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Раздел 2
МАШИНОСТРОЕНИЕ
Section 2
MECHANICAL ENGINEERING

**A STUDY ON THE APPLICATION OF SEVERE PLASTIC DEFORMATION
TO ALUMINUM ALLOYS**

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Abstract

In severe plastic deformation (SPD) processes materials are deformed with basically shear stresses, and extremely high plastic strains are obtained in a single pass. Strain values are multiplied with additional passes throughout the subsequent processes. Equal channel angular pressing (ECAP) is the most applied method among the SPD processes due to relative ease of die manufacturing of the required dies. In the presented work, some brief results of an experimental study were given. In the study, an ECAP die was designed and manufactured. 5083 Aluminum alloy specimens were deformed in single pass using the dies and hardness variation were obtained. Results were discussed with those in the related literature.

Keywords: ECAP, die design, hardness variation.

INTRODUCTION

In severe plastic deformation processes (SPD), deformations up to 100 percent or high levels can be obtained by relatively simple dies and die arrangements even in single pass [1,2,3]. Because of the additional repeats of the passes mean multiplication of the deformation, overall deformation amounts by can also be raised to very high ratios [3,4]. Due to this high plastic deformation, effective grain refinement, high strength and hardness increases are obtained. Among the severe plastic deformation processes although there are some problems about the die strength, equal channel angular pressing (ECAP) is mostly preferred in the research works due to relative ease of fabrication of the dies. In the process entrance and exit cross sections of the material are same but there is an angular difference between them [1,2,3,4,5]. In the presented study, some results of a graduate thesis on the application of the ECAP process using Al.5083 alloy rectangular specimen are given[4].

LITERATURE SURVEY

There are several methods that can be regarded as severe plastic deformation process, and total deformation amounts obtained in the process including the number of the passes (n) are given in the figure 1.

According to the figure, as the number of the passes or process repeats increase, very high total deformation amounts can be obtained. Due to the high strains and the strengthening, average grain sizes are considerably decreased by high shear strains.

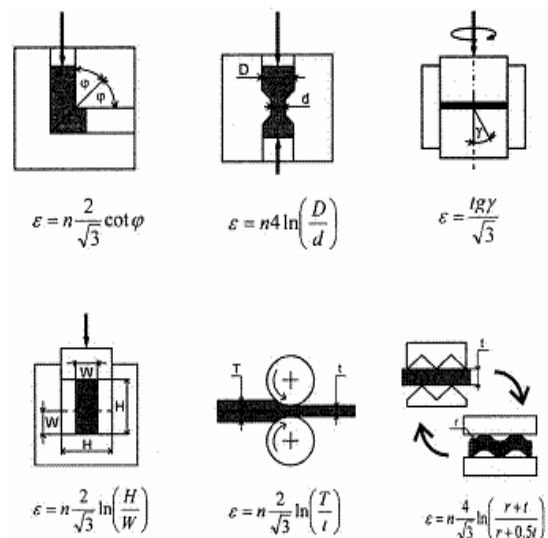


Fig.1. The amounts of the deformation amounts in some SPD processes [1,2,3,4,5]

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Ultra fine grains are obtained by the processes and the subject also regarded in nano-structure applications. There are several articles about the grain size effects on the mechanical properties [1, 2, 3, 4, 5]. For classical ECAP applications, entrance and exit cross sections are machined square in shape, and the dimensions vary according to the available press loads, material properties and frictional conditions (Fig. 2).

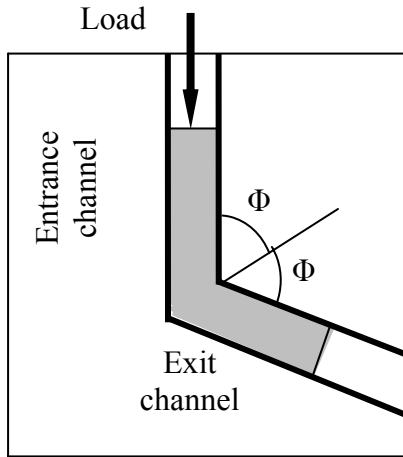


Figure 2. Basic die geometry and process parameters for the ECAP processes

Equal channel dimensions permit the specimen repeatedly be deformed in order to obtain higher strain values. The average strain value obtained after multiple passes (n) is calculated as $\epsilon = (2n / \sqrt{3}) (\cot \Phi)$.

Some SPD processes can be applied as in continuous manner in order to obtain severely plastic deformed industrial products (Fig. 3).

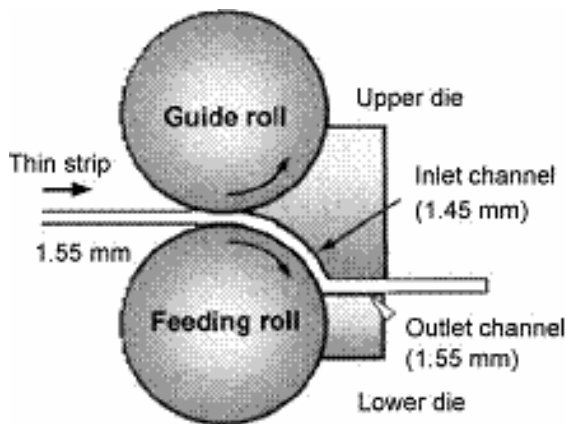


Fig. 3. The principle of the ECAP process for the use in continuous production [2, 3]

Although the high performance on the mechanical properties, there are some problems on the strength of the ECAP dies. As can be guesses, increasing overall strains require high extrusion forces and therefore the frictional forces between material and die walls are high even lubricants are used. High total load requires high strength materials for the punch and other die parts. Buckling is a great problem for the punches due to small cross-sections and high loads. Additionally, for square and rectangular cross sections impose very high stress concentration on the die corners causing cracking [3].

In the presented study, some ECA Processing was done using 5083Aluminum 10x10 mm cross-sectioned bars. Hardness values were measured before and after one pass processing, and results were examined.

EXPERIMENTAL WORK

Among the ECAP dies, the zero rounding off and perpendicular channel die ($2\Phi = 90^\circ$) is the most applied form with approximately 115% equivalent strain in one pass due to the easiness of machining and with maximum grain refinement. This type of geometry was chosen in this study. Channel cross sections are machined as 10x10 mm² and length of the entrance channel was machined as 60 mm (Fig. 4).

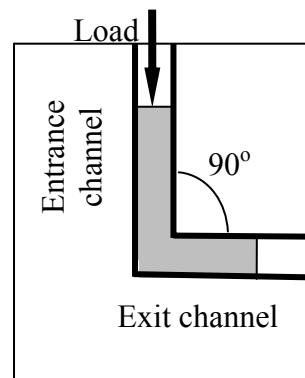
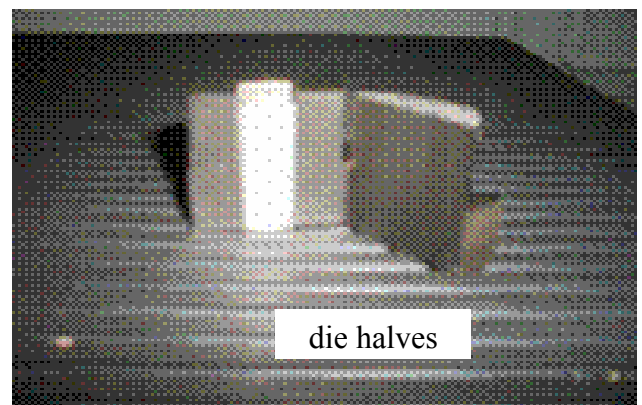


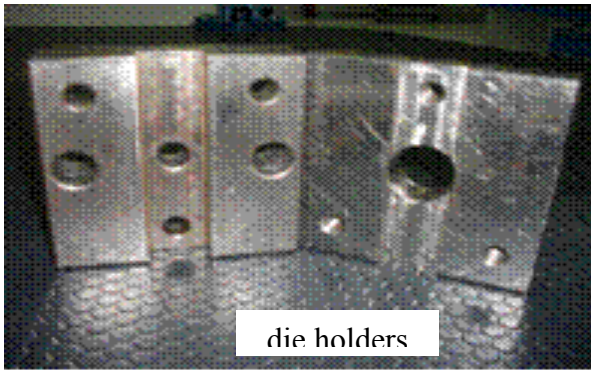
Fig. 4. Chosen die type in the study

Considering the harsh frictional conditions and high pressure in the channel regions, die parts are machined AISI H13 hot work tool steel, hardened at 1040°C and tempered at 600°C to 50 HRC hardness level. After the heat treatment, dies were polished before the tests. Punches were cut from 10x10 mm² high speed tool steel cutters.

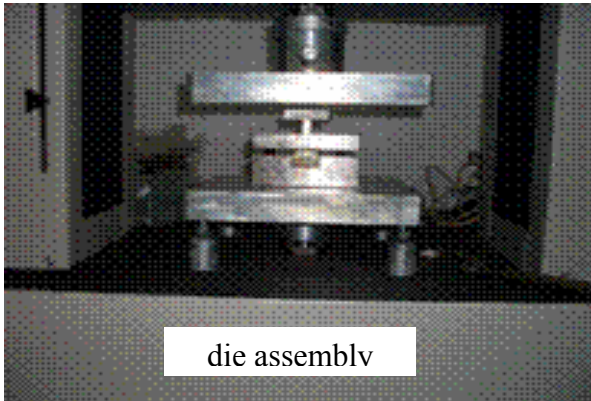
ECAP dies were manufactured into two halves, and channels were machined with milling and turning on the first die half and the second half was flat. Die halves were placed into a two-part die holder. Die parts, die holders and processed specimen are given in figure 5.

Specimens were machined from 12 mm thick H32 grade AA5083 aluminum alloy sheet. The plate was cut into 55 mm wide strip, the thickness decreased to 10 mm by milling, the specimens were cut from the strip and machined in order to obtain 10x10x55 mm dimensions.





die holders



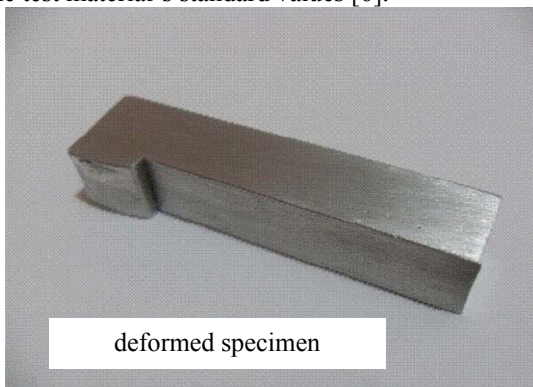
die assembly

Fig. 5. Die parts, holders and main assembly in the study

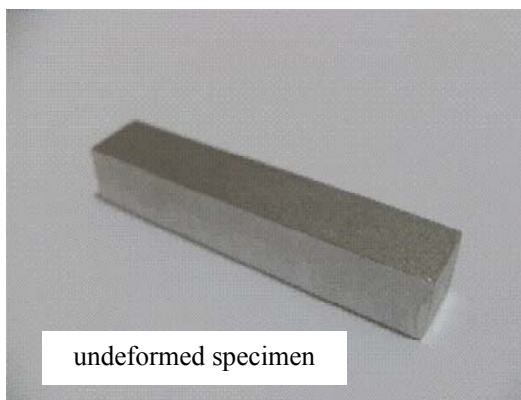
In the experimental work of the study, specimen were ECAPed using a 100 kN screw driven universal material testing machine with constant cross-head speed of 10 mm/sec.

Specimens were ECA Processed in one pass and hardness values were measured before and after the deformation. Specimens are given in Figure 6.

Average hardness of the specimens was measured as 85 HV before the ECA processing. This value is very close to the test material's standard values [6].



deformed specimen



undeformed specimen

Fig. 6. Examples of deformed and un-deformed specimen

Hardness distribution on the specimen in entrance and exit channels regions was measured by a hardness tester (Fig.7).

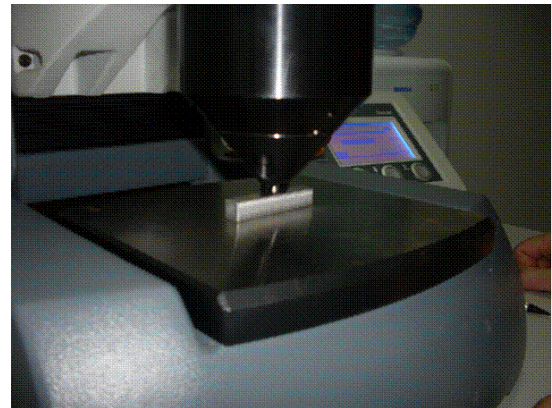


Fig. 7. EMCO Hardness tester used for hardness measurements

Main hardness increase occurred in the narrow corner region. This variation was observed in all the test specimens. Hardness increase due to ECA processing can be calculated approximately 45% between entrance and exit channels and 70% with respect to initial material hardness. This values are harmonious with the literature [1,3,6].

On the other hand some corner cracks occurred around the exit channel region, processed specimens can be regarded as sufficiently successful for this primer work.

CONCLUSIONS

Presented study was directed as a part of master thesis within an Erasmus exchange program between TUGAB and Istanbul Aydin University-Turkey. Recently a new method of the Equal Channel Angular Processing was applied using a die set and assembly that was designed and manufactured for the thesis.

Although there are some points to be developed in the die design, an experimental work has been done in a new deformation area.

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