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# Effect of precipitation on the warm deformation behavior of AA2024 alloy

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ABSTRACT

The warm deformation behavior of precipitation hardening alloys depends on the changes in precipitate morphology. In this research, the kinetics of dynamic precipitation of AA2024 were investigated and compared to static precipitation at temperatures of 200 °C, 230 °C, and 260 °C. Results show that deformation increased the precipitation kinetics rate than that of the static precipitation. Also, the rate of increase in electrical conductivity and hardness of dynamic aging was more than static aging. The dynamic precipitation process considerably increased flow stress value during hot deformation in the supersaturated specimens. The most effective strain-precipitation-hardening was found in the temperature range of 200–230 °C. This effect was dependent on the strain rate while the diffusion mechanism controlled the precipitation process.

## 1. Introduction

Alloy AA2024 is a medium strength alloy. Major alloying elements are copper and magnesium and minor alloying elements as iron, silicone and manganese. The primary purpose of copper and magnesium is to improve the strength, by forming precipitation [1,2]. It is well know, that precipitate particles play an important role during deformation. Obtaining the knowledge of microstructure just before deformation is important to understand the deformation behavior.

The hot deformation behavior of precipitation hardening alloys can be affected by changes in precipitate morphology when are solution-treated or preaged. Results are shown that pre-aged alloys at elevated deformation temperature present a low peak stress with gradual work softening because of precipitation coarsening. However, solution-treated alloys show a higher stress with high dislocation density due to dynamic precipitation (DPN), with rapid softening which particles coalesce, solutes deplete and DRV (Dynamic recovery is a restoration mechanism while stored energy decreases during defamation due to removal and rearrangement of dislocations) progresses [3–7].

Two type of precipitation may occur in thermo-mechanical process. These are (1) static precipitation; defines as precipitation that occurs before the warm deformation and (2) dynamic precipitation (DPN) that occurs during the warm deformation. However, investigation on dynamic precipitation nucleation is based primarily on low strain rate tests.

There have been some efforts in the last years for investigation dynamic precipitation; Pollock and Argon [8] investigated the directional coarsening in Ni base single crystals with high volume fractions of coherent precipitates in tension test; Deschamps et al. [9] showed that DPN during deformation of supersaturated solid solution in 7000 series aluminum alloys can substantially affect work hardening behavior, even at a temperature as low as 4.2 K; Evangelista et al. [10,11] found that the flow stress in 6000 series aluminum alloys exhibit a sharp peak and a rapid decline to failure, which coincide with the precipitation of semi-coherent particles and work hardening. Poole and Shercliff [12] observed that deformation of a supersaturated solid solution of an Al-Zn-Mg alloy resulted to an anomalously high work-hardening rate, and proposed that this was due to dynamic precipitation. On the other hand, the nucleation, growth and coarsening behavior of precipitation hardening alloys is important in determining the warm deformation behavior and the stability of mechanical properties. Also precipitation or/and solute elements may affect recovery mechanisms in several ways. During generation and annihilation of dislocations to form subgrain, the precipitations may pin the dislocations and thus inhibit this stage of recovery. Therefore, the deformation of supersaturated solid solution is complex and requires further investigations.

Hui et al. [13] investigated the effect of solution and aging heat treatment on the hot deformation of 2026 aluminum alloy. Microstructure results show dynamic precipitation particles with size of less than 0.01 μm while exhibit a high density dislocation with low cellularity. Therefore the higher strain energy may speed up dynamic precipitation during hot deformation of Al-Cu alloys.

Jimenez et al. [14] studied the hot torsion tests to fracture on a solution treated Al–Cu–Mg alloy (Al 2024-T351). Mechanical results indicate that at the lowest test temperatures, flow softening in the

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