Effect of Equal Channel Angular Pressing (ECAP) on Mechanical Properties of Al-5052 Alloy

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Abstract- *Equal channel angular pressing of aluminium alloy leads to enhance the strength and grain refinement. ECAP has been effectively used in the Microstructural refinement of almost all thee structural materials. In the present work, an aluminium was processed by ECAP via route BC using a die formed by two channels connected at an angle Φ=90◦. The grains were significantly refined after 2 passes for ECAP processed billets. Before the ECAP Process, Al 5052 alloy was subjected to the annealing treatment to relieve the thermal stresses was introduced during the machining. The ECAP specimens were analysed using tensile property and microhardness measurements. The experimental results revealed the increase in yield and tensile strength and microhardness values as compared to the base material.*

Keywords- Aluminium alloy 5052, ECAP, Tensile properties, Microhardness.

I. INTRODUCTION

Severe plastic deformation processes have been receiving increasing attention as methods to develop fine grained microstructures. The most attractive is equal channel angular pressing (ECAP) or extrusion (ECAE) [1-2]. Equal Channel Angular Pressing is one of the most developed methods to prepare bulk ultrafine-grain (UFG) materials. A bar shaped specimen is machined to fit into a channel contained within a die and is pressed through the die using a plunger. Shear deformation is introduced into the specimen because of the shape of the channel which is generally bent at an angle equal or very close to 90°. As the cross-section of the specimen after pressing is unchanged, it can undergo repeated pressing to obtain a high degree of strain. During the ECAP process, the different slip system is activated by rotating the billet around its longitudinal axis between each pass. This leads to four basic processing routes. There is no rotation of the billet in route A, rotations by 90° in alternate directions or the same direction in routes BA and BC, respectively, and rotations by 180° in route C. When using a die with a channel angle of Φ = 90°, the route BC is generally the most expeditious way to develop the UFG structure consisting of homogeneous and equiaxed grains with high angle grain boundaries.

Aluminium alloys are extensively used in industrial, structural and transport applications due to their high strength, low density and excellent corrosion resistance. Major alloying element of 5052 is magnesium. Magnesium is considerably more effective than manganese as a hardener, about 0.8% magnesium being equal to 1.25% manganese, and it can be added in considerably higher quantities. Al-5052 alloy gives good welding characteristics and good resistance to corrosion in marine atmosphere.

The objective of the current investigation is to study the mechanical properties of Al-5052 alloys processed by equal channel angular pressing, for this purpose to enhance the tensile strength and hardness values. The experimental results revealed the increase in yield and ultimate tensile strength and hardness as compared to the base material. In this study, we attempt to decrease the grain size and increasing in ultimate tensile strength and microhardness values were observed under route BC.

II. EXPERIMENTAL PROCEDURE

The experiments were conducted using Al-5052 alloy as the main ECAP material. The chemical composition of Al5052 alloy is shown in table 1. Prior to ECAP, the as-received extruded rods were annealed at 420°C for an hour and then cooled in the furnace. The rectangular die and plunger is made up of same material as hardened steel H13. The Al-5052 rods were cut into rectangular samples with cross section of 15×15 mm and height of 60 mm and then pressed through an ECAP die having a channel angle of Φ=90° and an outer curvature angle of Ψ=20°. All the billets were pressed up to 2 passes at room temperature, using the processing route of BC [1-2].

Table.1 Chemical composition of Al 5052 alloy

Mg	Cr	Cu	Fe	Mn	Si	Zn	others	Al
2.80	0.35	0.10	0.40	0.10	0.25	0.10	0.20	Balance

2.1 Tensile Testing

The tensile property of base sample and ECAP sample was analysed by using Tinius Olsen machine setup. Tensile deformation tests provided time vs applied force characteristics. Tensile specimens from the ECAP processed material were machined from the centre of the processed billets, in the longitudinal direction, with a gauge length of 20 mm. The samples were taken from a zone which is believed to carry an approximate homogeneous deformation. For further details concerning the homogeneous zone, the tensile test was conducted at room temperature with a strain rate of 1×10-3 s-1.

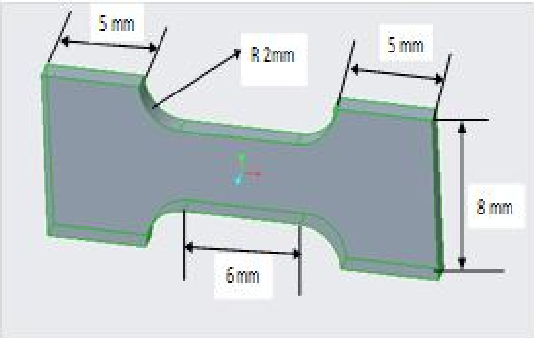

Fig 2.1 Schematic diagram of tensile sample

2.2 Microhardness Testing

Vickers microhardness was measure on the plane perpendicular to the extrusion direction of the ECAP processed billets. The specimens were prepared by using abrasive papers and then applied for diamond paste for about 15s. Hardness values were measurements were taken with loads of 300g applied for 10 s. It was performed after two passes for all the coordinates planes namely XY, YZ and XZ. The specimens for tensile test were machined from the received and the extruded billets with gauge length of 10 mm and cross section of 5×5 mm2. Each hardness value was the average of five measurements.

III. RESULTS AND DISCUSSION

3.1 Tensile deformation test

Tensile stress-strain curve obtained for the base sample and ECAP processed sample of Al-5052 alloy are shown in figure 4. Tensile test was carried out on the base sample and ECAP sample which was machined in to a dog-bone shape. The initial strain rate is 1×10-3 s-1. The results from the tensile tests are depends on the yield strength at increasing number of the ECAP passes. The ultimate tensile stress increases as the number of passes increases in the material with the increase in hardness. The maximum of increase in strength is high and minimum increase is observed in the number of passes. In generally, the strength increases, the ductility decreases during ECAP. However, in this work as the strength increases the percentage of elongation also increases after the two passes. The improvement in ultimate tensile strength was due to the significant work hardening and multiple grain dislocation during ECAP. The tensile strength result suggests that the precipitates and deformation path in ECAP has greater influence on work hardening behaviour of Al 5052 alloy. In present work, the ultimate tensile strength has increased from the range of 226 MPa to 386 MPa for 48% increases after 2 passes under route BC.

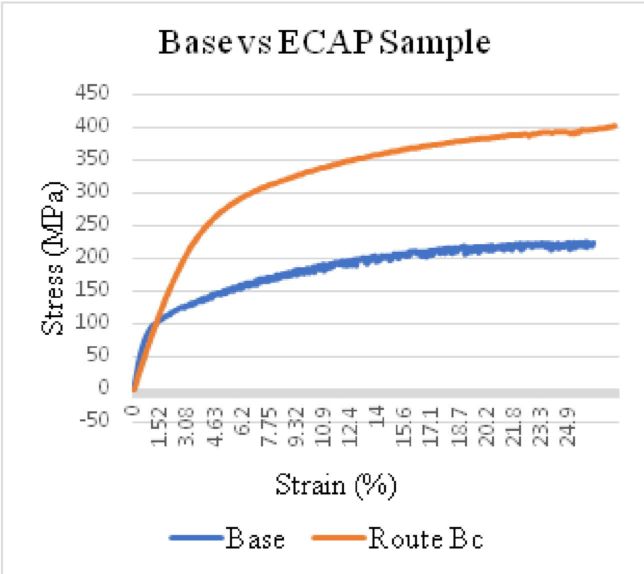

Fig 3.1 Tensile graph between Base and Route BC sample

3.2 Vickers Microhardness test

The microhardness test shows that the improvement in hardness values when it compares the both specimen of before ECAP and after ECAP. It can be observed that the hardness of specimen before ECAP is slightly higher than that of the specimen after ECAP. The range of hardness values obtained for five measurements for each specimen. The variation of the microhardness in both base samples and ECAP samples are shown in fig. The microhardness values increased from 72 HV to 120 HV were observed in 2 passes under route BC. In present study, the hardness values were increased up to 43 % obtained after 2 passes in route BC.

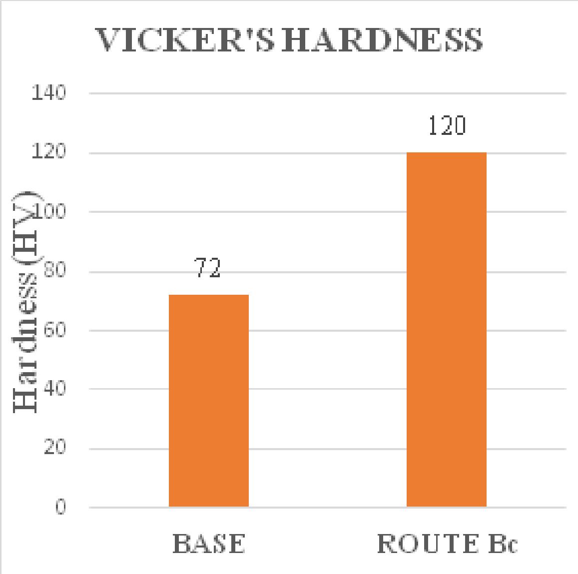

Fig 3.2 Comparison graph between Base and Route BC

IV. CONCLUSION

The present work was focused on the characterization of the mechanical properties development through ECAP process. Due to more uniform strain during the processing, integrity of the parts was obtained even after a number of passes. It takes up to multiple passes to produce an ultrafine grain structured samples. Significant improvement for all the ECAP'ed samples. The ECAP processed samples have higher hardness and tensile strength than the base samples to the same strain rate. The hardness values are increases from 72 HV to 120 HV after 2 passes in route BC. The Ultimate tensile strength is increased from 226 to 386 MPa after 2 passes in route BC.

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