

Microstructure and Mechanical Properties of Cp Al Chips Consolidated Through Hot Equal Channel Angular Pressing

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ABSTRACT: The strength and ductility strongly depend on microstructure. This project focuses on the Microstructure And Mechanical Properties of CP Al Chips Consolidated Through Hot Equal Channel Angular Pressing (HOT ECAP). The starting materials are CP Al and 2014 Al alloys. Equal channel angular pressing is carried out using 90° die through the processing route B_c. The chips were obtained by changing the following parameters 1) speed, 2) depth of cut, and 3) angle of cut. The collected chips were crushed using a ball mill, and then the powder were consolidated in the Hot ECAP die. The microstructure evolution and mechanical properties were studied for the above conditions.

KEYWORDS: ECAP; Bimodal microstructure; Processing routes

I. INTRODUCTION

In Aluminium alloys, aluminium (Al) is the predominant metal. The typical alloying elements are copper, magnesium, manganese, and zinc. There are two principal classifications, namely casting alloys and wrought alloys, both of which are further subdivided into the categories heat-treatable and non-heat-treatable. About 85% of aluminium is used for wrought products, for example rolled plate, foils and extrusions. Aluminium alloys are widely used in engineering structures and components where light weight or corrosion resistance is required. Alloys composed mostly of the two lightweight metals aluminium and magnesium have been very important in aerospace manufacturing. Aluminium-magnesium alloys are both lighter than other aluminium alloys and much less flammable than alloys that contain a very high percentage of magnesium. Selecting the right alloy for a given application entails considerations of its tensile strength, density, ductility, formability, workability, weld ability, and corrosion resistance. Aluminium alloys are used extensively in aircraft due to their high strength-to-weight ratio. On the other hand, pure aluminium metal is much too soft for such uses, and it does not have the high tensile strength that is needed for airplanes and helicopters. The International Alloy Designation System is the most widely accepted naming scheme for wrought alloy. Each alloy is given a four digit number, where the first digit indicates the major alloying elements. Wrought aluminium is identified with a four digit number which identifies the alloying elements. For this study 2000 series aluminium alloy is used for experimentation. 2000 series are alloyed with copper, can be precipitation hardened to strengths comparable to steel. Formerly referred to as duralumin, they were once the most common aerospace alloys, but were susceptible to stress corrosion cracking and are increasingly replaced by 7000 series in new designs. 5000 series are alloyed with magnesium.

These aluminium alloys (2011, 2014, 2017, 2018, 2124, 2219, 2319, etc.) require solution heat treatment to obtain optimum properties; in the solution heat-treated condition, mechanical properties are similar to, and sometimes exceed, those of low-carbon steel. In some instances, precipitation heat treatment (aging) is employed to further

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increase mechanical properties. This treatment increases yield strength, with attendant loss in elongation; its effect on tensile strength is not as great. The aluminium alloys in the 2000 series do not have as good corrosion resistance as most other aluminium alloys, and under certain conditions they may be subject to intergranular corrosion. Aluminium grades in the 2000 series are good for parts requiring good strength at temperatures up to 150°C (300°F). Except for the grade 2219, these aluminium alloys have limited weld ability, but some alloys in this series have superior machinability. Aluminium grade 2024 is the most popular alloy and is commonly used in aircraft construction.

II. SPD OF AL ALLOYS

Equal channel angular pressing (ECAP) process provides an efficient procedure for achieving ultrafine grained microstructures with excellent mechanical properties in metallic materials. In this article, a simulation scheme for predicting the mechanical behaviour during and after ECAP was proposed. The proposed scheme was applied for interstitial-free (IF) steels, which are widely used for the automobile body applications. Plastic deformation behaviour during several passes of ECAP in route Bc, including such aspect as deformed geometry, corner gap, forming load and strain uniformity, was predicted. Tensile testing responses of the ECAP-processed IF steel, including strain hardening, onset of necking, and post-necking behaviour, were analyzed using the finite element method and compared with the experimental results. The predicted tensile curves, ultimate tensile strength, and elongation varying with the number of ECAP passes were in good agreement with experimental results. The computational scheme developed was demonstrated to successfully predict not only the plastic deformation behaviour during ECAP but also the mechanical properties of the ECAP-processed material[3].

III. BIMODAL DISTRIBUTION IN AL ALLOYS

Mechanical properties as yield strength and strain-hardening coefficient of micrometer-grained and UFG regions in bimodal Cu-Al alloys were determined by the nanoindentation method. Results indicate the positive relationship between the uniform elongation and the strain-hardening coefficient of micrometer-grained region, that helps us to further understand the mechanics of toughening through bimodal mechanism and also make it possible to predict model its overall material response as a composite[4].

The mechanical response of metals with a bimodal grain-size distribution is modelled using the secant Mori-Tanaka (M-T) mean-field approach. The actual microstructure of bimodal metals involves a grain size distribution in the ultrafine and coarse regimes; the model approximates this in terms of two phases with distinct grain sizes and with specific volume fractions. The model is applied to two bimodal materials: the Al-5083 alloys of Lavernia et al. and the Cu of Wang et al. In both the materials, the predictions agree well with the experiments. In the bimodal Al alloy, the effect of extrusion on the anisotropy in yield strength and flow behaviour is also addressed. Finally, based on the model predictions, an empirical expression of the Voce form is proposed to describe the overall flow behaviour of both bimodal metals[5].

IV. NANO MICROSTRUCTURE IN AL ALLOYS

Micro structural evolution taking place during equal channel angular pressing (ECAP) was studied in an as-cast 0.16%Zr modified 7475 aluminium alloy at a temperature of 673 K. The structural changes are characterized by development of deformation bands due to large strain in homogeneity occurring through the ECAP die. Repeated deformation leads to an increasing of number and misorientation angle of the boundaries of deformation bands, finally followed by formation of new fine grains at high strains. The misorientation angle distribution for newly developed boundaries shows a single peak type at relatively low misorientations in low strain and changes to a bimodal distribution with two peaks at low and high misorientations in moderate strain. Pressing to a strain of 12 leads to a full development of new grains surrounded by medium to high angle boundaries with an average size of about 1.7 nm. It is concluded that grain refinement occurs by a deformation-induced continuous reaction, that is essentially similar to continuous dynamic recrystallization [6].

The microstructures of pure aluminium produced by equal channel angular extrusion (ECAE) with routes Bc and C were characterized quantitatively by the use of transmission electron microscopy. A comparison with the results

of cyclic-extrusion-compression reported in the literature is also presented, which indicates that ECAE is more effective in generating high angle boundaries[7].

To effectively demonstrate the dependence of ductility improvement on the scheme of introducing bimodal structure into nanostructure materials, a three-step processing was adopted in hypo-eutectoid Cu–Al alloys to obtain controllable bimodal structure of micrometer-grained pre-eutectoid phase embedded on ultrafine-grained (UFG) matrix with eutectoid composition: (1) pre-deformation heat-treatment was proposed to achieve controlled distribution of pre-eutectoid phase in the matrix with eutectoid composition, (2) both pre-eutectoid phase and eutectoid matrix were refined to sub micrometer level by usage of high-pressure torsion (HPT), (3) annealed HPT-processed samples at selected temperature. All samples subjected to this novel processing route imparted a high strength, meanwhile obvious uniform plastic elongation in tensile deformation was also observed at those with bimodal structure[9].

Cutting tool geometry varies with the type of work to be done. Facing tools are ground to provide clearance with a center. Roughing tools have a small side relief angle to leave more material to support the cutting edge during deep cuts. Finishing tools have a more rounded nose to provide a finer finish. Round nose tools are for lighter turning. They have no back or side rake to permit cutting in either direction. Left hand cutting tools are designed to cut best when traveling from left to right. Aluminium is cut best by specially shaped cutting tools that are used with the cutting edge slightly above centre to reduce chatter[11].

V. EXPERIMENTAL PROCEDURE

The chip removed from pure aluminium by turning operation considering the various parameters. Keeping the tool post angle say 75° with constant speed and varying the doc as 0.4 mm. The chips are removed by oblique cutting using a left hand turning tool of rake angle 10° .

There are four basic processing routes in HOT ECAP and these routes introduce different slip systems during the pressing operation so that they lead to significant differences in the microstructures produced by HOT ECAP. The schematic diagram for route Bc is show in Fig 16. In route A the sample is pressed without rotation, in route B_A the sample is rotated by 90° in alternate directions between consecutive passes, in route B_C the sample is rotated by 90° in the same sense (either clockwise or counter clockwise) between each pass and in route C the sample is rotated by 180° between passes. Various combinations of these routes are also possible, such as combining routes B_C and C by alternating rotations through 90° and 180° after every pass, but in practice the experimental evidence obtained to date suggests that these more complex combinations lead to no additional improvement in the mechanical properties of the as-pressed materials. Here we follow the route B_C process. Shown in fig1

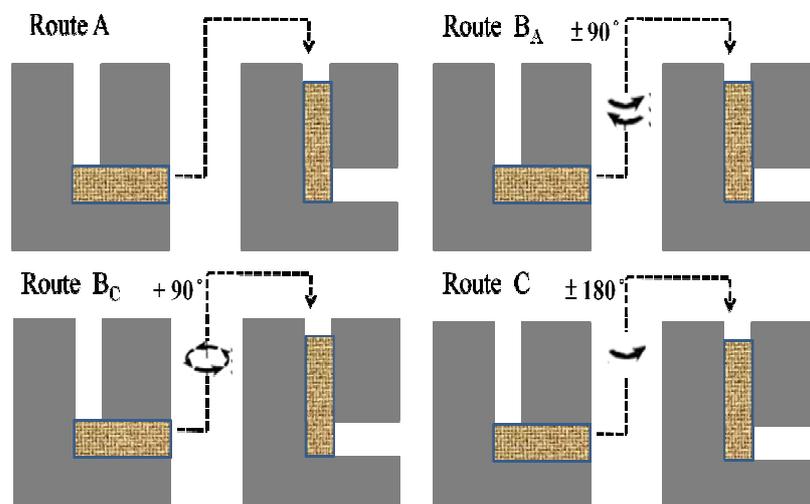


Fig -1: ECAP Process

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The various processing conditions considered for chip removal process are 1. Speed of lathe should be kept minimum for turning operation by changing the belt drive in stepped cone pulley. 2. The depth of cut for various aluminium alloys are kept as 0.1 mm, 0.2 mm and then the chips are collected. 3. the angle of tool post is kept in three different angles say 30°, 60°, 90° and then three depth of cuts were given at each angle of position. The crushed chip from ball mill is consolidated using 90° ECAP die using various processing routes. We consider the processing route as B_c for consolidation. The machining and chip collection work has been completed. It is common that the tool life depends upon the cutting speed during machining. Based on the requirement there exists a variation in cutting speed, also taking into account other machining parameters. Though a very low cutting speed was maintained, we were able to obtain a reasonable tool life.



Fig -2: chips for pure aluminium.

VI. RESULTS

Microstructure is defined as the structure of a prepared surface or thin foil of material as revealed by a microscope above 25× magnification.

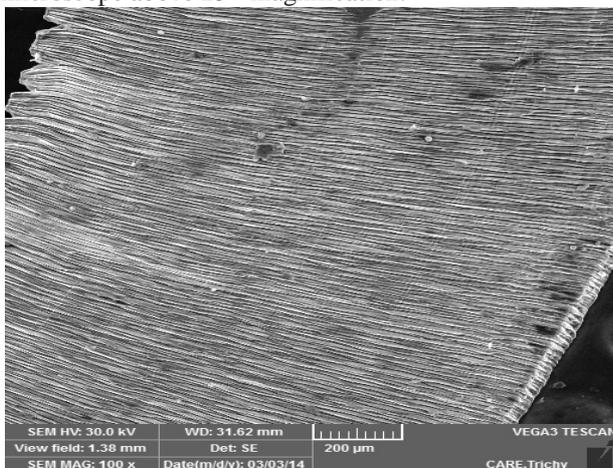


Fig -3(a): SEM test for chip

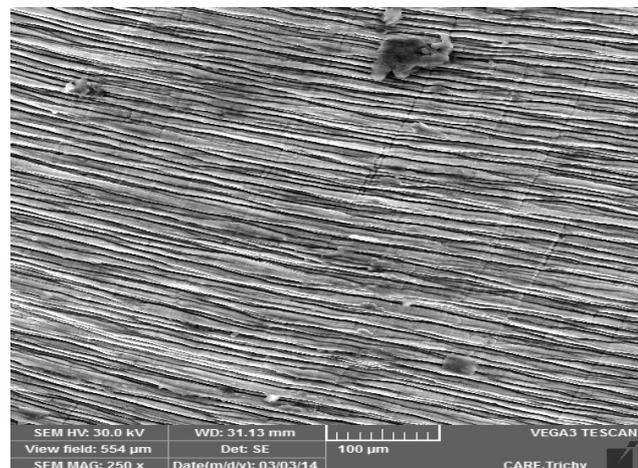


Fig -3(b): SEM test for chip

Bimodal Al alloys are made of cryomilled nanocrystalline Al powders blended with a specified volume fraction of unmilled Al chip. The mixture is consolidated at ambient temperature (via cold isostatic pressing) and extruded (in bar form) at a high temperature. The final microstructure shows a grain size (d) distribution with a

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significant fraction (nearly 60 to 70 pct) at approximately 200 nm, designated the ultrafine-grained phase (UFG). Furthermore, depending on the amount of unmilled Al added during blending, the remaining grain-size distribution ranges between 500 and 1000 nm, designated the coarse-grained (CG) Al phase. Figure 5 shows a typical microstructure of bimodal Al with 30 pct CG phase in the longitudinal direction: both UFG (dark regions) and the CG (light regions) phases are elongated along the extrusion direction. Compression results of the bimodal Al alloys with 0, 15, 30, and 50 pct volume fractions of CG-Al are available[13] in both the longitudinal and transverse directions at a strain rate of 10⁻³ s⁻¹. Although the real microstructure has a distribution in the grain size, the model presented in this article approximates this as explicitly bimodal, with two distinct grain sizes (dufg-Al 5 200 nm and dcg-Al 5 1 mm). Their corresponding stress-strain behaviours are used to compute the overall mechanical response.

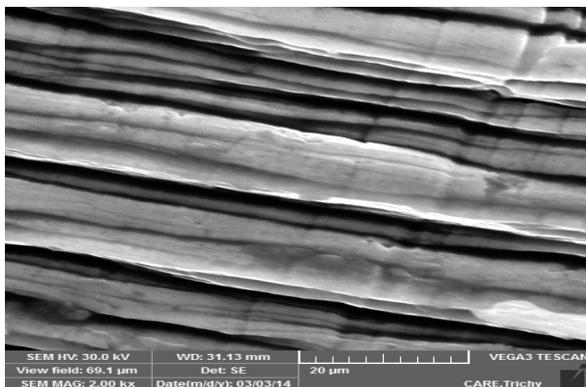


Fig -3(c): SEM test for chip

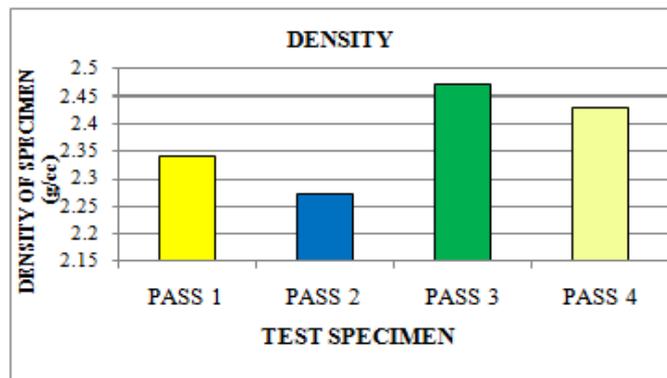


Fig-4: Density Result Chart

The effect of ECAP passes and density is shown in fig The density of extruded compacts varied from 2.27(g/cc) to 2.47(g/cc) after ECAP up to 4 passes. The compacts with low density showed poor consolidation of chips. As the number of passes increases the density is increasing due pore closure during ECAP. Maximum density can produced pass 3 & pass 4.

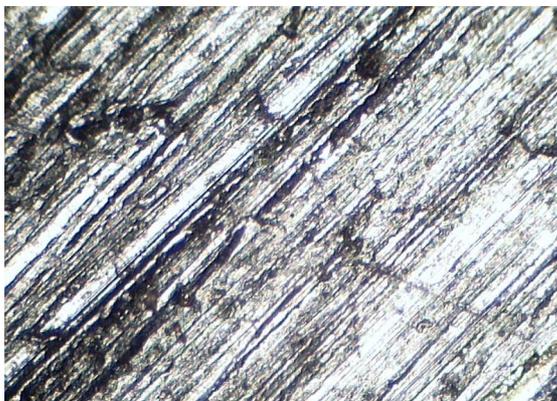


Fig-5: Microstructure of sample (Pass 1)

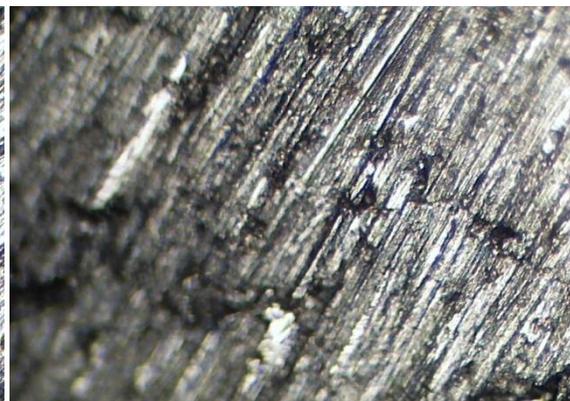


Fig-6: Microstructure of sample (Pass 2)

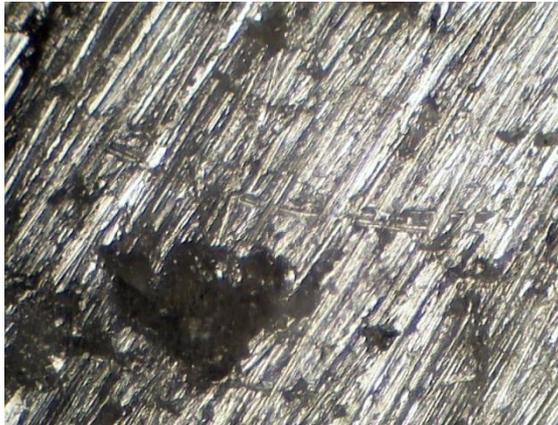


Fig-7: Microstructure of sample (Pass 3)

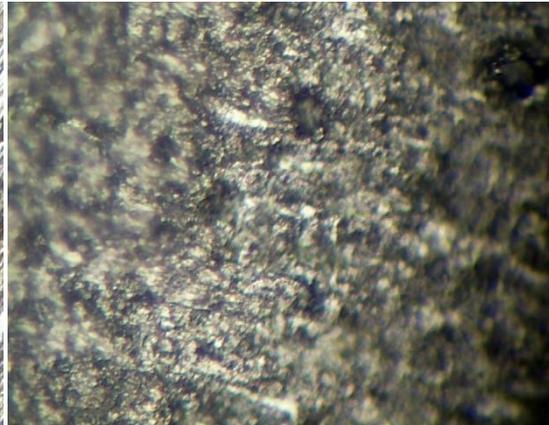


Fig-8: Microstructure of sample (Pass 4)

The optical microstructure of consolidated samples is shown in fig. The idea behind the consolidation of machined chips is to achieve a bulk nanostructured CP Al through ECAP. The densification of CP Al chips can be improved by high temperature of ECAP. The densification of CP Al chips can be improved by high temperature of ECAP. At warm temperatures diffusion of defects between the interfaces of chips will improve the bonding between the chips. The annealing behaviour study on Al 6061-T6 chips observed minimal coarsening of nanocrystalline microstructure [21]. To achieve bulk nanostructured CP Al, warm temperature densification of machined CP Al chips through ECAP is in advancement.

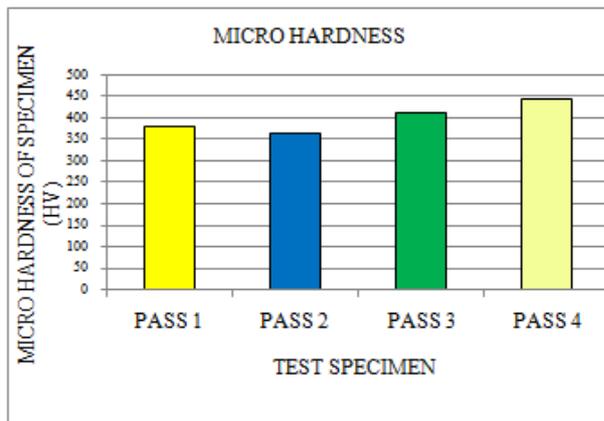


Fig-9: Micro Hardness Result Chart

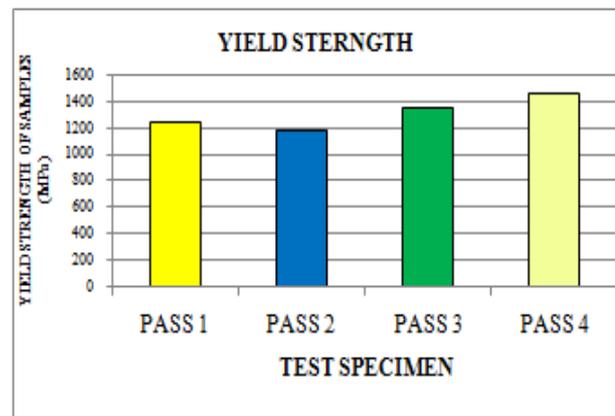


Fig-10: Yield strength Result Chart

The effect of ECAP passes and Micro hardness is shown in fig. The Micro hardness of extruded compacts varied from 363(HV) to 446(HV) after ECAP up to 4 passes. Maximum Micro hardness can produced pass 3 & pass 4. The maximum yield strength obtained is pass 3 (4040 MPa) & Pass 4 (4374 MPa) for chips prepared by angle of cut 75° and depth of cut 0.4 mm/rev.

Fig.2. is the chips collected for 75° angle of cut and 0.4 mm/rev depth of cut. Fig.3.(a-c). shows an SEM image of chip from machining operation. The surface of the chips is seen to be composed of flow lines indicating the direction of shear strain during machining. The edge of the chips consists of discontinues cracks for all the angle of cut. Nanostructured Al grains nearer the edge of the chips can be resolved by using TEM. However preparing TEM samples in the edge of chips is complicated and difficult. These Nanostructured grains in edges of the chips can be easily resolved after consolidating fully through ECAP. The compacts after consolidating through ECAP up to four passes are shown in fig. The density of compacts after the removal of the can is measured by Archimedes principle.

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The effect of ECAP passes and density is shown in fig. The density of extruded compacts varied from 2.27(g/cc) to 2.47(g/cc) after ECAP up to 4 passes. The compacts with low density showed poor consolidation of chips. As the number of passes increases the density is increasing due pore closure during ECAP. Maximum density can produced pass 3 & pass 4.

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VII. CONCLUSION

Processing of chips through the application of SPD is an attractive method for the production of bulk nanostructured materials. In this study, Microstructure and Mechanical Properties of CP Al Chips Consolidated Through Hot Equal Channel Angular Pressing is achieved near to full density.

1. It is found that angle of cut has significant effect on Mechanical Properties of CP Al chips. The maximum density obtained is pass 3 (2.47g/cc) & pass 4 (2.43g/cc) for chips prepared by angle of cut 75° and depth of cut 0.4 mm/rev.

2. The maximum hardness obtained is pass 3 (412 HV) & Pass 4 (446 HV) for chips prepared by angle of cut 75° and depth of cut 0.4 mm/rev.

3. The maximum yield strength obtained is pass 3 (4040 MPa) & Pass 4 (4374 MPa) for chips prepared by angle of cut 75° and depth of cut 0.4 mm/rev.

4. However for development of nanostructured materials complete densification is necessary, hence achieving complete densification is in progress.

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