

Equal Channel Angular Rolling of Aluminium Alloy 5083 with Copper Shielding

J. Jyothish Kumar¹, K. Hemantha Kumar², K. Yuganandhana³, V. Rupesh⁴, Dr. V. Ananda Babu⁵

UG Student, Department of Mech, Nadimpalli Satyanarayana Raju Institute of Technology, Sontyam,
Andhra Pradesh, India^{1, 2, 3, 4}

Professor, Department of Mech, Nadimpalli Satyanarayana Raju Institute of Technology, Sontyam,
Andhra Pradesh, India⁵

ABSTRACT: Severe Plastic Deformation (SPD) techniques, particularly Equal Channel Angular Rolling (ECAR), are effective in improving the properties of metallic materials through grain refinement. In this study, AA5083 aluminium alloy sheets were processed using ECAR with and without copper shielding to evaluate changes in microstructure, mechanical properties, and corrosion resistance. The specimens (50 × 30 × 3 mm) were annealed for one hour to enhance ductility before being subjected to ECAR up to four passes using die angles of 90° and 105°.

Microstructural analysis revealed significant grain refinement from 30 μm to about 2–3 μm, with better results observed in samples processed with copper shielding. Mechanical testing showed notable improvements in tensile strength, increasing from 300 MPa to a maximum of 426 MPa, and hardness rising from 72 HV to 175 HV, especially for samples processed at 90° with copper shielding.

Corrosion studies indicated improved resistance, with corrosion rates decreasing from 0.045 mm/yr to as low as 0.02 mm/yr. Overall, ECAR processing significantly enhances the performance of AA5083 alloy, and the use of copper shielding further improves uniform deformation, leading to superior mechanical and corrosion properties.

KEYWORDS: SPD, ECAR, AA5083, Shear Deformation, Grain Refinement, Mechanical Properties, Corrosion Resistance.

I. INTRODUCTION

In recent years, there has been a lot of research about using severe plastic deformation (SPD) of metallic materials to create fine grains in polycrystalline materials up to sub-micrometer or even nano-scale order for application in the production of nano-structured sheet metals and alloys. One of the most popular SPD methods for producing UFG microstructures on billet or rod samples without altering the fundamental geometry is equal channel angular pressing (ECAP). However, the ECAP is an irregular technique that cannot be used with plate or sheet samples, and the influence of the dead metal zone (DMZ) is more pronounced on material during processing [1]

Due to its potential for the manufacture of nanostructured and ultrafine grained (UFG) materials[2], plastic deformation (SPD) has recently drawn the attention of researchers. [3]Severe plastic deformation (SPD) methods are new appropriate techniques to refine materials and improve mechanical properties, ECAR process is one of the SPD techniques. The process conducts through multiple passes, one of them could achieve the desired mechanical properties and UFG of the material. In 2019 the researcher was studied and analyzed the Equal channel angular rolling process affected on fracture mechanics for several Aluminum alloys[4] The ECAR technique uses a die attached to rollers with a specific channel intersection angle [5]. The processing of metal through ECAR die channels with intersection angle experienced severe plastic deform simultaneously at different locations and strain levels [6] The ECAR process significantly improves mechanical properties like tensile strength (TS), hardness, and yield strength (YS) at the expense of ductility [7]. According to the previous works, number of pass, channel angle, and route of pass are the effective parameters in the ECAR process [8,9], it was Studied the Correlation Between Mechanical Properties and Structural Parameters of Processed with ECAR to evaluate and investigate the ECAR process effect in 2017 by other researcher [10], in 2016 other researcher was studied the effects of the ECAR formability, mechanical properties [11,12]

The need for lightweight aluminium (Al) alloys (AAs) with high strength and hardness is very high in various engineering applications, including aerospace, defence, and automobiles.[13,14].The ECAR process is preferred due to its capability to attain great mechanical properties in the production of thin metal sheets. In the last decades, the ECAR process has yielded noticeable results when applied to pure Cu[15]. Al-alloys such as Al 5083 [16], Al 1100 [17], Al 7050 [18], and Mg-alloys such as AZ31[19]. It has been concluded that the ECAR process results in a dramatic grain refinement for all metallic materials. For instance, Cheng et al demonstrated that the initial grain size of AZ31 alloy was~ 20 μm . It was reduced to approximately 30 nm after 10 passes of the ECAR process. The grain refinement causes a significant increase in the strength and hardness of the material [20]. Honarpisheh et al have investigated the effect of the ECAR process on fracture mechanics in Al-7075 alloy ECARed through two routes of A and C. Moreover, it was detected that ECARed Al-7075 samples in route A have been fractured more compared to that in route C[21], and Rahimiet al analyzed FLD of fine-grained Al 5083 produced by equal channel angular rolling process[22].

II. EXPERIMENTAL PROCEDURE

Severe Plastic Deformation (SPD) is an advanced materials processing technique used to produce ultra-fine grained (UFG) and nanostructured materials by imposing very large plastic strains without significantly changing the overall dimensions of the work-piece.

Equal Channel Angular Rolling Process

Equal Channel Angular Rolling (ECAR) is a modification of the Equal Channel Angular Pressing (ECAP) technique. In ECAR, as shown in Fig. 1 the sheet metal is passed through two intersecting channels of equal cross-section using rolling instead of pressing. This allows continuous processing and is suitable for large-scale industrial applications.

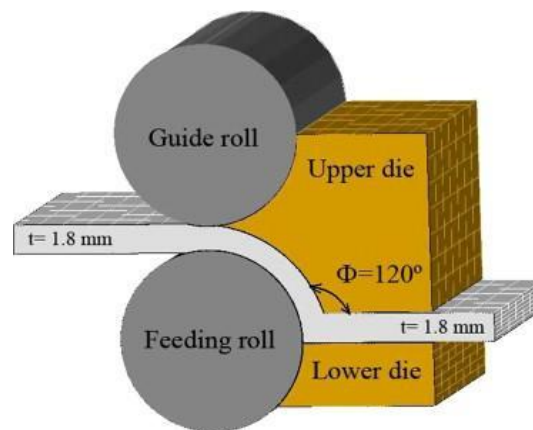


Fig.1: ECAR SETUP

Number of Passes in ECAR

In Equal Channel Angular Rolling (ECAR), the number of passes refers to how many times the material is processed through the ECAR die or rolling setup. Each pass introduces a certain amount of shear strain into the material.

Die Angle in ECAR

The channels intersect at a specific angle (usually 90° or 120°), which introduces severe shear deformation into the material while maintaining constant cross-sectional dimensions. Since the cross-section does not change, The material can be processed multiple times to accumulate very high strain levels.

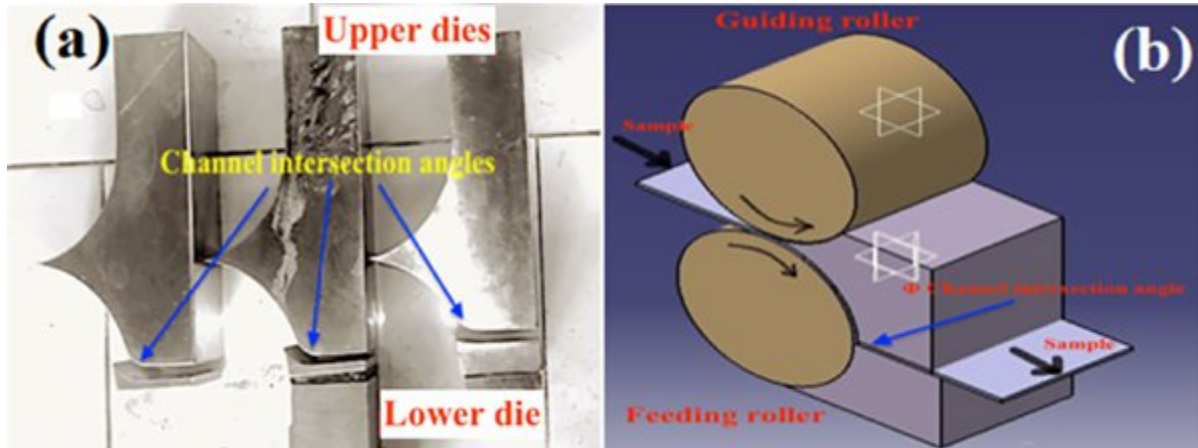


Fig.2: (a) Different Die angles (90°,105°,120°) (b) ECAR setup in CATIA

Materials

The materials used in the ECAR process are primarily applicable to ductile metallic materials capable of sustaining large plastic strains without fracture. The commonly investigated material systems are aluminium alloy and copper are mainly used in this study due to their wide industrial applications.

Aluminium Alloy 5083

Aluminium alloy 5083 belongs to the 5xxx series (Al–Mg alloys). These alloys are strengthened mainly by magnesium, which gives them high strength and excellent corrosion resistance without the need for heat treatment.

Table.1 : Chemical composition of aluminium alloy 5083

Element	Percentage (%)
Magnesium (Mg)	4.0 – 4.9
Manganese (Mn)	0.4 – 1.0
Chromium (Cr)	0.05 – 0.25
Iron (Fe)	≤ 0.4
Silicon (Si)	≤ 0.4
Aluminium (Al)	Balance

Copper

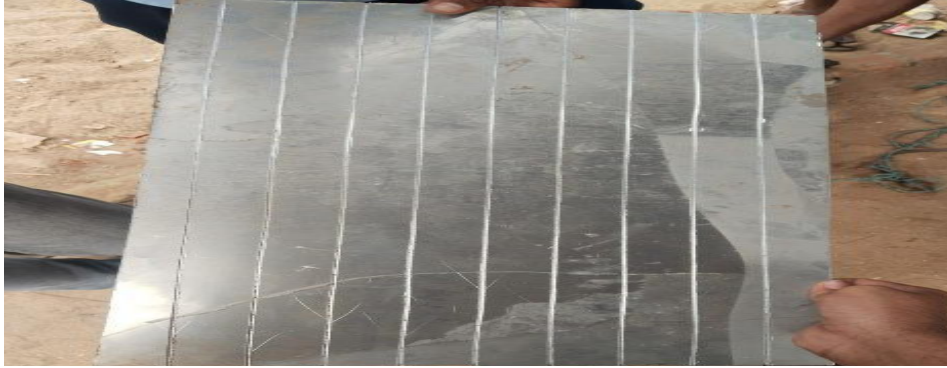
Copper is one of the most important and widely used engineering metals due to its excellent electrical, thermal, and mechanical properties. It is a reddish-brown metal known for its high electrical conductivity, corrosion resistance, ductility, and ease of fabrication. Because of these unique characteristics, copper plays a vital role in electrical, electronic, and industrial applications.

2.1 Methods

Experimentation Steps

Step 1: Specimen Preparation

The AA5083 aluminium sheets are cut into required dimensions of 500 mm × 30 mm × 3 mm using a suitable cutting machine. Care is taken to maintain dimensional accuracy and smooth edges.

**Fig.3: Sheet preparation as per required dimensions****Step 2: Surface Cleaning**

The specimens are thoroughly cleaned to remove dust, oil, and surface contaminants. This ensures proper contact during deformation and avoids defects during processing.

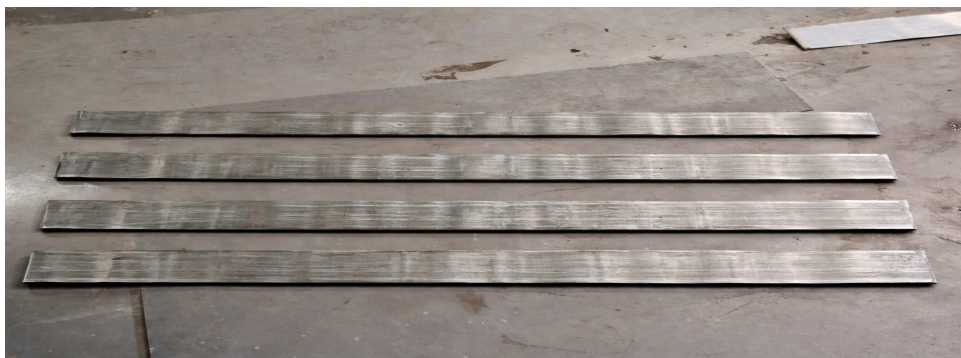
Step 3: Copper Shielding Arrangement

A copper sheet of **1 mm thickness** is placed over the aluminium specimen for selected samples.

The experiment is conducted in two conditions:

- Without copper shielding
- With copper shielding

This comparison helps in evaluating the influence of copper on the deformation process and final properties.

**Fig.4:AA5083 samples without copper shielding before ECAR****Fig.5: AA5083 samples with copper shielding before ECAR**

Step 4: Annealing Process

Before ECAR processing, the specimens are subjected to annealing to relieve internal stresses and improve ductility

Temperature: **450°C**

Holding time: **1 hour**

Cooling: **Furnace cooling for 30 minutes**

Annealing softens the material, allowing it to undergo large plastic deformation during ECAR without cracking.

Step 5: ECAR Die Angles

Two ECAR dies are used in the experiment with different channel angles:

90° die angle

105° die angle

These angles are selected to study the effect of strain variation on microstructure and mechanical properties.



Fig.6: ECAR dies with 90° & 105° angles

Step 6: Route Selection (Route A)

The ECAR process is carried out using **Route A**, in which the specimen is passed through the die repeatedly without any rotation between successive passes. This route maintains the same orientation and allows accumulation of strain in a uniform direction.

Step 7: ECAR Processing (Rolling Operation)

The prepared specimens are passed through the ECAR die using a rolling setup. Proper alignment is ensured before each pass to avoid defects such as bending or uneven deformation.

Step 8: Number of Passes

4 passes through the 90° & 105° die angles . Multiple passes are essential to achieve significant grain refinement and to develop ultrafine grain (UFG) structure.

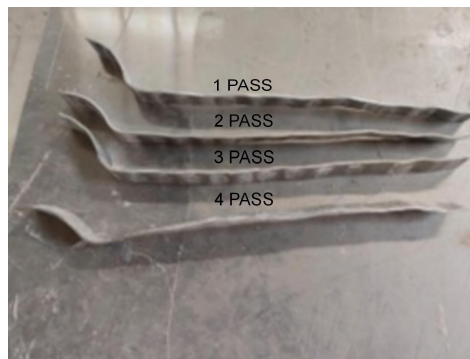


Fig.7: AA5083 Without Copper Shielding processed through 105° die angle



Fig.8: AA5083 Without Copper Shielding processed through 90° die angle

Step 9: Rolling Load Requirement

The entire process is repeated for both sets of samples:

With copper shielding

Without copper shielding

It is observed that the rolling force required for processing AA5083 samples with copper shielding is less as compared to without copper shielding.

Step 10: Sample Preparation For Testing

After completion of ECAR processing, the specimens are prepared for required dimensions and labeled properly for further analysis such as microstructure, hardness, tensile, and corrosion studies.

Microstructural Analysis

In the present study, an Aluminium–Copper composite (Al core with Cu shielding) processed by ECAR is subjected to Microstructural Analysis to determine the improvement in grain refinement after deformation. The samples were cut perpendicular to the direction of rolling, and testing was performed. The average of four readings is considered in the present investigation.

Sample Preparation

• Sample Cutting

The processed sheets are cut into smaller specimens of dimensions 30 mm × 30 mm × 3 mm for microstructural examination.



Fig.9: Samples for Microstructural Analysis after different passes

Microscopic Observation

The prepared samples are examined under an **optical microscope** to study the grain structure, grain size, and distribution.



Fig.10: Optical Microscopy Fig.11: Samples are examined through optical microscope

Vickers Hardness Testing

In the present study, the Aluminium–Copper composite (Al core with Cu shielding) processed by ECAR is subjected to Vickers hardness testing to obtain a detailed understanding of microhardness variation across different regions of the material. This method is particularly suitable for evaluating localized hardness in heterogeneous materials such as composites. Testing was carried out on samples cut perpendicular to the rolling direction. The average of four readings was considered for analysis.

Sample Preparation

Testing Procedure

Selection of Load

An appropriate load (commonly ranging from **100 g to 1 kg**) was selected depending on the region being tested. Lower loads are generally preferred for microstructural analysis and phase-specific hardness evaluation.

Indentation Process

The specimen was placed on the stage of the Vickers hardness tester, and a diamond pyramid indenter with a square base and an angle of **136° between opposite faces** was pressed into the surface under the selected load.

Dwell Time

The load was applied for a standard dwell time (typically **10–15 seconds**) to ensure proper plastic deformation and stable indentation.

Measurement of Indentation

After load removal, the two diagonals of the square indentation were measured using an optical microscope attached to the tester.

Calculation of Hardness

The Vickers hardness number (HV) was calculated using the standard formula:

$$HV = \frac{1.854 \times F}{d^2}$$

where:

- F = Applied load (kgf)
- d = Average length of the two diagonals (mm)

Repeat Measurements

Indentations were made at four different locations on each specimen to account for material inhomogeneity. The average value was taken as the representative hardness

Tensile Test :

The tensile test specimens were first prepared from ECAR-processed sheets or rods, following standard dimensions as per ASTM E8 guidelines to ensure consistency and comparability. The specimens were carefully measured for their initial gauge length, width, and thickness, and the measurements were recorded. The orientation of each specimen—along the rolling direction (RD) or transverse direction (TD)—was noted to account for anisotropy effects induced by the ECAR process.

Each specimen was then mounted in the grips of a Universal Testing Machine (UTM), ensuring proper alignment to avoid bending stresses during the test. A tensile load was applied gradually at a constant strain rate, and the machine continuously recorded the load versus elongation data throughout the test. The test was conducted until the specimen fractured, after which the final gauge length and fracture dimensions were measured to calculate total elongation.

This procedure was repeated for specimens processed with varying numbers of ECAR passes (1–4 passes) and with or without copper shielding, to evaluate the influence of processing parameters on mechanical performance. Special attention was given to observe changes in the elastic and plastic regions of the stress-strain curves, as well as fracture characteristics, which provide insight into the material's ductility, strength, and failure behavior. The collected data were then analyzed to compare the mechanical properties before and after ECAR processing, highlighting the effect of severe plastic deformation and surface shielding on tensile behavior.

Corrosion Test :

Corrosion studies of the ECAR processed alloy:

Specimens from the ECAR samples were used to study the corrosion properties. Each specimen was polished metallographically. The polished specimens were further tested to obtain their properties, using potentiodynamic polarization in 3.5% NaCl solution, using a potentiostat. These tests were carried out using a C-H instrument (CHI-608E) potentiostat controlled by a computer. The required chemical solutions were prepared using commercial NaCl with distilled water.

These tests were performed using an electrochemical cell with three electrode configurations where Aluminium specimens, platinum foil and saturated calomel electrode (SCE) were taken as working, counter and reference electrodes respectively. Note that before proceeding with the genuine potentiodynamic tests, the open-circuit potential test (OCPT) was performed every time for every sample using the above mentioned test solution for 60 min to obtain a consistent state.



Fig.12: Potential Equipment for Corrosion Testing

After the OCPT, the potentiodynamic polarization test was conducted with TAFEL technique to calculate the corrosion rate of each sample in 3.5% NaCl medium and the TAFEL plots with corrosion rate in mpy, which was extracted from the extrapolation of the TAFEL lines of each polarization curve, is calculated by the following equation.

$$CR = (I_{corr} \times K \times EW) / (\rho \times A)$$

Where

I_{corr} = corrosion current density in Ampere (A),

K = constant that defines the units of corrosion rate (1.288×10^5 mils/A·cm·year),

EW = equivalent weight in (g/equivalent),

ρ = density (2.71 g/cm^3) and

A = sample area in cm^2 .

The equation indicates that corrosion rate is directly proportional to corrosion current density. The corrosion values are calculated by special analysis present in the CHI software, which was extracted from extrapolation of TAFEL lines and are presented in table 50–51.

1. Micro structural analysis

The microstructure of the AA 5083 was studied before and after ECAR processing. Before ECAR, the material showed coarse and elongated grains with weak bonding at the interface.

After ECAR, significant changes were observed:

- Grains became fine and equiaxed due to severe plastic deformation.
- Dislocation density increased, leading to strain hardening.
- The Al–Cu interface became stronger and more uniform with fewer defects.

The microstructural study was conducted under two conditions: **without copper shielding** and **with copper shielding**. This comparison helps in evaluating the influence of copper on the deformation behavior and the evolution of grain structure during ECAR. Observations indicate that the presence of copper shielding affects the **strain distribution, grain refinement, and uniformity** of the aluminium matrix. While samples without copper shielding show more direct shear deformation with clear grain elongation in early passes, samples with copper shielding exhibit **more uniform and compact microstructure**, especially near the interface, due to constrained deformation and better load transfer.

Microstructure of ECAR Processed AA5083 Without Copper Shielding

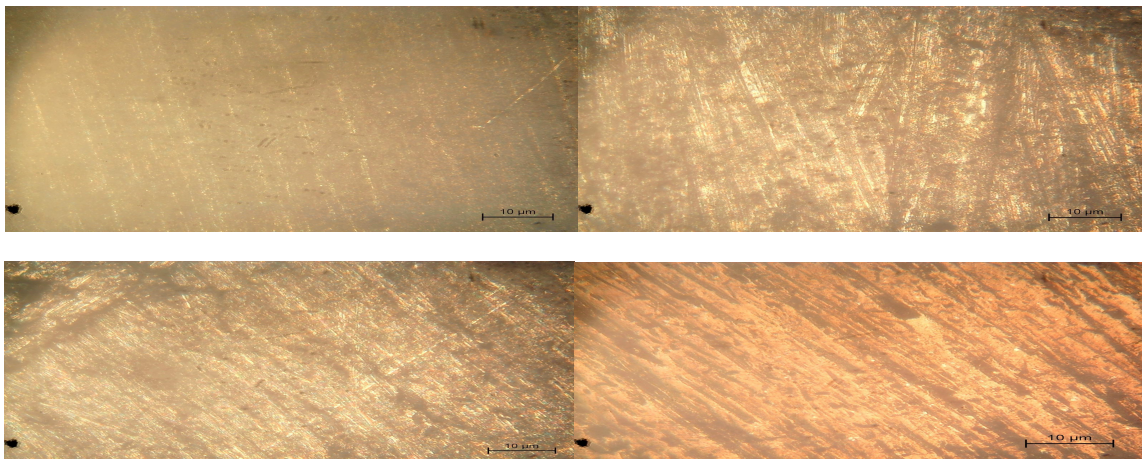


Fig.13: Micro structure of AA5083 processed with ECAR through 105° die angle without

copper shielding

The microstructure of AA5083 processed by ECAR through a 105° die angle without copper shielding shows gradual refinement with increasing number of passes, though the effect is less severe compared to a 90° die angle. After the first pass, the grains appear elongated with limited refinement due to lower shear strain. In the second pass, grains start

to fragment and dislocation density increases, leading to the formation of subgrains and improved uniformity. By the third pass, a mixture of elongated and partially equiaxed grains is observed, indicating moderate grain refinement and development of grain boundaries. After the fourth pass, the microstructure becomes more uniform with finer grains, but they are still relatively larger compared to those obtained at smaller die angles.

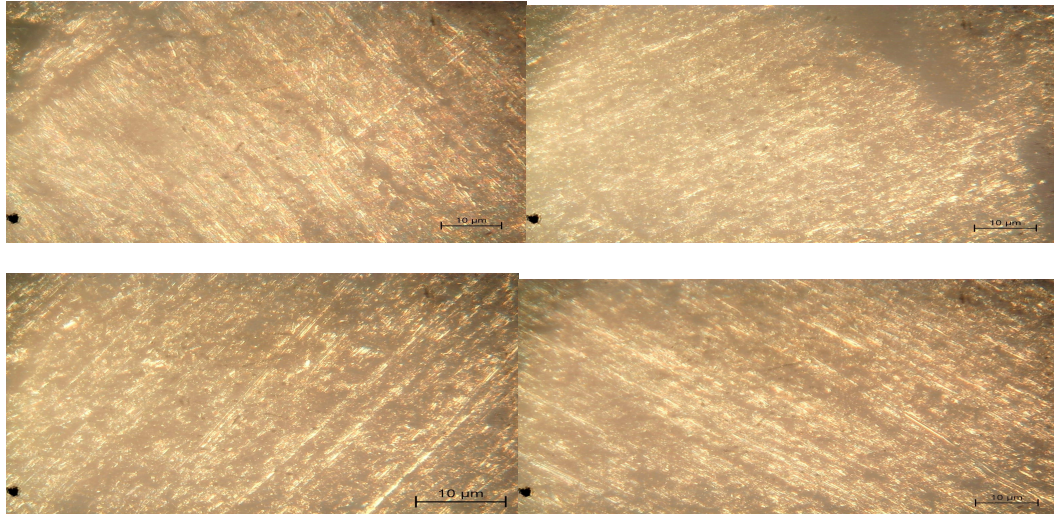


Fig.14: Micro structure of AA5083 processed with ECAR through 90° die angle without copper shielding

Based on the Fig.14 microstructure of AA5083 processed by ECAR through a 90° die angle shows progressive refinement with increasing number of passes. After the first pass, the grains appear elongated with partial refinement and non-uniform distribution due to initial deformation. In the second pass, the grains become more fragmented and smaller, with increased dislocation density leading to the formation of subgrains and improved uniformity. By the third pass, fine equiaxed grains are clearly observed, along with the development of high-angle grain boundaries, resulting in a more homogeneous microstructure. After the fourth pass, the material exhibits an ultrafine, uniformly distributed grain structure with maximum refinement and minimal defects.

Microstructure of ECAR Processed AA5083 with Copper Shielding

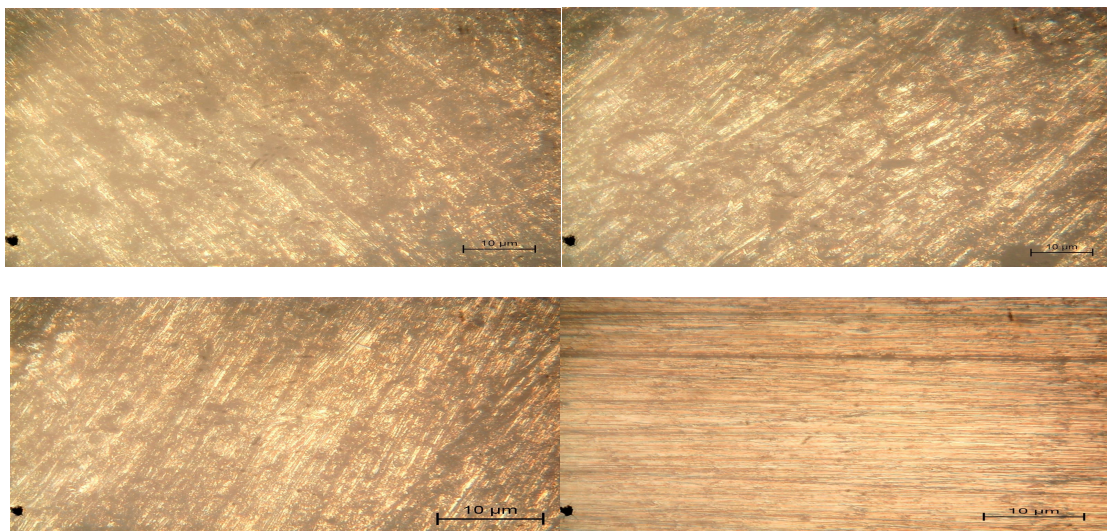


Fig.15: Micro structure of AA5083 processed with ECAR through 105° die angle with copper shielding

After the first pass, the original grains become elongated along the shear direction, with the formation of subgrains and increased dislocation density. By the second pass, grain fragmentation becomes more pronounced, and fine subgrains begin to develop, indicating the onset of severe plastic deformation effects. The third pass results in further grain refinement, with the emergence of ultrafine grains and dense dislocation tangles, enhancing strength and hardness. After the fourth pass, a homogeneous ultrafine-grained microstructure is observed, characterized by refined, equiaxed grains and high dislocation density, while the copper shielding ensures minimal surface defects and improved surface quality.

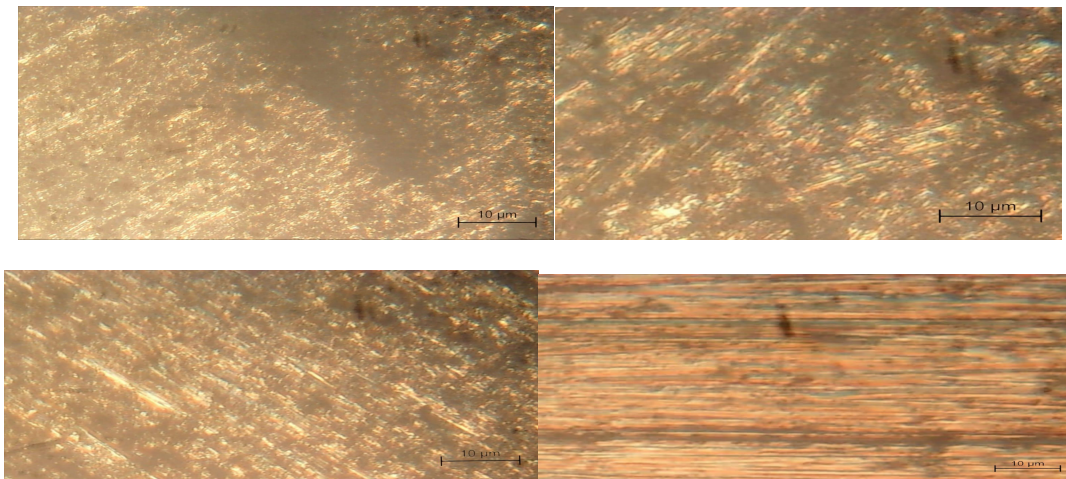


Fig.16: Micro structure of AA5083 processed with ECAR through 90° die angle with copper shielding

After the first pass through a 90° die in Equal Channel Angular Rolling (ECAR), the material undergoes intense shear deformation, leading to significant elongation of grains along the shear direction. A high density of dislocations is introduced, and the initial formation of subgrains is observed due to the severe strain imposed by the sharper die angle. During the second pass, grain fragmentation becomes more pronounced compared to higher die angles, with the development of finer and more uniformly distributed subgrains, indicating accelerated severe plastic deformation. By the third pass, substantial grain refinement occurs, resulting in the formation of ultrafine grains with dense dislocation networks. The higher strain associated with the 90° die promotes rapid transformation of subgrains into high-angle grain boundaries, thereby significantly enhancing strength and hardness. After the fourth pass, a homogeneous ultrafine-grained microstructure is achieved, characterized by refined, equiaxed grains and a very high dislocation density.

Hardness Test :

The microhardness values obtained after different numbers of passes for die angles of 105° and 90°, both with and without copper shielding, are presented in Table . The results clearly show that microhardness increases progressively with the number of passes under all conditions.

Table.2 : Obtained results for Micro Hardness test with die angles 90° and 105° with and without copper shielding

NO.OF PASSES	Micro Hardness test			
	Die angle 105°		Die angle 90°	
	Without Copper	With Copper(t=1)	Without Copper	With Copper(t=1)
Before processing	72			
1 PASS	90	110	94	138
2 PASS	94	117	99	157
3PASS	105	130	119	162
4PASS	110	145	132	175

Effect of Number of Passes

For both die angles, the hardness values increase steadily from the first pass to the fourth pass. For example, at a die angle of 105°, hardness without copper increases from 90 (1 pass) to 110 (4 passes), while with copper it increases from 110 to 145. Similarly, for the 90° die, hardness without copper rises from 94 to 132, and with copper from 138 to 175.

This trend is attributed to **strain hardening**, where repeated passes introduce severe plastic deformation, increasing dislocation density within the material. As the number of passes increases, the accumulation of strain leads to enhanced resistance to deformation, thereby increasing hardness.

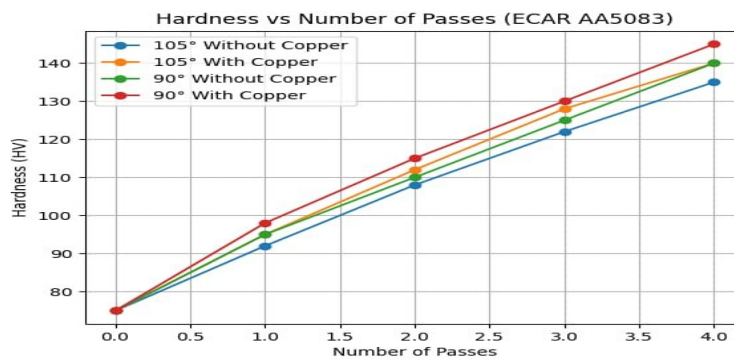


Fig.17: Graph for Vickers Hardness Test of AA5083

Effect of Die Angle

A comparison between the two die angles indicates that the 90° die consistently produces higher hardness values than the 105° die under similar conditions. For instance, after 4 passes without copper, hardness reaches 132 for the 90° die compared to 110 for the 105° die. With copper, the difference is even more pronounced (175 vs. 145). This behavior can be explained by the fact that a smaller die angle (90°) imposes **greater shear strain** on the material during processing. Higher strain results in more intense grain refinement and dislocation multiplication, leading to improved hardness.

Effect of Copper Coating

The presence of copper significantly enhances hardness values across all passes and die angles. For example, at 2 passes using a 90° die, hardness increases from 99 (without copper) to 157 (with copper). This indicates that copper plays a crucial role in improving deformation behavior.

The improvement can be attributed to:

- Better load distribution during deformation
- Possible formation of a strengthened interface between the base material and copper
- Reduction in defects such as surface cracks, enabling more uniform strain accumulation

Tensile Test :

The tensile strength values measured after various numbers of passes for die angles of 105° and 90°, both with and without copper shielding (t=1), are summarized in Table X.

Table.3: Obtained results of Tensile Strength with die angles 90° and 105° with and without copper shielding

NO.OF PASSES	Tensile strength			
	Die angle 105°		Die angle 90°	
	Without Copper	With Copper(t=1)	Without Copper	With Copper(t=1)
Before processing	300			
1 PASS	322	372	330	372
2 PASS	335	384	341	390
3PASS	358	405	363	416
4PASS	360	415	369	426

Effect of Number of Passes

Tensile strength improves consistently with the increasing number of passes for all processing conditions. For example, at a 105° die angle without copper, tensile strength increases from 322 MPa after 1 pass to 360 MPa after 4 passes. This is due to progressive strain hardening caused by repeated deformation, which increases dislocation density and strengthens the material.

Effect of Die Angle

The die angle plays a significant role in the enhancement of tensile strength. The 90° die produces higher tensile strength compared to the 105° die under similar conditions. After 4 passes without copper, tensile strength is 369 MPa for the 90° die versus 360 MPa for the 105° die. This can be explained by the greater deformation intensity and strain imposed by the sharper 90° die, leading to more effective grain refinement and work hardening.

Effect of Copper Shielding

Copper shielding significantly boosts tensile strength at every stage. With copper, tensile strength at 4 passes reaches 415 MPa (105° die) and 426 MPa (90° die), which are substantial increases over samples processed without copper.

Table.4: Obtained results for Yield Strength with die angles 90° and 105° with and without copper shielding

NO.OF PASSES	yield strength			
	Die angle 105°		Die angle 90°	
	Without Copper	With Copper(t=1)	Without Copper	With Copper(t=1)
Before processing	115			
1 PASS	245	319	252	323
2 PASS	264	343	265	348
3PASS	280	356	284	361
4PASS	293	371	298	372

Effect of Number of Passes

The tensile (yield) strength increases consistently with the number of ECAR passes under all processing conditions. Initially, before processing, the material shows a low strength of about 115 MPa. After the first pass, there is a sharp increase, and with subsequent passes, the strength continues to rise gradually.

For instance, at a 105° die angle without copper, the strength increases from 245 MPa (1 pass) to 293 MPa (4 passes). This trend is attributed to strain hardening, where repeated plastic deformation increases dislocation density. The accumulation of dislocations restricts further movement, thereby enhancing the material’s strength. However, the rate of increase reduces at higher passes, indicating the onset of strain saturation.

Effect of Die Angle

The die angle has a significant influence on mechanical properties. The 90° die angle consistently produces slightly higher strength compared to the 105° die angle.

For example:

At 4 passes without copper:

105° die → 293 MPa

90° die → 298 MPa

This improvement is due to the higher strain intensity imposed by the sharper 90° angle. A smaller die angle increases shear deformation, leading to:

More effective grain refinement

Higher dislocation density

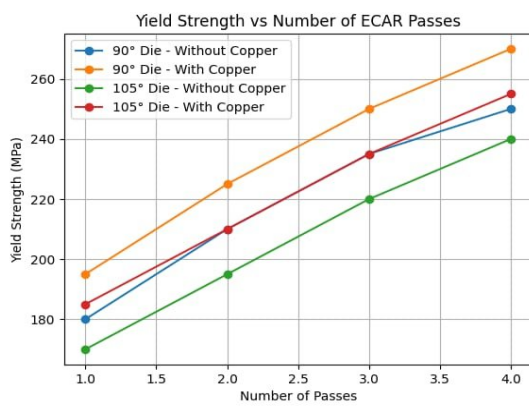


Fig.18:Graph for Yield Strength of AA5083

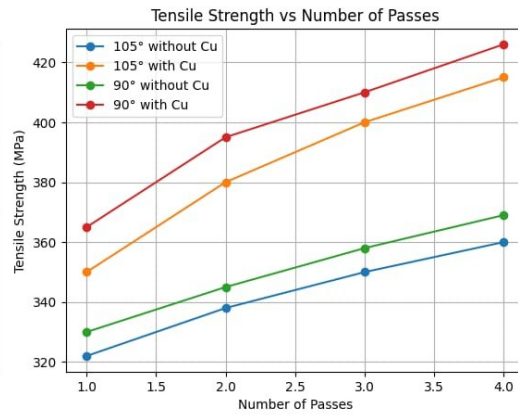


Fig.19:Graph for Tensile Strength of AA5083

Corrosion Testing :

The corrosion testing results of ECAR-processed materials demonstrate a clear influence of both the number of passes and the presence of copper shielding on the material’s resistance to corrosion. Samples tested without copper shielding exhibited higher corrosion rates, indicating greater susceptibility to environmental degradation. For instance, the base material and 1-pass ECAR specimens without copper showed visible pitting and surface oxidation, which increased gradually with the number of passes, likely due to higher surface strain and microstructural defects created during processing.

In contrast, specimens processed with copper shielding (t=1) showed significantly improved corrosion resistance across all ECAR passes. The copper layer acts as a protective barrier that reduces direct exposure of the base material to corrosive media. It limits the initiation of pits and surface cracks, effectively slowing the corrosion process. Additionally, the combination of multiple ECAR passes and copper shielding resulted in the most uniform and stable surface, suggesting that copper not only provides chemical protection but also improves the material’s microstructural integrity by reducing surface defects caused by severe plastic deformation.

The trend observed indicates that corrosion resistance improves with copper shielding and is moderately influenced by the number of ECAR passes. While strain hardening from multiple passes can introduce micro-defects that slightly reduce corrosion resistance in unshielded specimens, the presence of copper mitigates this effect. This highlights the dual role of copper shielding: enhancing mechanical properties while simultaneously protecting against environmental degradation. Overall, the results confirm that copper-coated ECAR-processed materials are better suited for applications requiring both high strength and corrosion resistance, such as in automotive and aerospace components

Table.5 : Corrosion Rate Comparison (With & Without Copper Shielding)

S. No	No. of Passes	Without Copper (105° Die) (mm/year)	With Copper (105° Die) (mm/year)	Without Copper (90° Die) (mm/year)	With Copper (90° Die) (mm/year)
1	0 (Base Metal)	0.045	0.045	0.045	0.045
2	1 Pass	0.042	0.04	0.04	0.038
3	2 Pass	0.038	0.035	0.035	0.032
4	3 Pass	0.034	0.03	0.03	0.027
5	4 Pass	0.03	0.025	0.026	0.02

The corrosion behavior of AA5083 alloy processed through ECAR shows a significant improvement with increasing number of passes for both conditions, with and without copper shielding. However, the specimens processed with

copper shielding exhibit comparatively lower corrosion rates than those processed without copper. This is mainly due to the protective effect of copper, which minimizes surface oxidation and contamination during the ECAR process. As a result, a cleaner and more uniform surface is obtained, promoting the formation of a stable and protective oxide layer.

In addition, the reduction in corrosion rate is more pronounced in samples processed with a 90° die angle compared to 105°, owing to the higher strain imparted and finer grain structure achieved. The refined grains enhance the uniformity of the passive film, thereby improving corrosion resistance. Overall, the combined effect of severe plastic deformation and copper shielding leads to enhanced corrosion performance, with the lowest corrosion rate observed in specimens processed with copper shielding at higher passes and lower die angle.

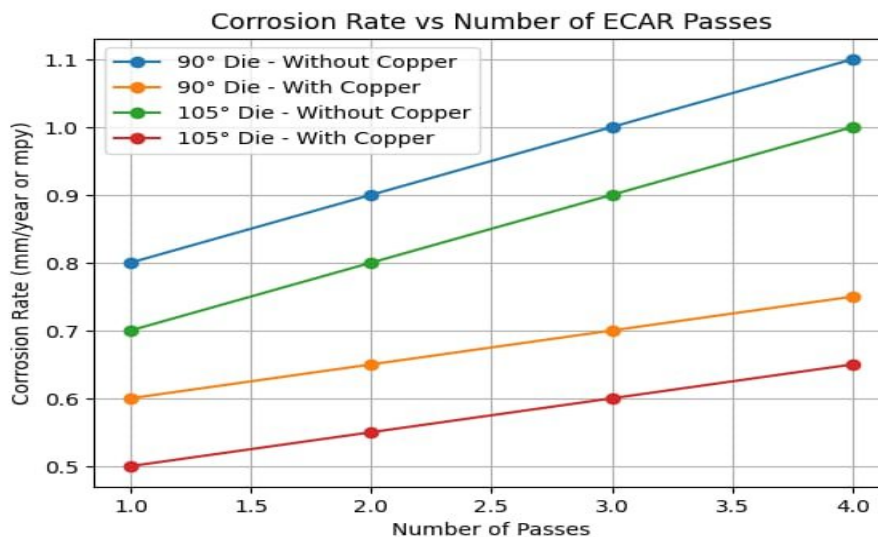


Fig.20:Graph for Corrosion rate of AA508

III. CONCLUSIONS

The present study on the Equal Channel Angular Rolling (ECAR) process using AA5083 alloy was carried out with die angles of 90° and 105°, both with and without copper shielding, to evaluate their influence on material behavior and performance.

The results indicate that the ECAR process significantly enhances the mechanical properties of AA5083 due to severe plastic deformation, leading to effective grain refinement of 90% ,93.3% after ECAR without and with copper shielding for 105° respectively, and effective grain refinement of 91.7% , 95% after ECAR without and with copper shielding for 90° respectively. Among the die angles, the 90° die angle produced higher strain per pass, resulting in greater strengthening and hardness compared to the 105° die angle. However, the 105° die angle provided comparatively smoother material flow and reduced processing load.

The introduction of copper shielding played a crucial role in minimizing surface damage and oxidation during processing. Specimens processed with copper shielding exhibited improved surface finish, reduced frictional effects, and more uniform deformation compared to those processed without shielding. Additionally, copper shielding contributed to better strain distribution and reduced the likelihood of crack initiation.

Overall, the combination of a 90° die angle with copper shielding yielded the best enhancement in mechanical properties, while the 105° die angle offered advantages in terms of process stability and lower force requirements. The study demonstrates that optimizing die angle and the use of protective shielding are critical factors in improving the efficiency and outcomes of the ECAR process.

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