Improvement in Mechanical Properties of Aluminum Alloy 6061 by Equal Channel Angular Pressing

Sohel Atar[1] ,Mayur Deshmukh[2], Harshal Rote[3], Suhas Tarde[4]

[1] Student, Department Of Mechanical Engineering, D.Y. Patil College Of Engineering,Maharashtra,India
[2] Student, Department Of Mechanical Engineering, D.Y. Patil College Of Engineering,Maharashtra,India
[3] Student, Department Of Mechanical Engineering, D.Y. Patil College Of Engineering,Maharashtra,India
[4] Student ,Department Of Mechanical Engineering, D.Y. Patil College Of Engineering,Maharashtra,India

ABSTRACT

Equal Channel Angular Pressing (ECAP) is one of the severe plastic deformation processes in which an ultra large plastic strain is imposed on the material to get ultrafine grain structure. In this research a die having angular channel was designed. The channel angle and outer curvature angle were kept as 90˚ and 15˚ respectively. In order to investigate the effect of the grain refinement during ECAP on mechanical properties of Al 6061 alloy, the specimens was pressed by specific route. ECAP causes an impressive grain refinement and strengthening of material. Microstructural observation was undertaken using microscopy. In this research improvement in the mechanical properties of aluminum alloy 6061 after passing through ECAP was studied. Also change in microstructure was studied. We evaluated the mechanical properties such as tensile strength, ductility, and hardness. Effect of process parameters such as route and temperature on the microstructure and mechanical properties was studied.

Keyword : - *Equal Channel Angular pressing, Aluminum alloy 6061*

---

1. INTRODUCTION

Aluminum alloy 6061 is one of the most widely used material. It is used in aerospace industries, construction industries, automobile industries (Chassis of Audi A8), military application etc. As reduced in weight in automobile results in greater fuel efficiency, so there is increase in the use of aluminum in automobile. It is important to improve mechanical properties of aluminum alloy 6061 to increase its use.

Severe plastic deformation (SPD) process is one of the best process to improve mechanical properties of material The most common process of SPD is equal channel angular pressing (ECAP), which involves pressing a billet through a die consisting of angular channel having an angle typically 90º. The process of ECAP allows us to introduce very large plastic deformation to a work piece without altering the overall geometry of the work piece. This result in a ultrafine grain structure of workpiece [1]. According to Hall Petch equation the yield strength of material vary inversely with its grain size so using ECAP yield strength of material can be increased.

Hall Petch equation is,

$$\boldsymbol{\sigma_y = \sigma_0 + k/\sqrt{d}}$$

Where,

σ_y = Yield Stress
σ_y = Material constant for starting stress for dislocation movement
k = Strenthening constant
d = Average grain diameter

1.1 Objective

1] To design the ECAP die for Al-6061 alloy.
2] To carry out ECAP process on Al-6061 alloy
3] To study microstructural changes in Al-6061 after processing through ECAP at different temperature.
4] To study the changes in the mechanical properties of Al-606 alloy

1.2 Four fundamental routes of ECAP

ROUTE 'A' - Sample is pressed repetitively without any rotation.
ROUTE 'B (A)' - Sample is rotated by 90º in alternate direction between consecutive passes.
ROUTE 'B(C) ' - Sample is rotated in same sense by 90º between each passes.
ROUTE 'C' - Sample is rotated by180º between passes.

2. EXPERIMENTAL PROCEDURE

2.1 Material

Aluminum alloy was investigated in this study, Al 6061, which is an Al–Mg–Si alloy. The Al 6061 specimens were obtained from 10*10 mm square bar stock. The specimens were machined such that the specimen axis was parallel to the extrusion direction of the rod. For die and plunger steel C45 is selected as it has sufficient hardness to avoid crack at corner and for machining.

2.2 Design of ECAP die

In the design of ECAP die the parameter such as channel angle, angle of arc of curvature are selected such that the process is optimum. For optimum process channel angle and angle of arc of curvature is selected as 90º and 15º respectively [3].

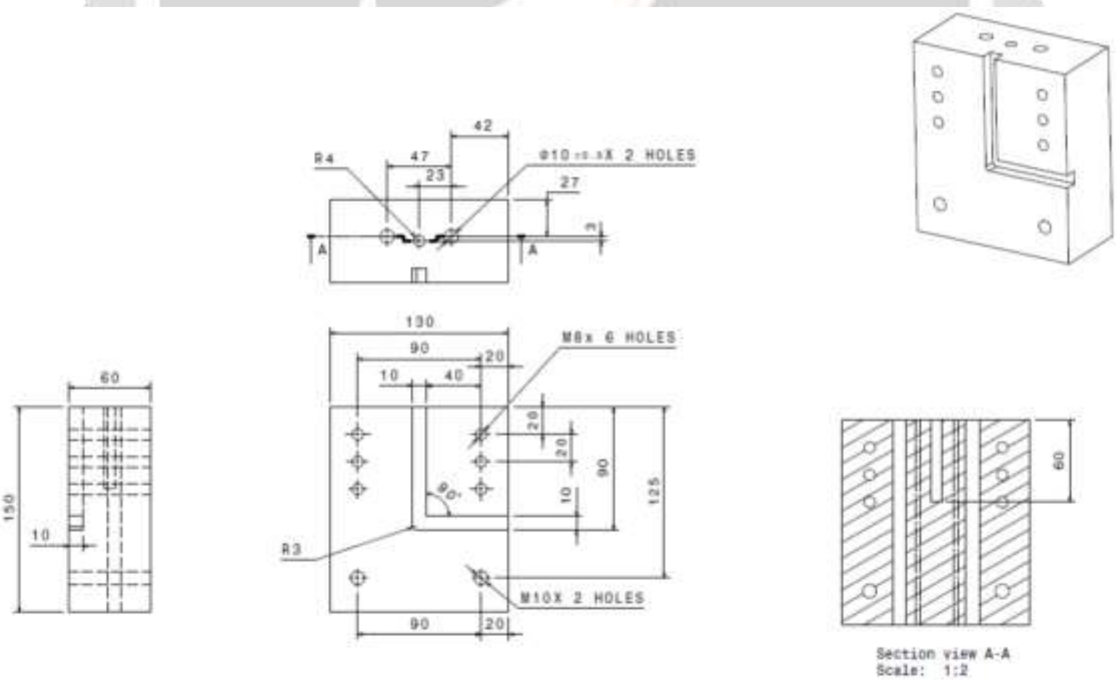


Fig 1 Design of ECAP die.

2.3 Equal channel angular pressing procedure

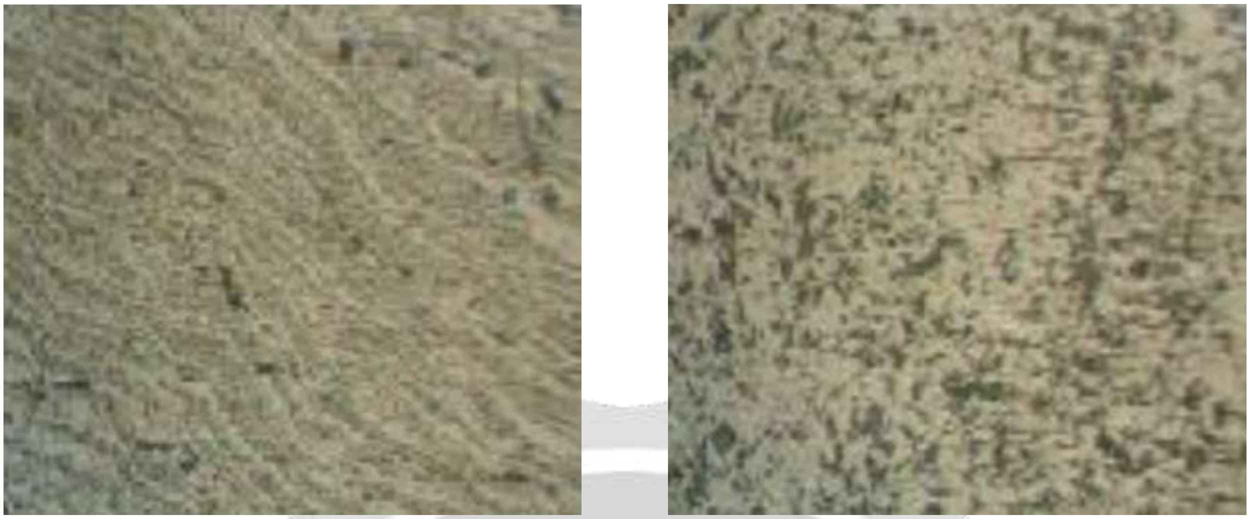
Billet of 10*10mm square shape and 85mm length was heated in furnace up to 200ºC and placed into die. The die temperature was maintained using rod type heater. The temperature of specimen is recorded using infrared temperature sensor. Then the sample was pressed using UTM of capacity 100 metric tons. The 110KN plunger forced required to extrude the sample. The MoS_2 is applied on specimen surface as lubricant. The sample is pressed by route B(c).

Fig 2 Experimental setup

3. RESULT AND DISCUSSION

Microstructure

The microstructure of specimen before and after ECAP process for single pass is shown in figure 3. As shown in fig ultra-fine structure was obtained. The microstructure was observed under electro spectrum microscopy.



(a) (b)

Fig 3 Microstructure of initial specimen (a) and specimen after single pass through ECAP

4. CONCLUSIONS

In this research microstructure of aluminum alloy 6061 subjected to ECAP process at 120ºC was investigated and compared to the sample with no ECAP. The ultra-fine microstructure of aluminum alloy 6061 was obtained. The mechanical properties can be related to the microstructure by using Hall Petch equation. So it can be seen that by obtaining ultra-fine grain structure mechanical properties of aluminum alloy 6061 was improved. The strain distribution depends on process route and number of pass. To use this process for mass production the process time should be reduced.

5. ACKNOWLEDGEMENT

The authors are grateful to Professor Manoj Joshi of D. Y. Patil College of Engineering, Pune for providing the ECAP die details and acknowledge the support of the Department of Mechanical Engineering D. Y Patil College of Engineering, Pune.

6. REFERENCES

[1] J.K.kim , H.K. kim, J.W. Park, W.J.Kim, Large enhancement in mechanical properties of the material after single pressing by ECAP, Scripta Materialia 53 (2005) 1207–1211.
[2] L.J. Chena, C.Y. Ma , G.M. Stoica , P.K. Liawb, C. Xuc, T.G. Langdon, Mechanical behavior of a 6061 Al alloy and an Al2O3/6061 Al composite after equal-channel angular processing, Materials Science and Engineering A 410–411 (2005) 472–475.
[3] W.J. Kim, J.Y. Wang , Microstructure of the post-ECAP aging processed 6061 Al alloys, Materials Science and Engineering A 464 (2007) 23–27.
[4] Akhtar S. Khan , Christopher S. Meredith, Thermo-mechanical response of Al 6061 with and without equal channel angular pressing (ECAP), International Journal of Plasticity 26 (2010) 189–203.
[5] Omid Nejadseyfi , Ali Shokuhfar , Amirreza Dabiri , Amin Azimi, Combining equal-channel angular pressing and heat treatment to obtain enhanced corrosion resistance in 6061 aluminum alloy, Journal of Alloys and Compounds 648 (2015) 912e918.