"Severe Plastic Deformation of 8 % Titanium Boride Reinforced Aluminum Alloy"

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Abstract:- **Grain refinement is one of the technique, which provides finer grains and hence strength and ductility combinations demanded for ambient and cryogenic temperature applications. On the other hand, severe plastic deformation (SPD) is an effective tool for producing bulk ultrafine grain structure. Equal channel angular pressing is one of the SPD technique which provides the potential for refining the grain size of a polycrystalline material to a sub micron scale by producing a large amount of shear strain into the material without changing the billet shape and dimensions.**

In the present study, Aluminium titanium boride (Al-8%TiB_2) composite was deformed through the equal channel pressing (ECAP) by route B_c up to 4 passes. Significant improvement in hardness nearly 74% of hardness has been increased compare to base metal Al6061 alloy and ultimate strength of 517 MPa was obtained nearly 66% increase in UTS in the samples after 4 ECAP pass. The Microstructure analysis revealed that dendritic coarse grain was broken down to fine structured and grains were elongated after ECAP.

Key word: Metal matrix composites, Al6061 alloy, ECAP.

I. INTRODUCTION

Different techniques for producing ultra fine grained (UFG) materials for structural applications have been introduced and patented, especially in the last decade [1]. The advantages of fabricating materials with sub-micron size grained microstructure as structural components lie in their improved mechanical properties such as strength, hardness, ductility, fatigue resistance and low-temperature super plasticity [2-3]. Equal channel angular pressing (ECAP), introduced and developed by Segal *et al.* and Segal [1, 3], is a promising technique that uses severe plastic deformation (SPD) to refine microstructure. ECAP has the important advantage to maintain billet shape. A typical ECAP die, Fig. 1, consists of two intersecting channels of identical cross-section. A billet of material is introduced in the vertical channel and forced by a plunger into the horizontal one. Shear strain per pass through the die is determined by the angles of channel intersection and curvature. Many processing parameters have dramatic effects on the resulted microstructure [4]: die angles (determining the strain introduced into the material), the number of passes (accumulation of strain), deformation route (critical Parameter for texture and microstructure evolution with strain), and also the extrusion speed, temperature, friction. Langdon and co-workers [5] found the angles $\Phi = 90°$ and $\Psi = 20°$, Fig. 1, to be the most efficient, while the extrusion speed and specimen-die channel friction have minor influence on the refining process. A number of theories have been proposed to explain the effect of processing routes on the microstructure. Iwahashi *et al.* [6] and Furukawa *et al.* [7] proposed that route Bc (90° rotation of the billet at each pass) is most favorable for producing a microstructure consisting of essentially uniform and equiaxed grains separated by high-angle boundaries (HABs). This was suggested to be due to crossing shear planes and to a regular restoration into equiaxed structure during consecutive pressing. Sun et al. studied the different routes: (A, BA, BC, and C, where the route A refers to repetitively pressing the sample without any rotation, the route B_A refers to a rotation of 90^0 back and forth between each pass, route B_C refers to a rotation of 90° between each pass and route C refers to a rotation by 180° between each pass as a function of different microstructure parameters.

Aluminium alloy is extensively used in structural application. However, application of ECAP for Al-TiB_2 composite to improve their mechanical properties has been studied by only few researchers [9]. Multi-pass ECAP was applied to Al-8wt%TiB2 Composite to break coarse brittle θ phase around Al grain boundaries into small particles and to distribute them uniformly throughout the matrix [10]. ECAP was applied to Al-TiB2 composite up to 4 passes, which significantly increased the hardness, ultimate tensile strength. The microstructure evolution and hardness in a coarse grained Al-TiB2 composite during ECAP was investigated at 200°C temperature condition was ECAPed up to 4 passes through route Bc. For ECAP process, the high-level of refinement ingrain size can be obtained through rotating billets by 90^0 in clockwise directions between consecutive pressings in the die cavity.

Therefore, the aim in this study is to examine the microstructure and mechanical characteristics at room temperature after obtaining the UFG structure of Al-8%TiB_2 composite.

II. EXPERIMENTAL PROCEDURE

The AA 6061 aluminium-titanium boride composite was prepared using stir casting technique. Commercially available AA6061 aluminium was reinforced by in situ reaction between chemicals TiO_2, KBF_4 and Na_3AlF_6.The XRD graph of the composite revealed that 8% of TiB_2 was formed in the base alloy.

The ECAP was done at a temperature of 200^0C,the samples was annealed at a temperature of 200^0C for about one hour later ECAP carried by pressing cylindrical samples through a special die using a hydraulic press of capacity 100 tons capacity.

The sample had a diameter of 10mm and lengths of 65mm and the die was constructed so that it contained two channels, equal in cross section, intersecting at an angle of 130^0 and with an arc of curvature of 30^0 at the outer point of intersection of the two channels. Using this configuration, it can be shown that the strain accrued on a single passage through the die is ~2[11] and multiple passes may be undertaken to attain high strains. In the present experiments samples were pressed for 4 passes to a strain of ~10 using pressing route of B_c in which the samples are rotated in the same direction by 90^0 between consecutive passes through the die.

The extrusion was performed at the same temperature as ECAP carried out at a temperature of 200^0c,the samples was annealed at a temperature of 200^0c for about one hour later extrusion carried out by pressing cylindrical samples through a die using a hydraulic press.

The samples initially had a diameter of 20mm and length of 30mm and the die was constructed such that reduction in diameter occurs the diameter reduced from 20mm to 8mm.

Following ECAP and extrusion, hardness specimens were cut parallel to the pressing directions with a length of 10mm and diameter of 10mm after each passing. The hardness of these samples was measured by mechanically polishing and then using Rockwell hardness tester equipped with B-scale indenter. For each measurement, a load of 100kg was applied for 15s at three different locations and measurement was done.

To check whether there was any breaking of the Al-TiB_2 composite during the ECAP, polished samples were prepared in both the As-cast and the ECA-pressed conditions and these samples were examined using a quantitative image analyzing facility attached to an optical microscope.

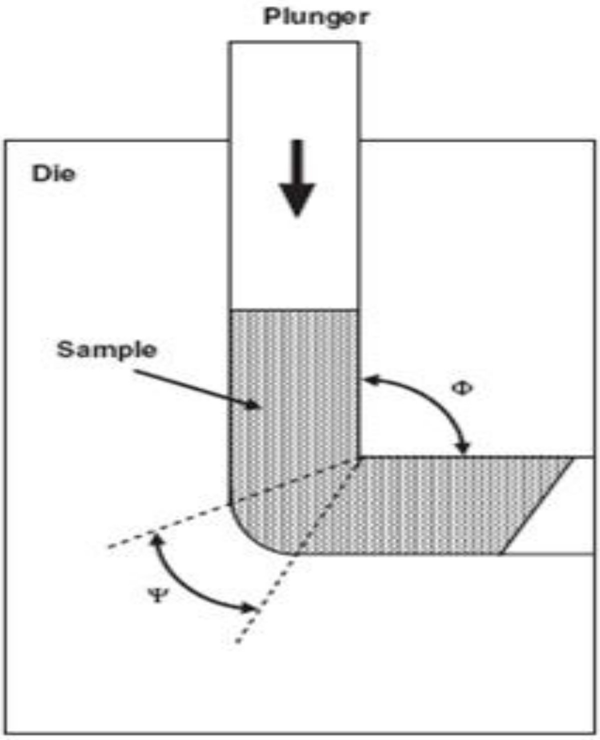
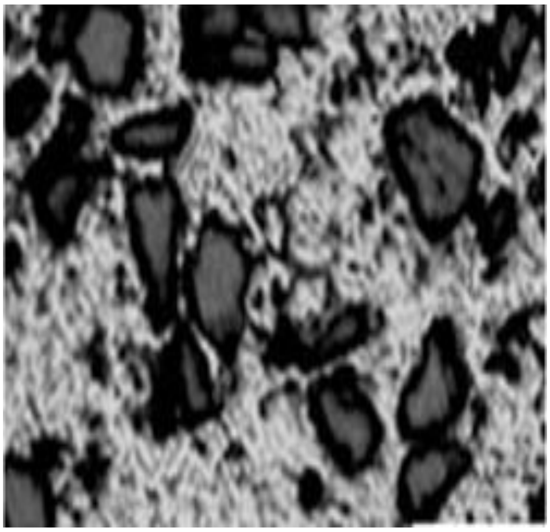


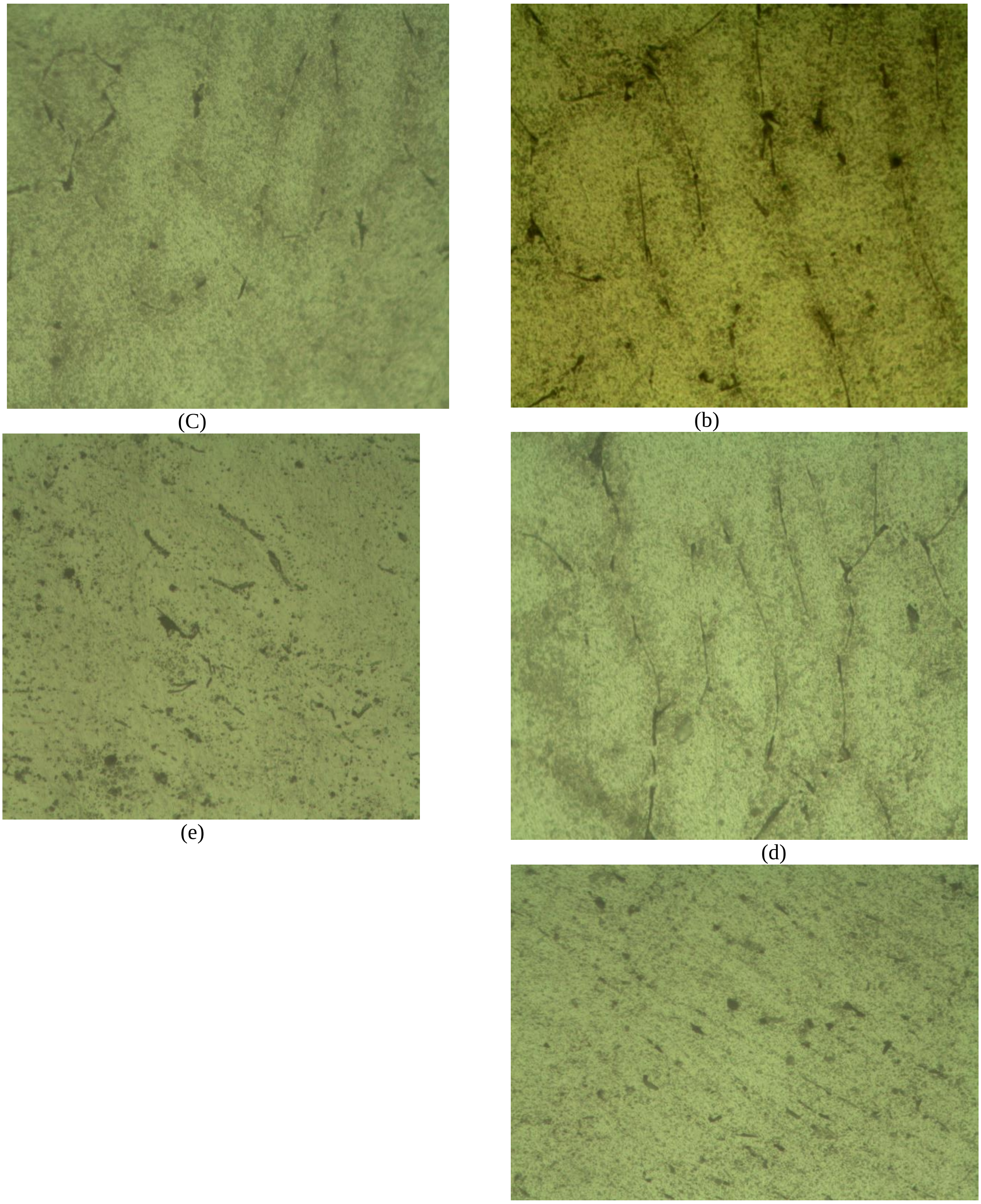
Fig1: Principle of ECAP

III. RESULTS AND DISCUSSIONS

A. Micro structural characteristic



(a)



(C) (b)

(e) (d)

(f)

Fig 2:Microstrcture (optical 500X of Al 6061 alloy (a) and ECAP pressing (b-e) & extrusion (f) of Al-8%TiB_2 composite.

Figure 2 shows the optical microstructure of ECA pressed of Al-8%TiB_2 composites up to 4 passes. Initially, the un-pressed material (fig 2a) composed of coarse grains with intermetallic particles. After one ECAP pass, Microstructure consists of dendrites of aluminium solid solution, Intermetallic particles are seen at inter dendritic regions (fig 2b). After second pass, it consists of aluminium solid solution with fine, intermetallic particles Partial breaking down of the dendritic structure can be seen (fig 2c). After third pass, Microstructure consists of aluminium solid solution with fine, intermetallic particles. Dendritic structure has almost broken down (fig 2d). After fourth pass, Microstructure consists of aluminium solid solution with fine, intermetallic particles. Grains appear elongated (fig 2e). The same Al-8%TiB_2 was done conventional extrusion, Microstructure consists of a mixture of fine and slightly coarse grains of aluminium solid solution with fine, intermetallic particles at the grain boundaries, and Grain deformation is restricted to the sub-surface regions, while the Centre of the section shows hardly any deformation.

B. Hardness

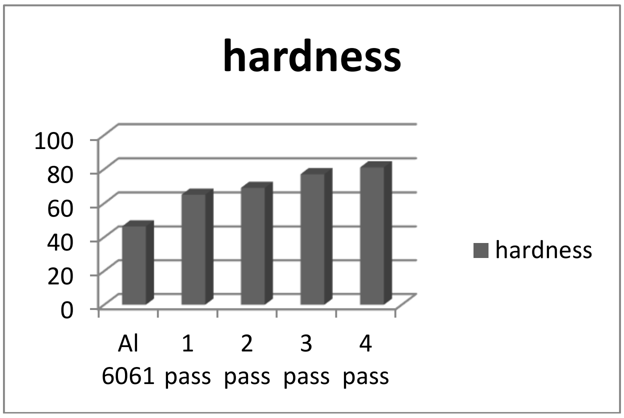


Fig3:.Variation of hardness with the number of passes

Hardness of the as-cast aluminum 6061 alloy and hardness of the ECA pressed aluminium-titanium boride composite are shown in figure 3. ECAP leads to substantial increase in hardness after each pass. Hardness has been increased from 46.36HRB to 81HRB. Hardness increased with increasing number of passes due to strain hardening mechanism in the initial stage. Further, ECAP passes promoted the formation of equiaxed grains accompanied with gradual decrease in dislocation density as already reported by several researchers. At the same after extrusion the hardness values also increased.

C. Comparison between extrusion and ECAP

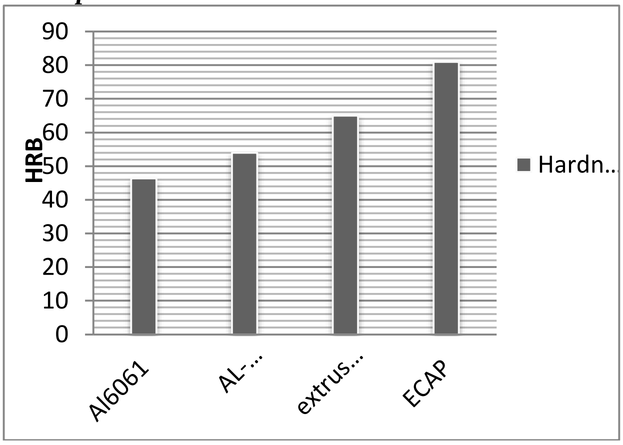


Fig4: Extrusion v/s ECAP

Fig.4 shows ECAP is better than extrusion significant increase in hardness occurs in ECAP than Extrusion. A hardness of 81HRB is obtained after 4 passes in ECAP, whereas 65HRB is obtained after extrusion.

IV.CONCLUSION

On the basis of experimental results, the following points can be concluded as listed below:

- Defect free aluminium matrix TiB_2 reinforced composite was produced in sir casting.
- An Al-6061 metal matrix composite reinforced with 8% wt TiB_2 particulate was subjected to ECA pressing at a temperature of 200^0c to a total strain of ~10.
- An Al-6061 metal matrix composite reinforced with 8% wt TiB_2 particulate was subjected to extrusion at a temperature of 200^0c.
- Because of simple shear the fine grains obtained from coarse grain structure.
- Increase in hardness obtained after ECAP, hardness increased from 46.36HRB to 81HRB and in extrusion 65HRB was obtained
- UTS of 517 Mpa obtained after ECAP.

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