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MECHANICAL PROPERTY ENHANCEMENT OF ALUMINIUM ALLOY AA 7068 PROCESSED THROUGH AN EFFECTIVE GRAIN REFINEMENT PROCESS CALLED ECAP

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Abstract—**In the present scenario there is an immense need for highly designated material with better mechanical and physical properties for a variety of engineering applications. This article discusses a well-known severe plastic deformation process called equal channel angular pressing (ECAP), which was conducted on Aluminium alloy AA7068 at elevated temperature 220°C with repetitive ECAP cycles using route A, up to four passes in order to improve the mechanical properties of the material by producing ultrafine grained (UFG) microstructure. The microstructure of homogenized and ECAP processed samples were analyzed using optical microscope and mechanical properties were examined through tensile and microhardness tests. Investigation results showed an improvement in tensile strength and hardness of ECAP processed samples with a considerable amount of grain refinement up to 15 μm after four ECAP passes as compared with unprocessed samples.**

Keywords— **AA7068 aluminium alloy, SPD, ECAP, grain refinement.**

I. INTRODUCTION

Severe plastic deformation (SPD) is an effective processing tool to improve the mechanical properties of different materials as compared with the conventional metal forming process such as rolling, extrusion and drawing. The major difference in deformation mechanism between conventional practices and severer plastic deformation is that, during traditional plastic deformation method formation of continuous evolution of dislocation structure which does not support grain refinement where as in SPD it evidences a changeover from continuous dislocation mechanism to microlocalized flow which strongly supports grain refinement intern helps to improve the mechanical properties of the materials to prepare them fit for a variety of applications[1-4].There are different SPD methods in order to obtain ultra-fine grain structured materials such as equal-channel angular pressing(ECAP) [5], high pressure torsion extrusion [6], multidirectional forging (MDF) process [7], Constrained groove pressing (CGP)[8], accumulative roll-bonding (ARB) [9], repetitive corrugation and straightening (RCS) [10,11] etc. ECAP is one of the major SPD process which helps to process the material to get ultrafine grains structure through grain refinement for the betterment of mechanical properties of the material. ECAP was successfully applied on different materials like aluminium and aluminium alloys, magnesium, copper, steel, titanium and so on to enhance the properties of the materials. ECAP grain refinement process was started by Segal in 1997 [12]. Y. Iwahashi et al. conducted ECAP process on aluminium using two pressing routs such as route A where no rotation was given to the samples between successive passes and route C where a rotation of 180° was given to the sample under ECAP process between repetitive passes. ECAP was conducted up to ten passes and results showed that after four recitative passes only a ultrafine grain structure was achieved during the process and hence the resulted materials showed the improvements in their mechanical properties [13].

Jiang Da-ming et al. investigated the effect of ECAP process on Al-Mg-Mn alloy. ECAP was performed at an elevated temperature of 350 °C up to six passes followed by annealing process for one hour at 400 °C after ECAP passes. EBSD analysis was done to reveal the effect of ECAP and annealing process. Results found that ECAP passes were able to achieve a grain refinement of the material up to the grain size of 2 µm with six successful repetitive ECAP passes with good amount of high angle boundaries resulted in it microstructure but after annealing process the strength of the material decreased while attempting to relax the internal stress [14]. R. Ding et al. studied the influence of ECAP process on ZE41magnesium alloy. ECAP was conducted at 320 °C up to six repetitive passes. It was identified that after six ECAP passes a drastic reduction in the grain size was resulted up to a final average grain size of about 2 µm and the tensile strength was raised from 160 MPa to 230 MPa with a significant improvement in elongation of the material from 8% to 20% as a result of ECAP process [15]. Abbasi M. et al. experimented a reduced-scale ECAP process on pure titanium in order to improve the mechanical properties and corrosion resistance of the material which should be applied for the dental implantation application [16]. Aluminium is a most abundantly available light metal and is one of the major materials with attractive material properties. Aluminium with different alloying material led to the formation of different series of aluminium alloys [17]. Aluminium alloy is a light weight, high strength material with better ductility and good corrosion resistance this made a major space in various applications especially in aerospace, automotive and lot more engineering applications [18]. In our previous work ECAP was done on aluminium alloy using pressing route Bc at 200°C and a good amount betterment in the property of the alloy was reported [19]. Literatures identified a less or no effort was made to apply ECAP of AA7068 even though it found lot of applications in various applications [20].

This work is mainly focused on the enhancement of the mechanical properties of aluminium alloy AA7068 by using a severe plastic deformation process called ECAP, in order to make this material the best selection with improved strength for a variety engineering application.

II. MATERIALS AND METHODS

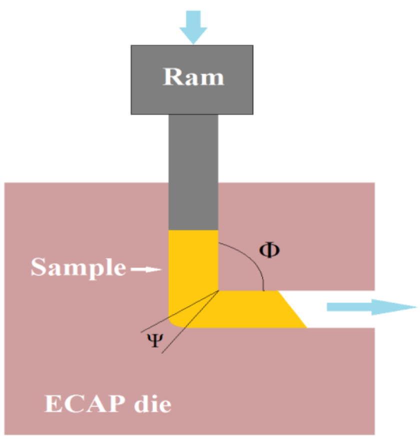

Fig. 1. ECAP Process

AA7068 is a aluminium alloy with zinc, magnesium and copper as primary alloying elements of 8.3, 3, and 2.4 wt.% respectively. This alloy is the strongest of all other aluminium alloys whose properties are comparable with that of steel. AA7068 found its applications in automobile sports, medical and ordnance. The ECAP setup was created on universal testing machine (UTM). The schematic representation of the ECAP process is as shown in figure 1. The ECAP die and plunger were fabricated with hotdie steel and heat treated to make them strong. The channel angle Φ and curvature angle Ψ for the ECAP split die were designed with 90° and 0° respectively. The ECAP die is specially equipped with heating coils to perform ECAP passes at an elevated temperature of 220°C, which was ensured and stabilized by soaking the samples for 15 min in the die at this elevated temperature before pressing through ECAP die. The samples were prepared to the required dimension and are homogenized with suitable heat treatment before sending for the ECAP passes. AA7068 samples thoroughly coated with molybdenum disulphide as lubricant were pressed through ECAP split die for four repetitive passes by using route A, where the samples are pressed without giving any rotation to the sample as done in other pressing routs between consecutive passes. The samples are pressed with a pressing speed of 50 mm /min on universal testing machine during ECAP passes. After ECAP process the samples microstructure was analyzed using optical microscope by slicing the samples perpendicular to its longitudinal axis as per ASTM E-112 standards with a proper polished surfaces. Further mechanical properties were tested on tensile and Vickers microhardness testing machines according to ASTM-E8 and ASTM-E384 standards respectively with necessary sample preparations. Figure 2 shows assembled view of ECAP die with plunger and clamps.

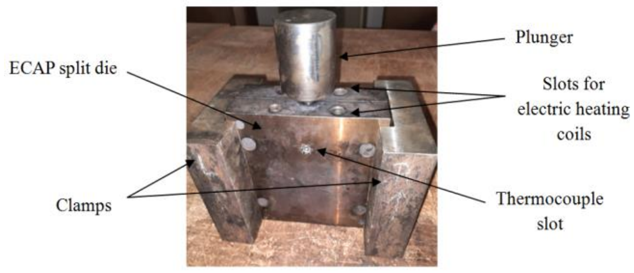

Fig. 2. ECAP die assembly

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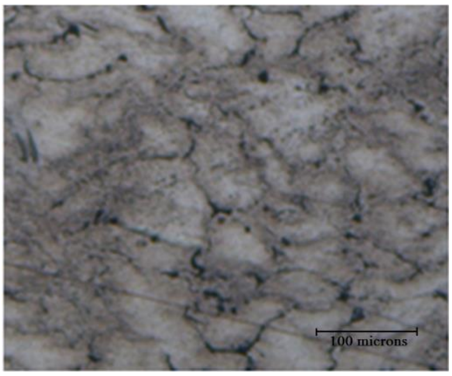
III. RESULTS AND DISCUSSION

A. Microstructural Analysis --

Microstructure of AA7068 aluminium alloy samples before ECAP process and after four ECAP passes are shown in figure 3 (a) and (b) respectively, which were observed in optical microscope (OM). By looking in to these figures it is clearly evidenced that a considerable amount of grain refinement was took place due to the influence of an effective severe plastic deformation (SPD) process called equal channel angular pressing (ECAP) by inducing a intensive severe strain in to the material through simple shear deformation [21]. After four ECAP passes an equiaxed and homogeneous microstructure was achieved due to the occurrence of dynamic recrystallization during ECAP pressings or static recrystallization caused by heating the samples before ECAP pressing to reach the required elevated pressing temperature [22].

Grain sizes of samples before and after each ECAP passes up to four pressings were measured using linear intercept method, which was resulted to be an average of 85, 70, 55, 30 and 15 µm, respectively and are plotted graphically as shown in figure 4.



(a)

(b)

Fig. 3. OM images of AA7068 samples (a) before ECAP passand (b) after four ECAP passes

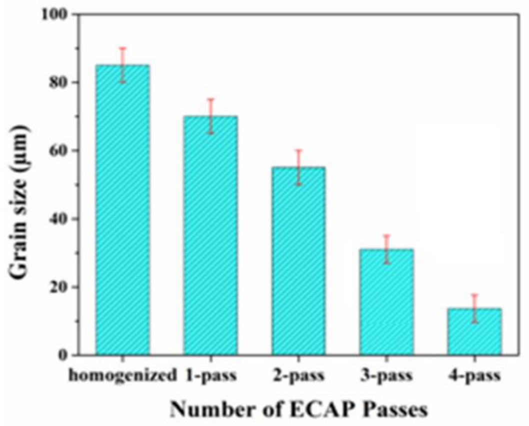


Fig. 4. Grain size in µm before and after ECAP process

B. Mechanical Properties –

Table -1 Experiment Result

Number of ECAP Passes	Grain size (µm)	Tensile Strength (MPa)	Micro Hardness Values(Hv)
0	**85**±15	**170**±10	**96**±8
1	**70**±13	**210**±12	**111**±7
2	**55**±10	**260**±11	**136**±10
3	**30**±9	**295**±11	**159**±9
4	**15**±5	**356**±10	**176**±10

The influence of ECAP process on mechanical properties such as microhardness and tensile strengths after each ECAP pass up to four passes are tabulated and comparative graphical representation is shown in following figures. Microhardness tests conducted on Vicker's micro hardness testing machine were plotted in figure 5, which shows a gradual increase in hardness values from 96 Hv upto 176 Hv after all four ECAP passes. Figure 6 shows tensile strength results obtained during tensile tests conducted on universal testing machine, graph shows an improvement in tensile strength with all ECAP passes up to 356 MPa. Both tensile values and microhardness values achieved during ECAP process were together plotted on the line graph as shown in figure7, which indicates comparative improvement strengths of the ECAPed samples. Table 1 tabulates all the test results obtained during tests conducted to analyze the influence of ECAP process on microstructure and mechanical properties of aluminium alloy AA 7068.

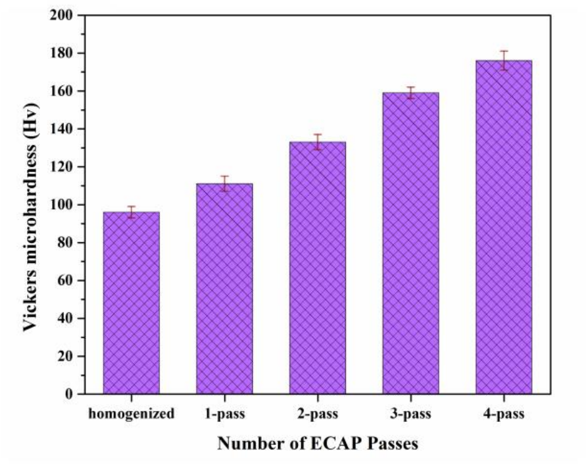


Fig. 5. Micro hardness values in Hv before and after ECAP process

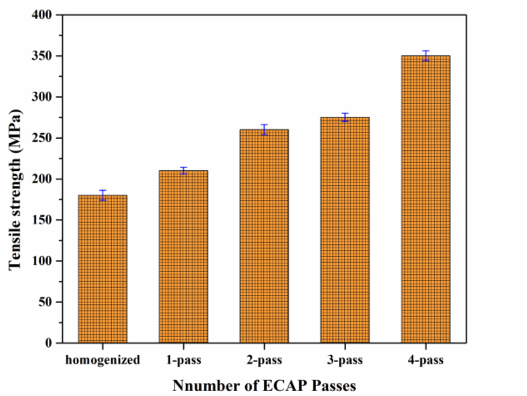


Fig. 6. Tensile strength in MPa before and after ECAP process

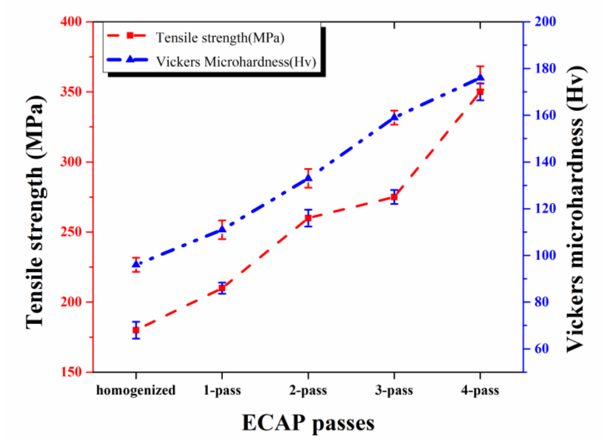


Fig. 7. Effect of ECAP on mechanical property of AA7068aluminium alloy

IV. CONCLUSION

Conclusion must be short and precise and should reflect the work or research work you have gone through. It must have same as above in introduction paper adjustment

ECAP was conducted on aluminium alloy AA 7068 at elevated temperature, and its influence on microstructure and mechanical properties of the alloy were summarized as follows based on the results obtained through different tests.

- Grain size reduction from ~85 µm to ~15 µm was achieved through four repetitive ECAP passes as a result of dynamic and static recriatalization caused during ECAP process on preheated samples.
- Optical micrographs evidenced that the samples after four ECAP passes were resulted with an equiaxed and homogenized microstructure as compared with that of unprocessed or homogenized samples.
- Tensile test results revealed that a gradual improvement in tensile strength from first pass to fourth ECAP passes as compared with homogenized samples of its initial ultimate tensile strength of 170 MPa were recorded as 210, 260, 295, and 356 MPa respectively.
- ECAP process contributed positively to improve the microhardness of AA7068 alloy by reporting Vickers microhardness values of 111, 136, 159, and 176 Hv for 1 to 4 repetitive passes respectively as compared with an unprocessed sample whose hardness was initially of 96 Hv.

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