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CONSIDERATION REGARDING DIE DESIGN FOR EQUAL CHANNEL ANGULAR EXTRUSION

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Abstract: *Equal channel angular extrusion (ECAE) is now a recognized technique in materials processing for properties. ECAE is used to introduce severe plastic deformations (SPD) to processed materials with the aim of improving their mechanical properties.*
The technique is able to refine the microstructures of diferent materials. ECAE produces significant deformation strain without reducing the cross sectional area.
This paper takes into account the ECAE dies proposed by Segal, the ECAE dies proposed by Iwahashi and the ECAE dies proposed by Luis, because the die design is critical on account of the large forces that it requires.
Key words: *SPD method, ECAE, processing techniques, die, design*

1. INTRODUCTION

In recent years, a growing importance in materials science and engineering was given to severe plastic deformation (SPD) methods. In particular, a number of difficulties connected with residual porosity in compacted samples, processing of large scale billets, impurities from ball milling, and practical application of the given materials were overcome with SPD methods.

The structures formed by the SPD are ultra fine-grained structures of a granular type containing mainly high angle grain boundaries. The interest in grain-size reduction is driven by the possibility to produce ultrahigh strength metals and high strain rate superplasticity, (Eivani & Taheri, 2007).

Presently, among the methods of SPD, equal channel angular extrusion (ECAE) is considered as the most promising for industrial applications.

Equal channel angular extrusion (ECAE) developed by Segal is widely known as one of the techniques to impose severe plastic deformation on bulk materials to produce ultra-fine grained materials, without causing a significant change in the dimensions of the processed parts, (Agnew et al., 2005).

The aim of the process is to impart high deformation to the processed materials as they cross the channel. The exit channel is usually manufactured with the same diameter as the entrance channel and hence cross-section of the processed material is not modified and so, there is no geometrical limitation to the deformations that is possible to impart to the processed materials.

It has been suggested that this technology has great advantages over the conventional mechanical attrition of ball milling because it can produce large sized samples free of any residual porosity.

Simple shearing is the key mechanism of the ECAE process. Simple shear can be considered a near ideal deformation method for structure refinement and texture formation in metal working.

Deformation during ECAE is achieved by simple shear in a thin layer at the crossing plane of the channels. Large and uniform strain intensity per pass can be reached in material under low pressure and load without a reduction of the initial billet cross-section. The process can be repeated a number of times in the die because the billet cross-section remains constant, (Tham et al., 2007).

2. MECHANISM OF ECAE

During the ECAE process a metal billet is pressed through a die consisting of two channels, equal in cross section and intersecting at an angle usually between 90º and 135º. The billet undergoes essentially simple shear deformation but retains the same cross sectional geometry, so that it is possible to repeat the pressings for a number of passes, each one refining the grain untill the extent which is determined by the material characteristics. High plastic deformations lead to an improvement in the dislocations density in ductile crystalline material and this improvement of the dislocation density is followed by an increase in the strength. Hence with enough accumulation of plastic strain a new structure of submicrometer or even nanometer grain size replaces the former grain size, (Gil et al., 1980).

By multiple passing, very large effective deformation can be developed in bulk products.

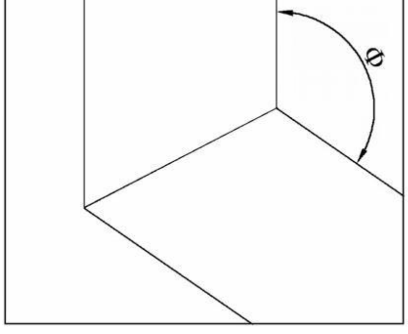
The process also leads to the formation of strong crystallographic texture in the material. In ECAE, it is possible to rotate the billet around its longitudinal axis between successive passes, creating different routes.

A nomenclature has evolved in the literature referring to the major variants as Routes A, B_A, B_C, and C (meaning no rotations between passes, 90º back-and-forth, 90º continuous, and 180º rotations, respectively), (Iwahashi et al., 1998).

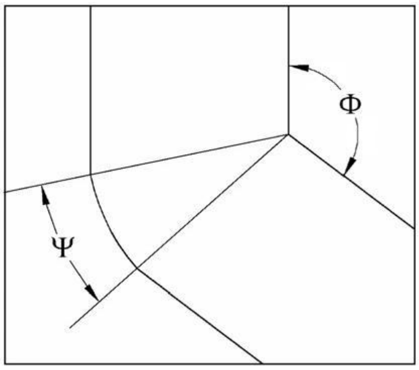
The amount of plastic strain introduced in the materials after ECAE processing depends on the die angle and the number of passes.

3. DIE DESIGN

The ECAE die is manufactured with two channels that usually intersect at an angle with the same cross-section. The material is extruded through the die and it is mainly deformed by a shear mechanism combined with a high hydrostatic pressure which exists within the die channels.



a



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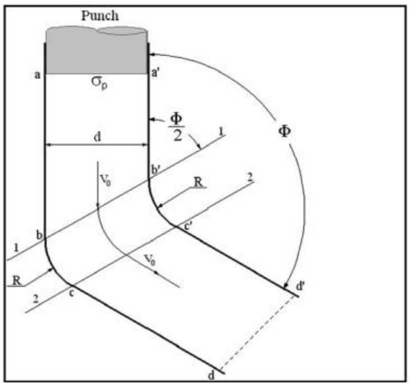


c

Fig. 1. Segal's geometry (a), Iwahashi's geometry (b) and Luis' geometry (c)

The simplest shape of these dies is the one containing of two straight channels intersecting with sharp outer and inner corners as shown in Fig. 1a, where Φ is the die angle being equal to α + β which in the case of ECAE, α = β, and so Φ = 2α.

Segal's geometry (Fig. 1a) was modified by Iwahashi (Fig. 1b), who proposed an ECAE die with a sharp edge of the inner part of the die and a Ψ-angle. Luis proposed ECAE dies (Fig. 1c) in which internal radius and external radius can have whatever value and both radii are tangent to the die walls, (Pérez & Luri, 2008).

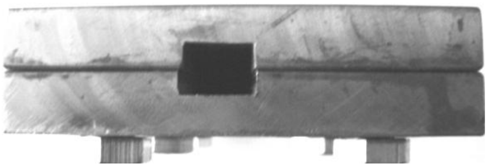
The design of the die took into account the necessity of having separated parts that permit (after dismantling the die) accessing the channel for maintenance if it is needed. These different parts were chosen so as to minimise the number of joints in the channel and to maximise the possibility of access to the channel.

The die is made up of the piston and the die body, which is made out of two parts. The die channel geometry is described by three areas: the input area, the calibrated area and the output area, (Ghiban et al., 2009). The die used in the ECAE experiments has two equal channels with a square cross-section of 10 mm x 10 mm and an intersecting angle of 90º.

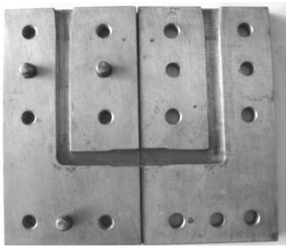
The image of our proposed die for ECAE is given in figure 2 (a, b). From figure 2 (a and b) one can observe that the die design has Iwahashi's geometry and has as a drawback the rapid wear of the die and the damaging of the material as is being extruded, because of the sharp edge.

Another drawback is the incorrect flow of the material in the ECAE process due to the fact that the walls of the die are not tangent to the outer radius. One can also observe that the ECAE die is decentred. Also, the thickness of the die body is only 30 mm, which is why the die can not stand in position during ECAE processing.

Another big disadvantage of the die is that the assemblage screws are threaded, and during the ECAE processing they warp and the die can not be opened.



a



b

Fig. 2. ECAE die: profile (a) and the two parts that make the die body (b)

4. CONCLUSION AND FUTURE RESEARCHES

The considerations made on our proposed die design for ECAE may reveal the following conclusions: the proposed die is not adequate for a proper ECAE processing because the die must be centered, the dimensions must be higher for a good position during ECAE processing and the die must not contain screws, because during the ECAE processing the screws warp and the die can not be opened.

Future researches will be based on designing a new ECAE die with Luis' geometry and also on the material flow behaviour through the die channel.

5. ACKNOWLEDGEMENTS

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