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Severe Plastic Deformation and Its Influence on Mechanical Properties of In-Situ Aluminum Titanium Boride Composite.

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ABSTRACT

High specific strength of the material is critical for many structural applications in automotive and aerospace design. Among many other approaches for strengthening the materials, development of superfine and nano grained microstructure is popular. Different techniques for producing ultra-fine-grained (UFG) materials have been introduced especially in the last decade. The advantages of fabricating materials with sub-micron size grained microstructure for structural components lie in their improved mechanical properties such as strength, hardness, ductility, fatigue resistance and low-temperature super - plasticity. Severe plastic deformation (SPD) is one such process wherein simple shear stress is applied to a billet during multiple passages through an angled channel of constant cross section. The process is capable of generating very large plastic strains that significantly refines the microstructure without altering the external dimension of the billet. According to Hall-petch relation it is well known that refining the grain size increases the yield strength of a material. The concept of super plasticity is applied in super plastic forming. The super plastic forming is an established industrial process for the fabrication of complex shapes in sheet metal. The very high ductility and low strength of super plastic alloys offer advantages such as - Lower strength requirement for tooling, due to the low strength of the material at the forming temperatures, hence the tooling costs are less. Complex shapes can be made out of a single piece with fine details and close tolerances and thus eliminating secondary operations. Weight and material savings can be realized because of formability of the material. Little or no residual stresses occur in the formed parts.

In this paper an attempt is made to highlight the significance of severe plastic deformation of in-situ aluminum composite. The deformed aluminum composite showed a minimum increase of 27.68 % in tensile strength, 29% in hardness. The wear rate decreases with the increase in sliding distance.

Key words : Ultrafine grains, Severe Plastic Deformation, In-situ, Equal Channel Angular Pressing.

I. INTRODUCTION

Equal-channel angular pressing (ECAP) is a promising technique for production of ultra- fine grain structure in bulk materials. An important advantage of this technique over conventional metal-working processes, such as extrusion and rolling, is that very high strain rates may be attained without any concomitant change in the cross-sectional dimensions of the sample, so that repetitive pressings may be undertaken to achieve very high total strains. Several factors influence the nature of the microstructures attained in ECAP including i) the processing route by which the sample is rotated between consecutive pressings, ii) the angle subtended by the two channels within the die, and iii) the speed and temperature associated with the pressing. Recent reports have established that it is possible to attain ultra- fine grain size in bulk polycrystalline metals, with grain sizes generally in the nanometer and sub micrometer range, by intense plastic straining of materials using procedures such as Equal-channel angular pressing (ECAP). The process is applied largely to pure aluminum, aluminum alloys, magnesium alloys but merely applied to composites [1], [2].

1.1 Some of the benefits of SPD

The very high ductility and low strength of super plastic alloys offer the following advantages:

1. Lower strength is required for tooling because of the low strength of the material at the forming temperatures. Hence the tooling costs are less.
2. Complex shapes can be made out of a single piece with fine details and close tolerances and thus eliminating secondary operations.
3. Weight and material savings can be realized because of formability of the material.

1.2 Principles of Equal Channel Angular Extrusion

ECAE is carried out by introducing a lubricated billet into a die containing two channels with equal cross-section. For sufficiently long billets, plastic flow is essentially steady and in one plane. The channels intersect at an angle denoted by Φ near the center of the die. The process is described in Figure 1. Under these conditions the billet moves inside the channels as a rigid body and deformation is achieved by simple shear in a "thin layer" at the crossing plane of the channels. Thus the complete billet, except the small end regions and the minor surface area is deformed in the same uniform manner. The die angle determines the incremental strain intensity applied as the billet passes through the shear plane.

The effective Von Misses strain per pass is given by [3], [4]:

$$\varepsilon = \frac{2}{\sqrt{3}} \cot \phi$$

The punch pressure needed to press the billet can be determined by:

$$p = \frac{2}{\sqrt{3}} \cdot \sigma_y \cdot \cot \phi$$

Where σ_y is the yield stress of the material?

The equivalent reduction ratio (RR) and the equivalent area reduction (AR) values of ECAE for N passes with respect to conventional extrusion [5] can be found as:

$$RR = \exp(N \cdot \varepsilon) \quad \text{and} \quad AR = (1 - RR^{-1}) \cdot 100\%$$

II. EXPERIMENTAL PROCEDURE

The present investigation was motivated by the observation that, high superplastic elongations are generally confined to a relatively narrow range of operating strain rates, a reduction in the grain size has the potential of both decreasing the temperature and increasing the strain rate associated with optimum super plastic flow.

The experiments were conducted on Aluminum-Titanium boride composites for 2passes using route $B_c$to study the effect on the mechanical properties. The in-situ preparation of the composite and its enrichment is given elsewhere.

2.1 Composite ECAP

The cast specimens were subjected to T_6-heat treatment process along with ageing at 175°C for12hrs [6]. These heat treated samples were pressed using a special die by hydraulic press slowly at the rate of 0.05mm/sec and at the load of approximately 65KN. Once the specimen is completely pushed, the specimen was rotated at 90^0 for the 2nd pass i.e. following B_c route. These pressed samples were tested for mechanical properties and the results are presented here.The schematic diagram for the die used for the process in shown in the figure 2[7].

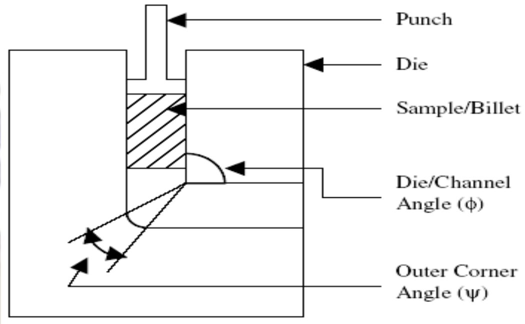

Fig.1 Schematic Illustration of ECAP

Fig.2 Schematic Illustration of split die used in the present work

III. RESULTS AND DISCUSSION

3.1 Tensile strength

It can be seen from the figure 3 that the value of UTS is increasing continuously from o percent to 6 weight percent of TiB_2 and later decreases considerably. Grain refinement is the likely cause for the above achievements as observed in the earlier investigation.The UTS is increased from 148.9 N/ Sq.mm to 205.9 N/ Sq.mm which is 27.68 times enhanced from the base alloy. This enhancement is just achieved for 2 passes of ECAP. Later the decrease in the tensile strength after 6 percent, is may be likely due to the agglomeration effect of the particles formed during the in-situ reaction which generally lowers is the critical flaw stress thus reducing the overall strength.

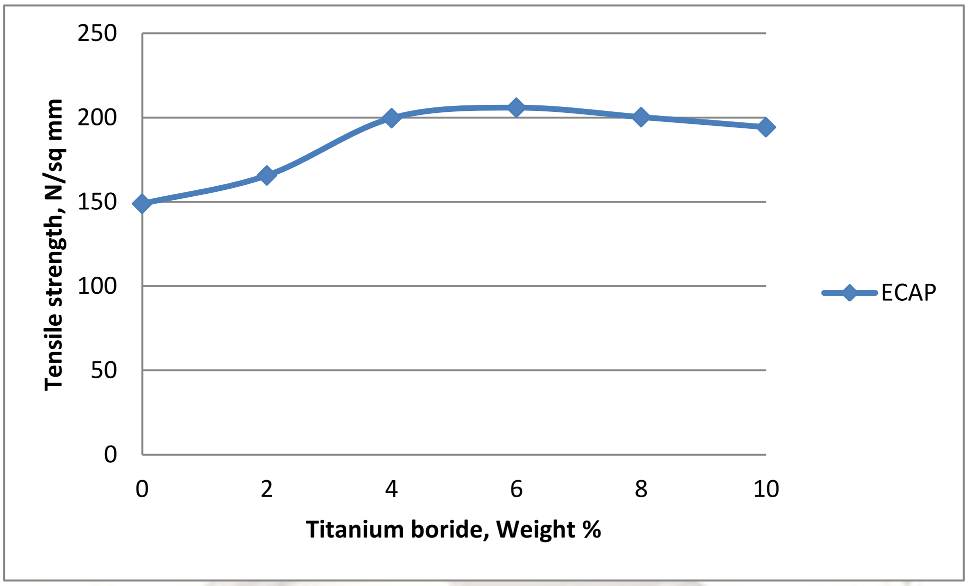

Fig.3 Tensile strength of ECAP for varying weight % TiB_2 dispersion

3.2 Hardness Test

In the figure 4 the Vickers Hardness number of varied TiB_2 composite subjected to ECAP samples are shown. It is clear that there is a considerable increase in hardness as the percentage of reinforcement is increased. There is 29% increased hardness when compared to base alloy. The increase in hardness may be accounted for the increase in the boride particles and the grain refinement and equal distribution of the reinforced particles after ECAP would enhance the micro hardness.

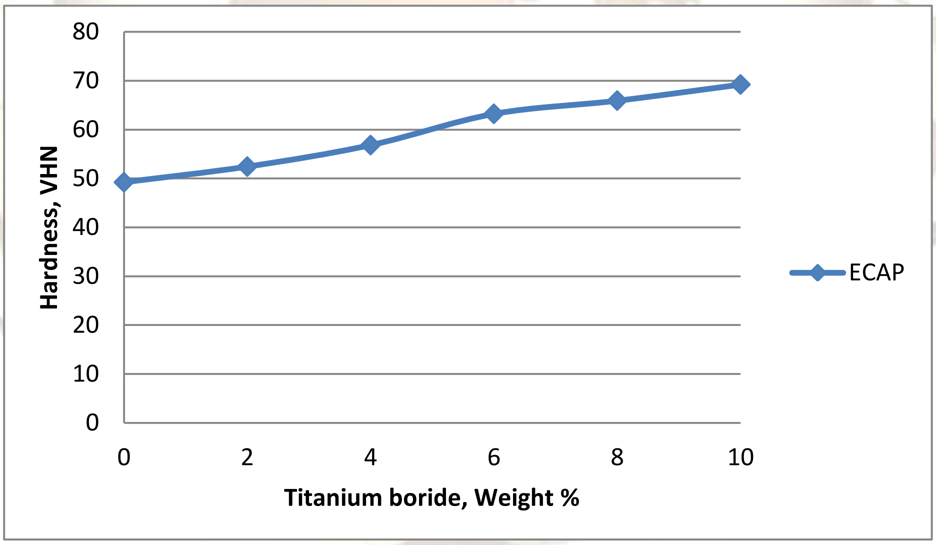

Fig.4 Hardness of ECAP for varying weight % TiB_2 dispersion

3.3 Wear Test

3.3.1 Effect of sliding distance

The variation in weight loss for different sliding distance is plotted in the figure 5. It is seen that there is an increase in weight loss with sliding distance. As the sliding distance increases the distance moved by the pin specimen also increases with the increase in wear of the composite. The TiB_2 particles may be embedded on to the disc surface and then accelerate the wear of the composite pins. Higher TiB_2 particles volume fraction may aggravate the matrix wear of the composites. The volumetric wear increases with increase in particle size and particle volume fraction. The volumetric wear increases exponentially with sliding distance.

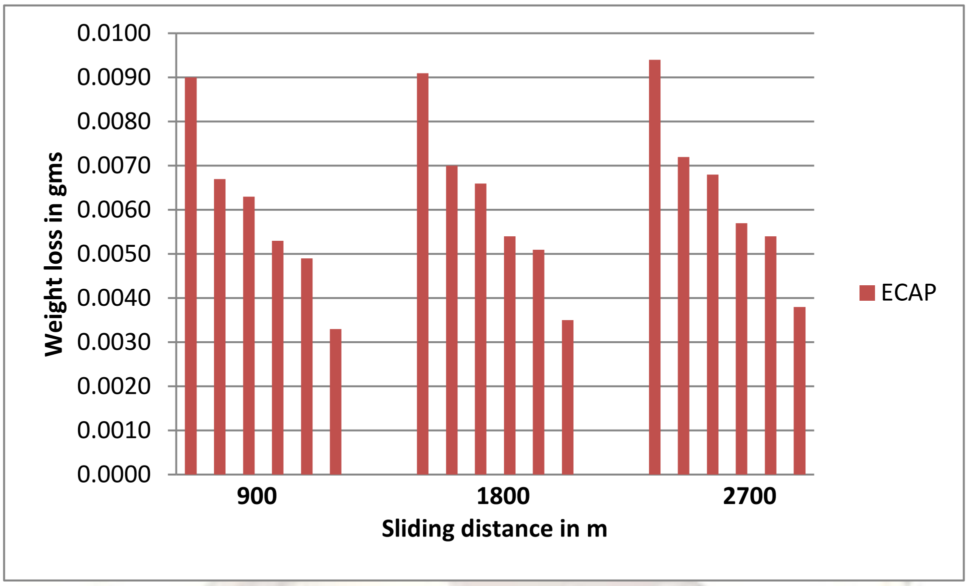

Fig.5 Weight loss for sliding distance of 900, 1800 & 2700 m at a constant load of 15N for various composition of TiB_2 in Al alloy

3.3.2 Effect of wear rate

It can be observed from the figure 6 that the wear rate decreases with the increase in TiB_2 percentage. Although the sliding distance is increased the wear rate i.e. weight loss / sliding distance show a decreasing trend. Initially the aspirates on the surfaces come in contact with each other during sliding and gets fractured resulting in high volume loss. When the same sample is continued for increase distance the surface will become even and steady state exist. Although temperature does affect the volume loss, it is very marginal.

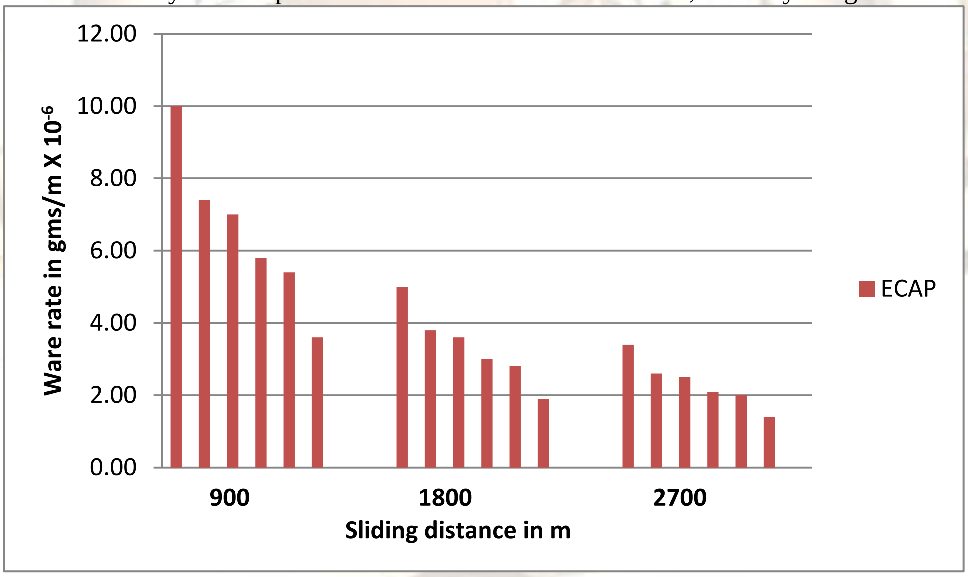

Fig.6 Wear rate for sliding distance of 900, 1800 & 2700 m at a constant load of 15N for various composition of TiB_2 in Al alloy

4. CONCLUSION

The experimentation carried out in the present study and the results obtained the following conclusions may be considered as listed below:

1. In the present study, an effective T_6 heat treatment process along with aging at 175º C for 12hrs to enhance the strength of cast specimens.
2. ECAP processing has been carried out at room temperature for T_6 heat treated specimens to enhance the mechanical properties such as tensile, hardness and wear.
3. The UTS is increased from 148.9 N/ Sq.mm to 205.9 N/ Sq.mm which is 27.68 times enhanced from the base alloy.
4. Significant increase in hardness obtained after ECAP, hardness increased 29% compare to base alloy.

5. The volumetric wear increases exponentially with sliding distance.
6. The wear ratedecreases with the increase in TiB_2 percentage and increase in sliding distance.

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