# Processing-Induced Microstructural Evolution in Pure Magnesium via Hot Extrusion and Rolling


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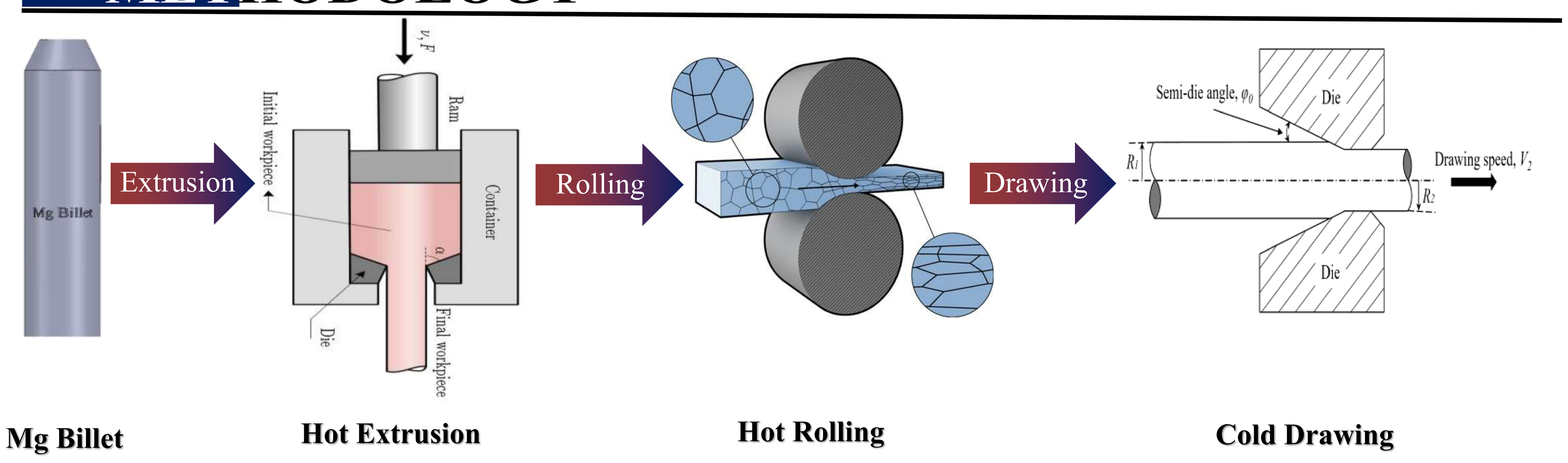
## ABSTRACT

This study explores thermomechanical processing of commercially pure Mg via hot extrusion and hot rolling. Three different extrusion ratios (6:1, 25:1, and 39:1) were investigated at 350°C, revealing that 39:1 ratio produced an optimal bimodal grain structure with beneficial twin morphology. Subsequently, hot rolling experiments were performed at varying linear speeds (26 and 130 mms-1) and interpass annealing times (2.5 and 10 minutes). Results demonstrated that higher rolling speeds led to finer microstructure, while longer interpass annealing times resulted in reduced twin fraction and more inhomogeneous microstructure. FEM simulations revealed a trade-off between slip and twin activity, where excessive twin–dislocation interactions caused hardening and fracture. Hot rolling showed that higher speeds refined grains, while longer interpass annealing reduced twins and induced inhomogeneity. Compression tests under varying temperatures and strain rates supported modeling of extrusion conditions and highlighted the role of adiabatic heating.


## INTRODUCTION

Owing to the global concern about energy consumption, special considerations have taken place on research and development of lightweight alloys. Among lightweight alloys, Mg has gained a stunning attention due to its low density (1.74 g/cm$^3$) and as a result, its high specific strength (130 kNm/kg). However, owing to the high tendency of Pure Mg and its alloys to form a strong basal texture during cold (in some cases, even hot) deformation, there's a huge drawback in production of Mg parts. Dynamic recrystallization (DRX), on the other hand, occurs readily in Mg during thermomechanical processing, which usually happens upon practical hot deformation processes. Although Mg has a relatively high stacking fault energy (SFE), which would typically limit DRX during hot deformation, the limited number of slip systems in its hexagonal close-packed (HCP) structure makes DRX a prominent grain-refinement mechanism in Mg alloys, especially during elevated-temperature thermomechanical processing when twinning is suppressed.

## METHODOLOGY




## MICROSTRUCTURE

Hot Extrusion

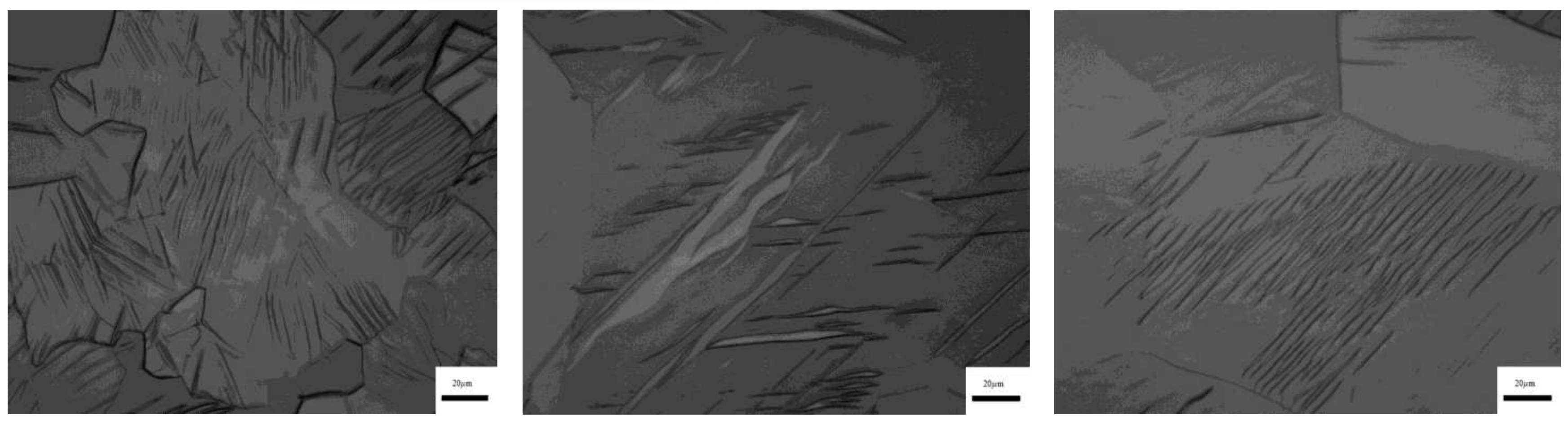


**Fig1.** Microstructural Evolution, OM 500X: A) ER=6, B) ER=25, C) ER=39.

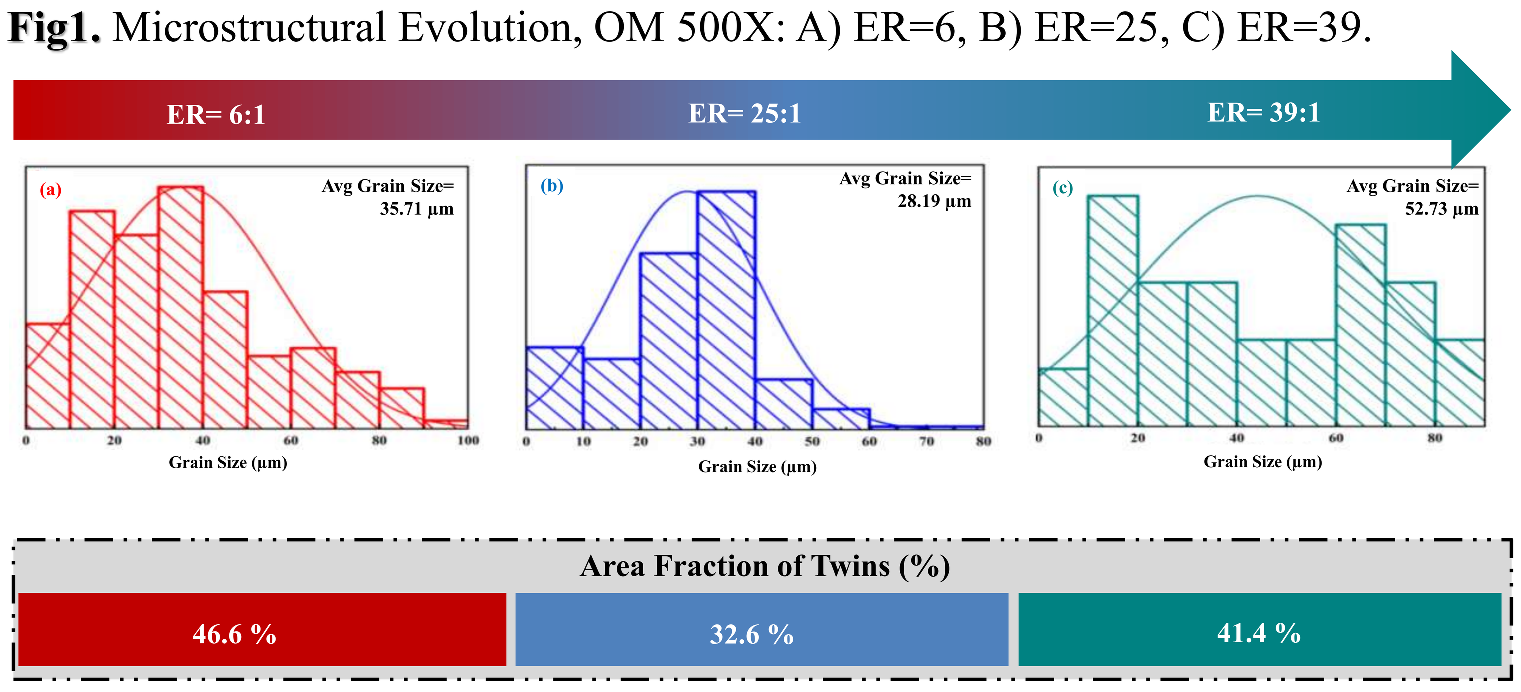



**Fig2.** Average Grain Size and Twin Area Fraction Evolution Through Different Extrusion Rates.

Hot Rolling

2.5 Min

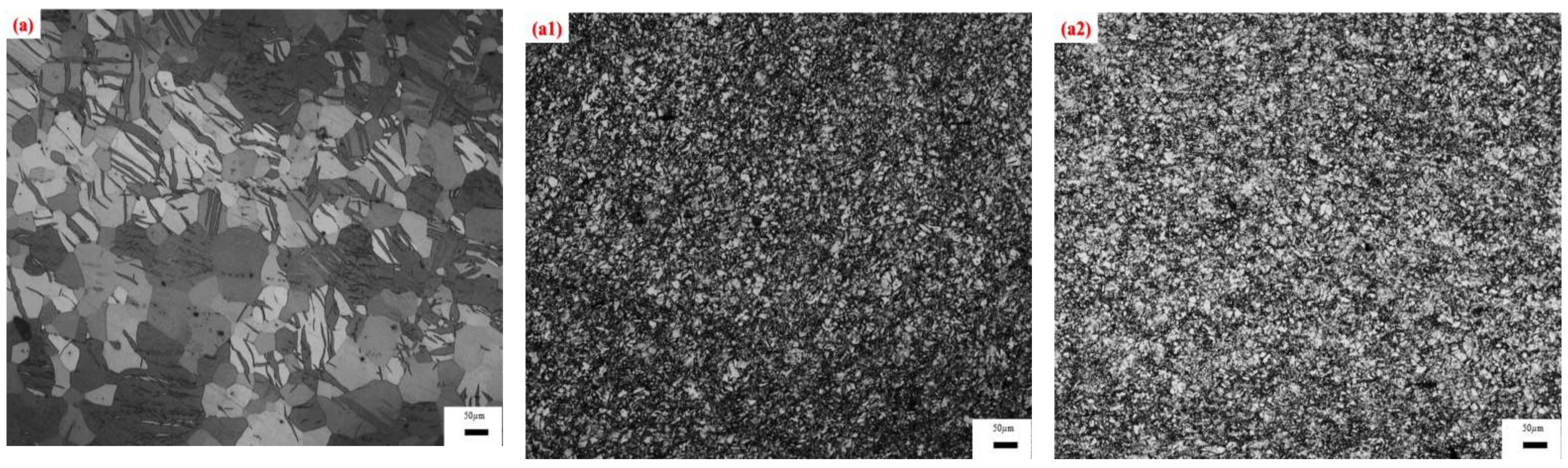


**Fig3.** Microstructural Evolution Through Different Starin Rates: a) Initial, a1) 26 mms$^{-1}$, a2) 130 mms$^{-1}$

10 Min

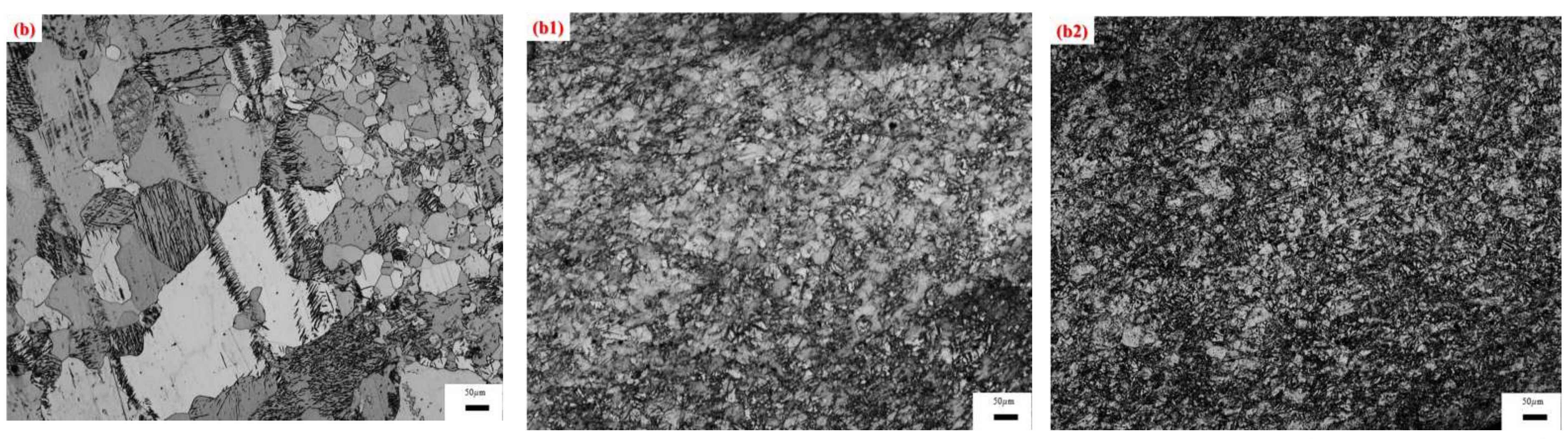


**Fig4.** Microstructural Evolution Through Different Starin Rates: a) Initial, a1) 26 mms$^{-1}$, a2) 130 mms$^{-1}$

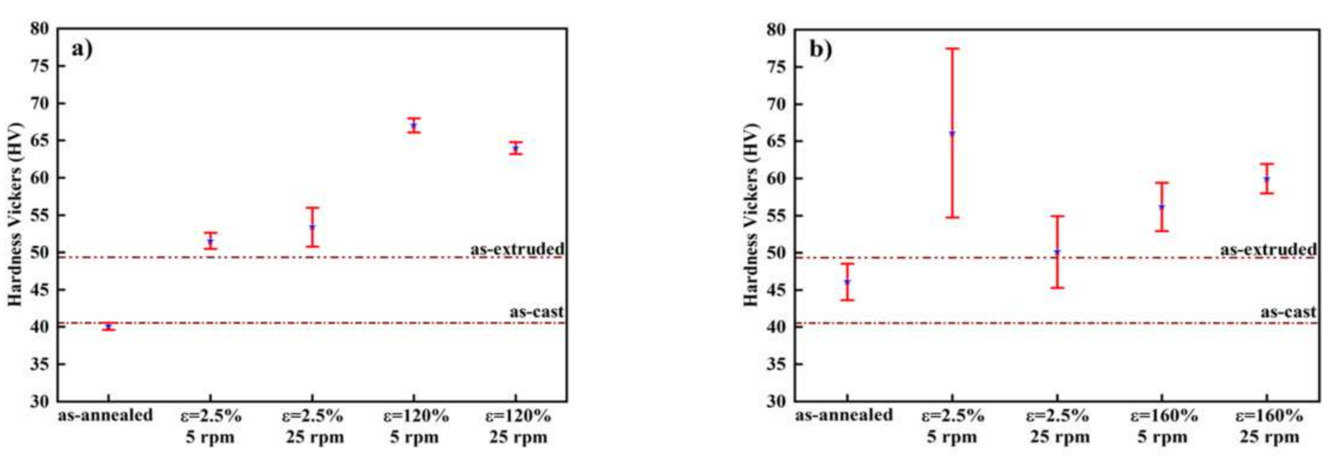



**Fig 5.** Hardness Variation with Strain Rates: a) 2.5 Min, b) 10 Min.

## FEM SIMULATION

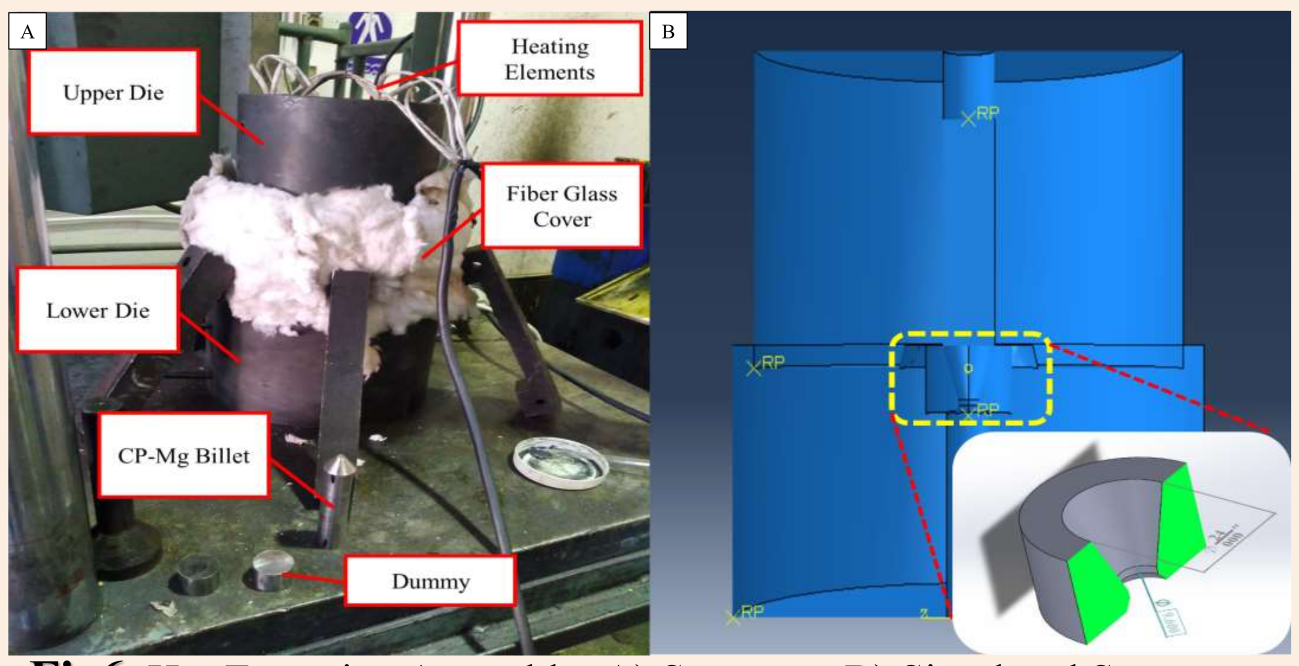



**Fig6.** Hot Extrusion Assembly: A) Structure, B) Simulated Structure.

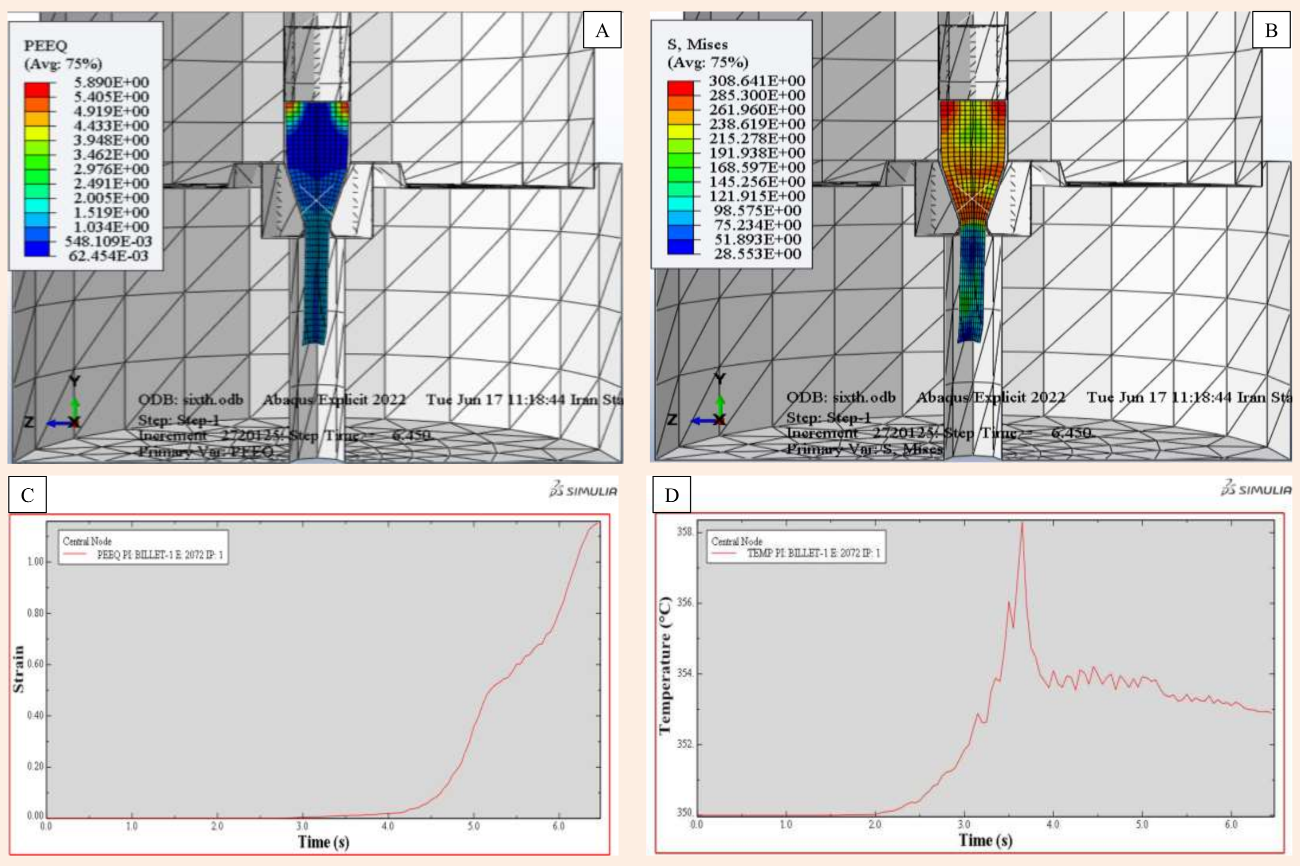


**Fig7.** A) Equivalent Accumulated Strain, B)Von – Mises Stress, C) Strain Variation, D) Temperature Variation.

## CHARACTERIZATION

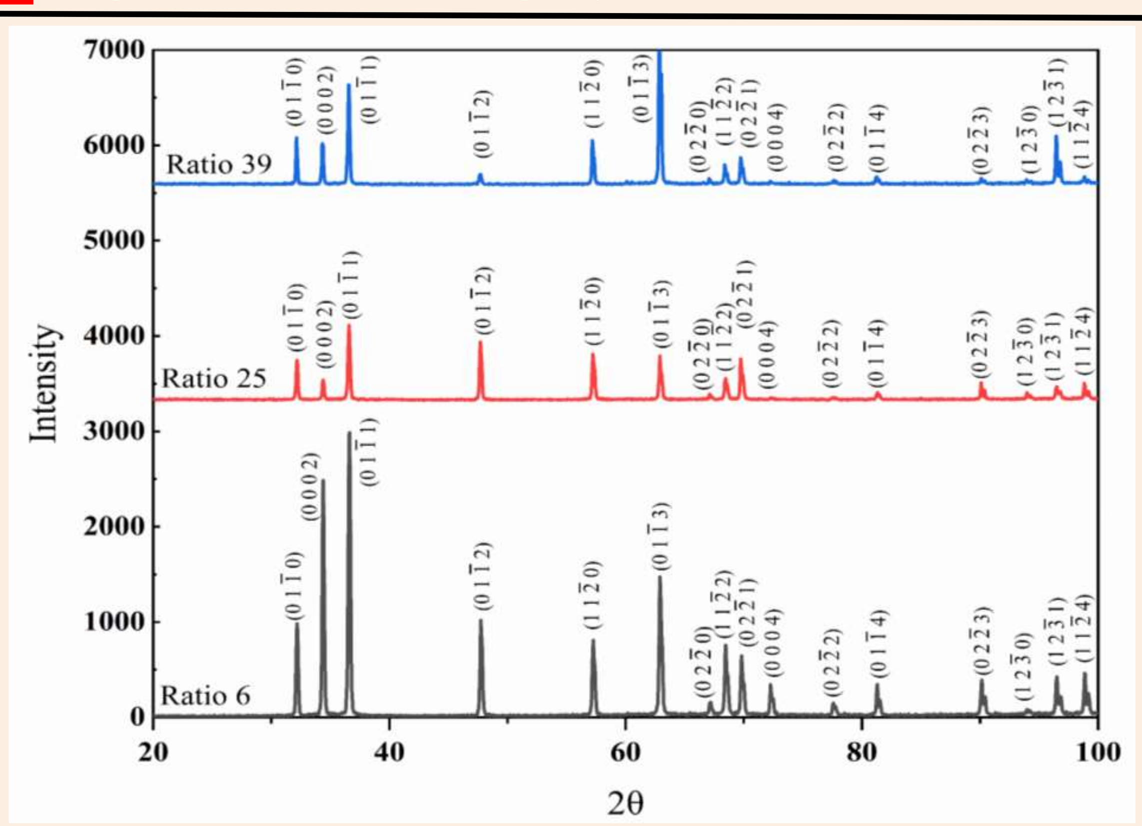



**Fig 8.** XRD Profile in Three Different Extrusion Ratio

## FRACTOGRAPHY

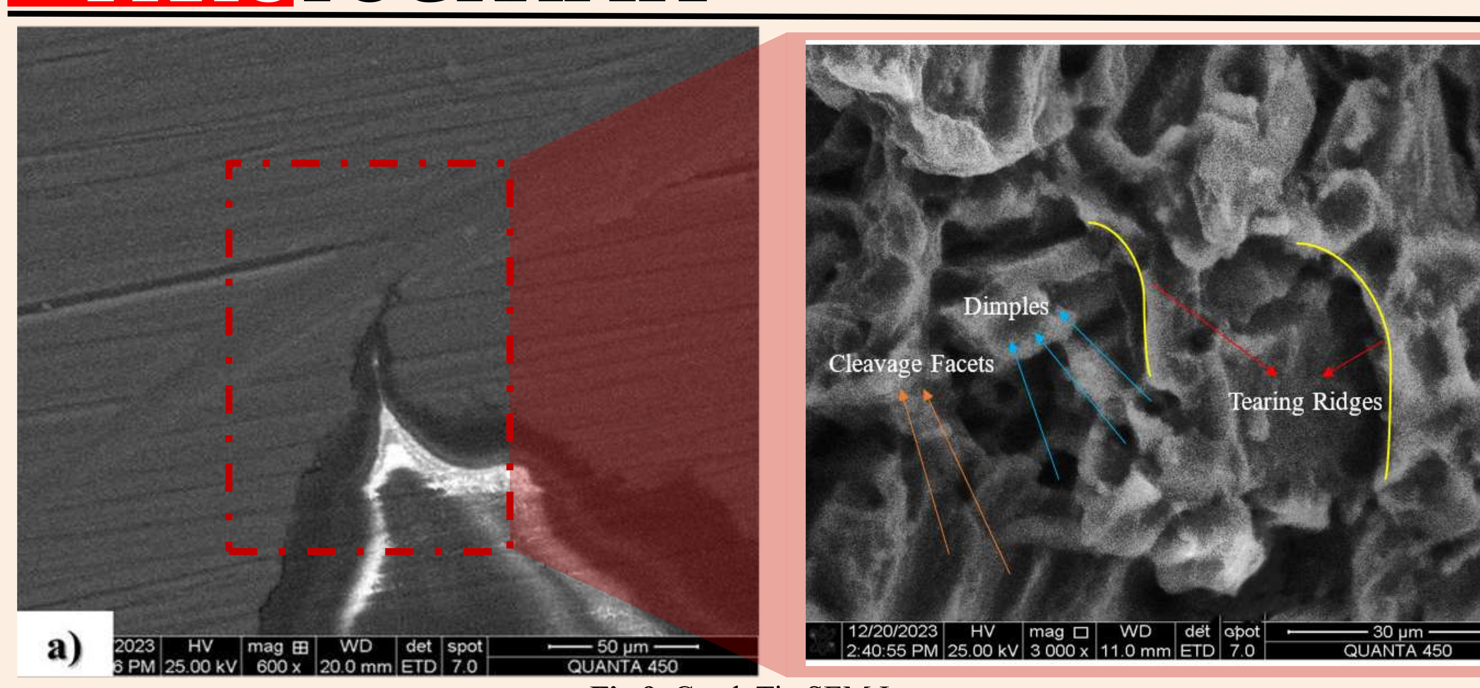



**Fig 9.** Crack Tip SEM Image

## CONCLUSION

In hot extrusion, an extrusion ratio of 39:1 at 350°C produced the optimal microstructure, characterized by:

- Ultra-thin twin lamellae with periodic behavior and enhanced strain accommodation capability due to the combination of fine and coarse grains.

During hot rolling, the following key relationships were established:

- Higher rolling speeds (130 mms$^{-1}$) resulted in finer microstructure due to increased dynamic recrystallization and Shorter interpass annealing times (2.5 min) led to smaller grains and higher twin fraction.

## REFERENCES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