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Effect of Die Angle on Temperature Distribution For Al6061 in ECAP Process

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Abstract

Equal – channel angular pressing (ECAP) is a perfect process to produce important refinement through grain structure by achieve severe plastic deformation . An increase in requirements to enhance the mechanical properties for light metal led to new changes in production methods. The plastic deformation through the process is controlled by die geometry , characteristic of billet material , and process variables . ECAP process is a convenient method to increase the strength of aluminum alloys by making ultrafine grain size . In this study , numerical method of Q Form program is used to investigate the effect of die angle on temperature distribution during ECAP process for aluminum alloy Al6061. Three type of angles are used in this study (90^{o}, 110^{o}, 135^{o}) to discuss the influence of increasing die angle on products temperature .The results show that when increase die angle the temperature will decrease because the friction factor will decrease ,while through using low angle , high friction factor occur and billet temperature raise .

Keywords: ECAP process , die angle , temperature distribution , grain refinement , aluminum alloys .

1. Introduction

Equal channel angular pressing (ECAP) is a process to produce material by using die with angular channel without make big change in shape and to achieve ultrafine grained material by sever plastic deformation . The amount of this deformation affects the amount of microstructure and mechanical properties .Die parameters (channel angles, channel size , corner angle) have significant effects on ECAP process [1].. Die parameters influence was studied to demonstrate effects on equal channel angular pressing parallel process . Numerical analysis was used to find the values of 1) strain hardening exponent 2) strength coefficient . I was seen that the die parameters and especially die channel angle has significant effect on strain magnitude . Reduce channel angle increase effective strain value and increase the force required for press. Besides , channel displacement more effective on homogenous of effective strain [2].

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Equal channel angular pressing use to improve the mechanical properties for Aluminum alloys . Transmission electron microscopy showed that there is good results for more refinement occur with ECAP process . the tensile test showed that high strength occur with raise pressing number [3]. For composite material Al6061-SiCp the study showed the effect of ECAP process on mechanical properties and microstructure . It shown that when decrease the weight of SiC to 2wt % more than three passes can achieve in ECAP process while for the cases of Al6061-4%Si an Al6061 -6% SiC only two passes can achieve . More increase of SiC particles decrease the number of passes and raise the hardness [4]. ECAP process used to produce ultrafine grained metals and for incremental , it is an extension of the classical equal channel angular pressing . The influence of process was studied for types of dies by using channel angle $\Phi = 90^{o}$ and $\Phi = 120^{o}$. The forces used to produce the part was studied . To find strain distribution , micro hardness test was done . By using numerical method , the study showed that using die with channel angle $\Phi = 90^{o}$ lead to increase forces of deformation and more uniform distribution of strain [5] . The influence of inner channel angle of ECAP process for aluminum was studied by using finite element method , the results show that the stress distribution was non- homogenous for both 90^{o} and 120^{o} inner angle [6]. For ECAP and post aging processes on 2024 aluminum alloy, the results show that the strength of aluminum alloys increase by combined effects .The angle of the die channel equal120^{o} was used to achieve sever plastic deformation. [7]. A new technique of ECAP conform for aluminum alloy was used for computer modeling . It is used to produce part with ultrahigh strains for one cycle .The computer modelling show that the axisymmetric area of the deformed billet exposed to compressive stresses and lead to produce parts with near free defect [8]. Many problems occur during equal channel angular pressing , therefore numerical solution and experimental work were done to investigate the main problems . The study discuss the effects of friction states and die geometry effect on change shear strain field through the cross section of the workpiece which lead to direct influence on mechanical properties [9]. For Aluminum alloy AlMg3 the effect of ECAP on hardness was studied . The study demonstrate that important changes in microstructure were achieved by using two types of dies and after one pass further shear rotated 30^{o} compared with transverse orientation .The structure superfine with shear and slip bands appear [10].

2. Material and method

A finite element method of 3D Q Form software was used to analyze the ECAP process and die angle effect for aluminum alloy 6061 workpiece material .The die material is H13 HRC50 .The load of press is 1.5 MN with hydraulic press machine , no lubrication used in the process . The process is cold working with environment temperature . Three types of die channel angle (90^{o}, 120^{o}, 135^{o}) were used to investigate the values of load and power with temperature distribution .

3. Simulation results

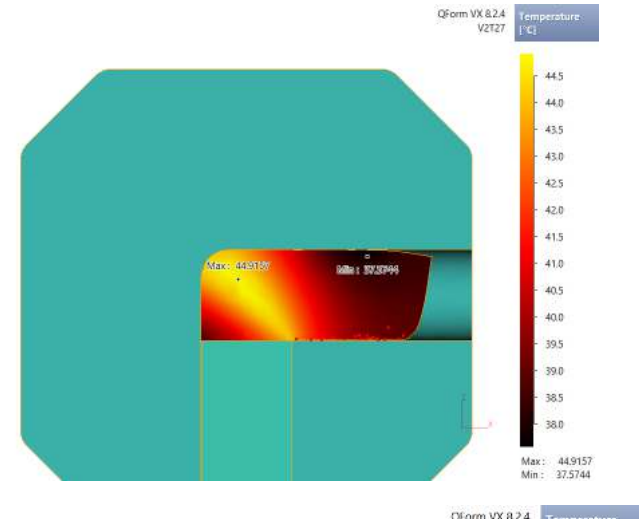

Figure.1 Temperature distribution for ECAP die angle (90^{0})

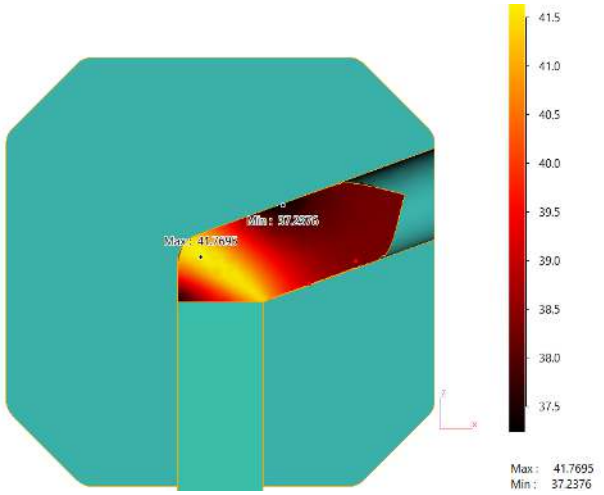

Figure.2 Temperature distribution for ECAP die angle (110^{0})

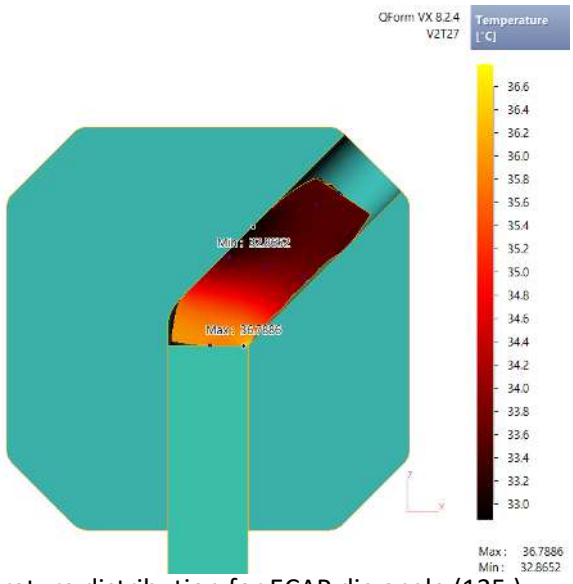

Figure.3 Temperature distribution for ECAP die angle (135)

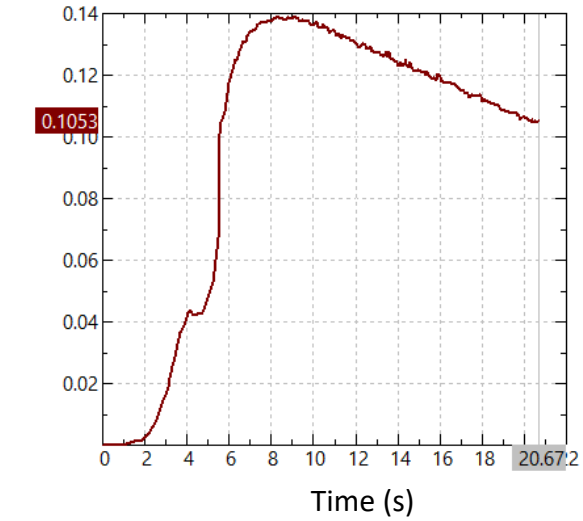

Figure.4 Load for ECAP die angle (90)

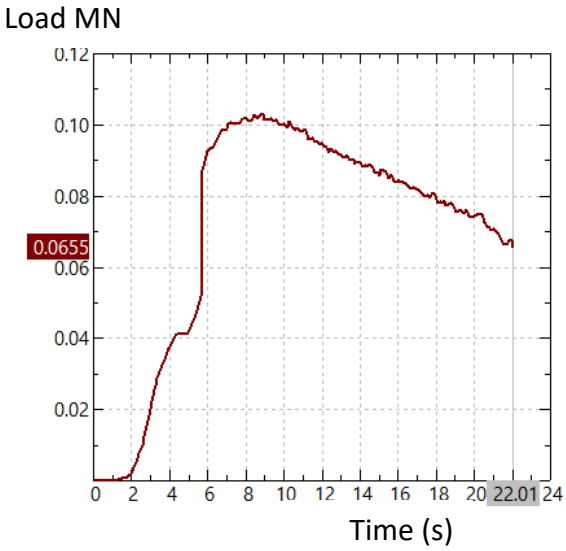

Figure .5 Load for ECAP die angle (110)

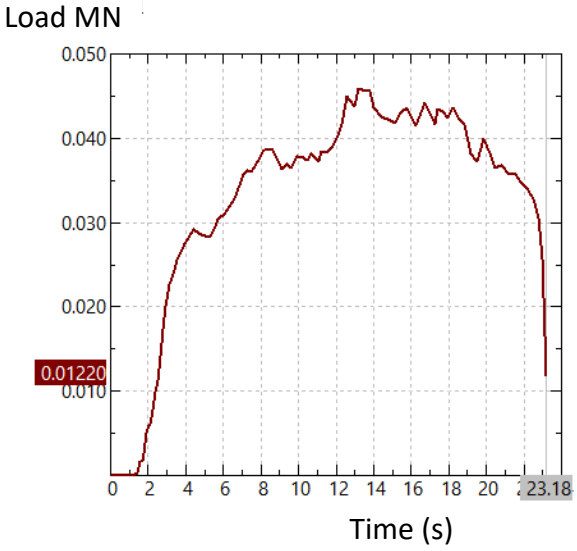

Figure.6 Load for ECAP die angle (135)

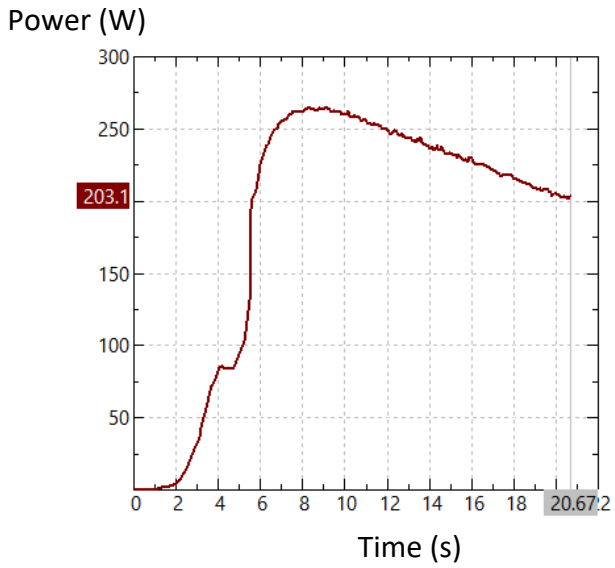

Figure.7 Power for ECAP die angle (90)[8]

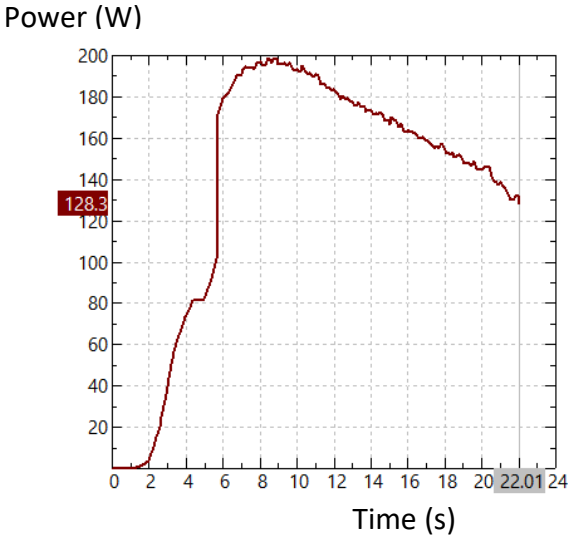

Figure .8 Power for ECAP die angle (110)

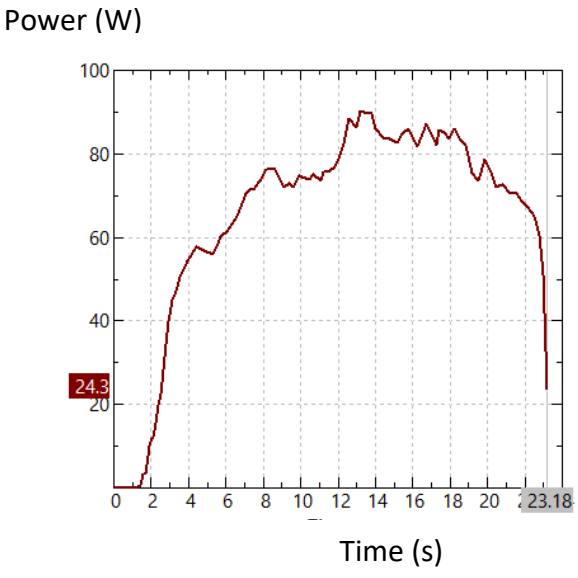

Figure.9 Power for ECAP die angle (135)

Table.1 Values of power ,load and temperature distribution for different ECAP die angles

Die angle	Temperature (C˚)	Load (MN)	Power (W)
90˚	45	0.139	264
110˚	42	0.102	197
135˚	36	0.045	89.7

4. Conclusion

One of the special method of metal forming is equal channel angular pressing used to produce materials and alloys with ultra-fine grain and Nano crystalline by achieve big plastic strain on the workpiece materials . This method needs special type of die of equal channel to extrude the billet without occurrence of basically changes in shape by sever plastic deformation . This method depend on apply large strain and change the type of grains to the Nano scale . In this study three types of die channel angles (90^{o},120^{o}, 135^{o}) were used to investigate the effect of increase these angles on temperature distribution for the work piece and the amount of load and power required to achieve this process for aluminum alloy 6061 during ECAP process. It was shown that increase channel angle degree lead to decrease the temperature across the workpiece because of reduce friction factor between the billet and channel wall which decrease the friction and then the heat generated . In addition , load and power required decrease when increasing channel angle . Large changing for load and power occur for the process used channel angle 135^{o} which lead at end to large reduction for both of them .

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