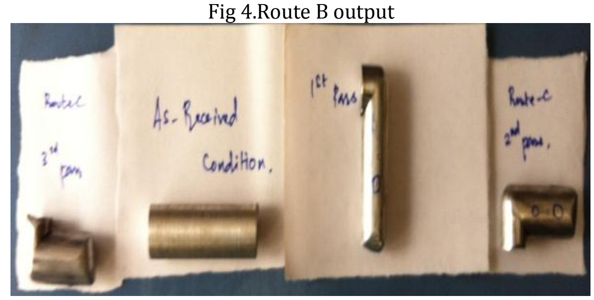


Fig 5.Route C output

Hardness test results:

S.No	Specimen / Pass No.	Dia. of Indenter(d)mm		Surface Area, mm^2	Mean Surface Area, mm^2	BHN
1.	As Received Specimen	d_1	0.945	0.7285	0.7285	82.36
		d_2	0.945	0.7285		
2.	1st pass	d_1	0.7406	0.7046	0.7046	85.14
		d_2	0.7406	0.7046		
3.	Route A – 2nd Pass	d_1	0.845	0.578	0.5695	105.35
		d_2	0.831	0.561		
4.	3rd Pass	d_1	0.817	0.53	0.5335	112.46
		d_2	0.809	0.528		
5.	4th Pass	d_1	0.740	0.4399	0.487	123.2
		d_2	0.813	0.5336		
6.	Route B -2nd Pass	d_1	0.842	0.5736	0.5646	106.26
		d_2	0.829	0.5555		
7.	3rd Pass	d_1	0.706	0.399	0.4575	131.15
		d_2	0.800	0.516		
8.	4th Pass	d_1	0.718	0.4137	0.4248	140.58
		d_2	0.740	0.4399		
9.	Route C – 2nd Pass	d_1	0.911	0.675	0.6867	87.37
		d_2	0.926	0.6984		
10.	3rd Pass	d_1	0.8355	0.5645	0.6362	94.32
		d_2	0.932	0.7078		
11.	4th Pass	d_1	0.807	0.5256	0.5525	108.6
		d_2	0.846	0.5793		

Fig.8 Brinell Hardness Results

Development of microstructure:

The processing route as described earlier exhibits continuous deformation in all the three planes and therefore evolution of grain size is uniform. Influence of magnitude of deformation on properties of metallic materials is connected with increase of internal energy. Internal energy increases right to the limit value, which depends on manner of deformation, purity, grain size, temperature etc…..As a result of ECAP by adopting the above said processing route, the internal energy gain is same throughout the material [11]. The density of dislocations increases with magnitude of Plastic deformation. From fig 1, optimal strain homogeneity in the material, without lower dead zone and without involving detrimental effects can be achieved, if 12.34°≤Ψ≤25° [1, 9, 10]. If no.of passes of the material are increased fine grains in the material can be formed [10, 11]. Fig 3 & fig 4 shows the TEM images of the material before and after ECAP process. It can be clearly seen that coarse grains are found as such the material is received and finer grains are formed after ECAP process.

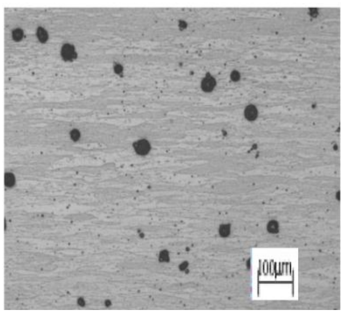


Fig 6. Structure of Initial Sample (before ECAP)

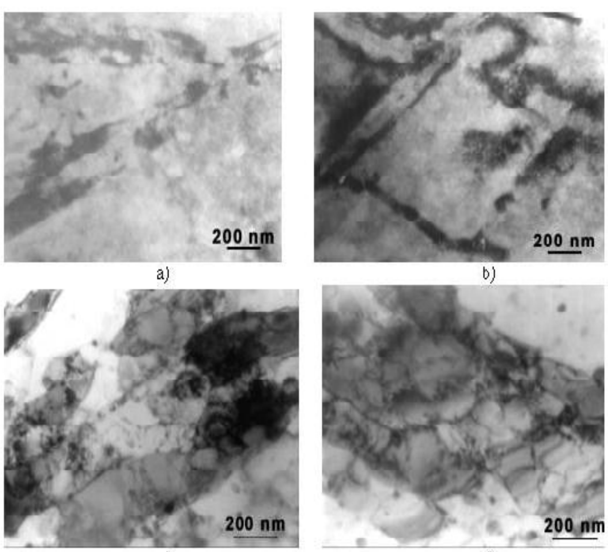


Fig 7. Substructure of Aluminum alloy 6082 after extrusion:
a) after the 1st pass, b) after the 2nd pass, c) after the 3rd pass,
d) after the4th pass

Fig 6 & 7 Source.M.Gregor, R.Kocich, L.Cizek, L.Kander. Journal of Achievements in Materials and manufacturing engg. Vol 15. Issue 1-2. March-April 2006.

Summary & Conclusions:

ECAP is a potential tool for refining of grain in poly-crystalline metals. This procedure makes possible to yield development of sub-structure after 5 passes. Using die with an angle of 90˚ or more intense deformation is achieved. Through various literatures it is found that.

1. The Material as received was composed of coarse grains.
2. Finer grains were formed when the specimens were subjected to ECAP process.
3. Mechanical properties (Hardness, Tensile strength…) were improved after ECAP process.

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