Influence of Equal Channel Angular Pressing (ECAP) on The Microstructure and Mechanical Properties of aluminum alloy 6061

Kanyanat Srisom[1], Chanun Suwanpreecha[2], Anchalee Manonukul[2], Sirinapa Shuecamlue[1,3], Wichuda Choodokput[1,3], Chaiyasit Banjongprasert[1,3*]

[1]Department of Materials Science, Faculty of Science, Chiang Mai University, Chiang Mai, Thailand
[2]National Metal and Materials Technology Center (MTEC), National Science and Technology Development Agency (NSTDA), Thailand Science Park, Pathum Thani, Thailand
[3]Materials Science Research Center, Faculty of Science, Chiang Mai University, Chiang Mai, 50200, Thailand
Email: chaiyasit.b@cmu.ac.th*

ABSTRACT

This research investigates the microstructure and mechanical properties of aluminium alloy 6061 (Al–Mg–Si) processed by Equal Channel Angular Pressing (ECAP) at elevated temperature (150°C). The ECAP process was conducted following Route Bc for 0,1 and 2 passes. After processing, the microstructure was characterized using Scanning Electron Microscopy (SEM), and Energy Dispersive X-ray Spectroscopy (EDS) to examine grain refinement and elemental distribution. In addition, Electron Backscatter Diffraction (EBSD) was used to quantify grain size and crystallographic orientation.The mechanical properties were evaluated through hardness to investigate the relationship between microstructural evolution and strength development. The results demonstrate that ECAP processing at elevated temperature significantly refines the grain structure and enhances mechanical properties. Increasing the number of passes led to a clear increase in hardness, confirming that ECAP is an effective technique for strengthening aluminium alloy 6061.

Keywords: aluminum alloy 6061 ECAP; Route Bc ; Grain Refinement; Mechanical Property.

INTRODUCTION

aluminium alloy 6061 (Al-Mg-Si)

- Precipitation hardening
- Corrosion resistance

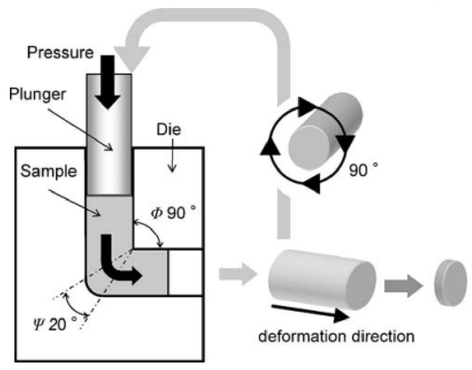
Equal Channel Angular Pressing (ECAP)

- Grain refinement
- Ultrafine-grained (UFG) structure
- Strength enhancement

Elements	Al	Mg	Si	Cr	Fe	Cu	Mn	Zn	Ti
Wt.%	Bal.	1.06	0.74	0.30	0.25	0.21	0.11	0.10	0.02

METHODOLOGY

Schematic diagram of the ECAP process:



Materials — **aluminium alloys 6061 - T6**
Solid Solutionize at 530°C for 1 hour

ECAP Process — **Route Bc ; at 150°C for 0,1 and 2 Passes**

Characterization
- **SEM with EDS**
- **EBSD**

Mechanical Property — **Vickers Hardness Test**
Load 200 g, dwell time 15 s.

RESULTS

Microstructural evolution

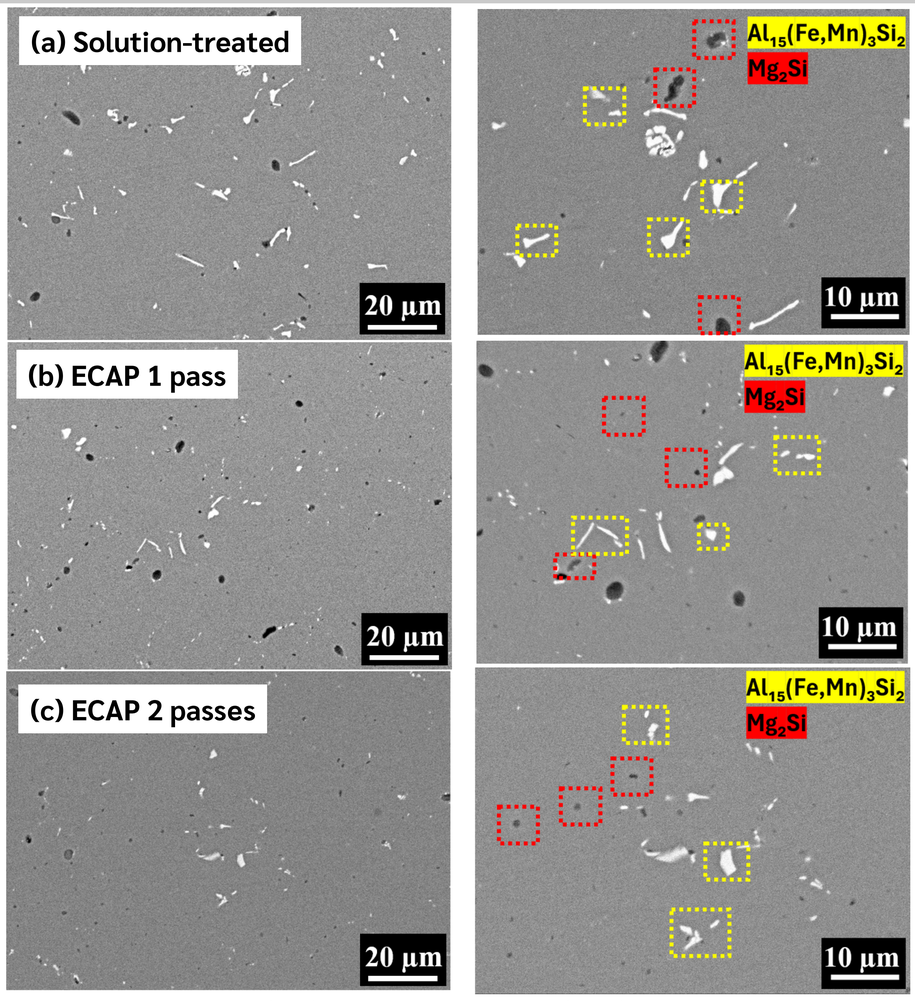
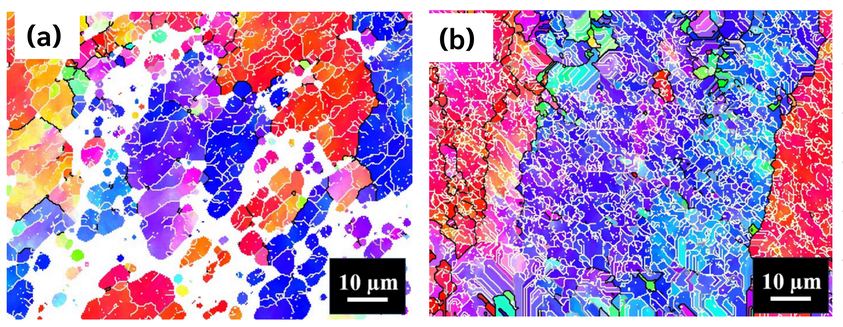


Figure 1. SEM micrographs showing microstructural evolution after ECAP processing: (a) Solution-treated (without ECAP), (b) ECAP 1 pass, and (c) ECAP 2 passes. Higher magnification images (right) highlight Mg_2Si (red boxes) and $Al_{15}(Fe,Mn)_3Si_2$ (yellow boxes).

EBSD analysis



(c)

Grain Size (µm)	
Solution-treated	18.2 ± 1.5
1 Pass	5.16 ± 5.48
2 Passes	3.47 ± 4.67

Figure 2. EBSD grain orientation maps showing grain refinement after ECAP processing: (a) 1 pass, (b) 2 passes, and (c) comparison of the average grain sizes.

Microhardness

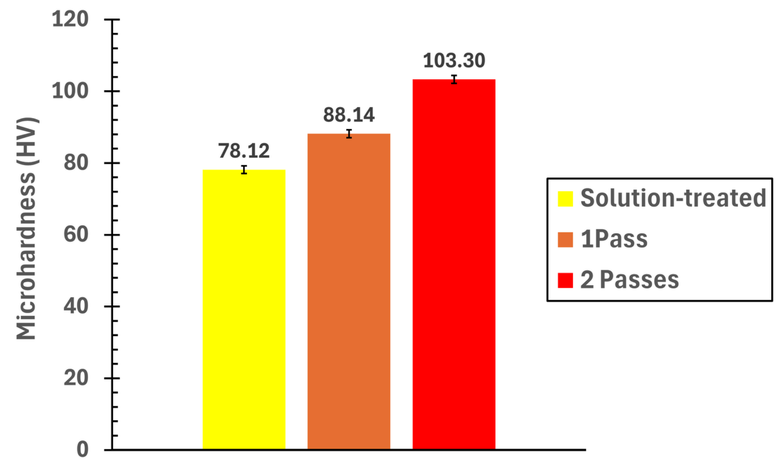


Figure 3. Microhardness values measured after different ECAP passes.

CONCLUSION

The results of this study can be summarized as follows:

- ECAP processing significantly modified the microstructure of the material, leading to fragmentation and redistribution of intermetallic compounds (Mg_2Si and $Al_{15}(Fe,Mn)_3Si_2$).
- Increasing ECAP passes resulted in pronounced grain refinement, with the average grain size decreasing from 18.2 µm (0 pass) to 5.16 µm (1 pass) and 3.47 µm (2 passes).
- The microhardness increased with the number of ECAP passes, rising from 78.12 HV in the solution-treated condition to 88.14 HV after 1 pass and 103.3 HV after 2 passes.
- EBSD analysis revealed noticeable texture evolution, indicating the development of preferred crystallographic orientations after ECAP processing.
- Overall, ECAP effectively refined the grain structure and enhanced the mechanical properties through microstructural modification and texture development.

REFERENCE

[1] Yang, Z. et al. (2025). Critical role of intermetallic particles in the corrosion of 6061 aluminum alloy. Acta Metallurgica Sinica (English Letters), 38, 904–924.
[2] Abd El Aal, M. I. (2020). Influence of ECAP and HPT processing on microstructure and mechanical properties of Al6061 alloy. Journal of Materials Research and Technology, 9(6), 12525–12546.
[3] Akiyama, E. et al. (2009). Effects of severe plastic deformation on corrosion behavior of aluminum alloys. J. Solid State Electrochem., 13, 277–282.