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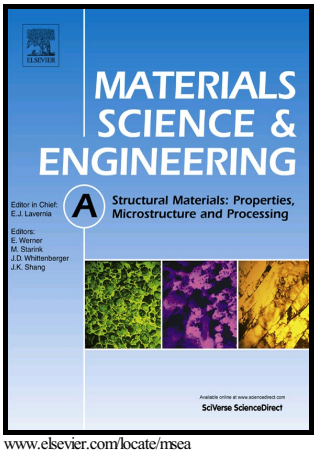

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Effects of pre-strain on Cu-Mg co-clustering and mechanical behavior in a naturally aged Al-Cu-Mg alloy

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Abstract

Effects of pre-strain on Cu-Mg co-clusters and mechanical behavior in a naturally aged Al-Cu-Mg alloy were investigated by tensile and fatigue testing, transmission electron microscope (TEM) and atom probe tomography (APT) in present work. Results show that pre-strain contributes to increasing tension strength, not only by increasing dislocation density as previously recognized, but also through enhancing Cu/Mg ratio of Cu-Mg co-cluster and resultant critical shear stress for dislocation slip. Fatigue crack propagation (FCP) resistance is not degraded by further increasing pre-strain from 5% to 10%, in spite of a FCP resistance degradation when a pre-strain of 5% is initially applied. APT analysis indicates, comparing with 5% pre-strain, 10% pre-strain remarkably enhances Cu-Mg co-cluster size and Cu/Mg ratio during natural aging, which leads to a greater critical shear stress for dislocation slip. This undoubtedly enhances fatigue crack closure effect, and retards FCP resistance degradation when a greater pre-strain of 10% is applied.

Keywords: Pre-strain; Cu-Mg co-cluster; Mechanical behavior; Al-Cu-Mg alloy; Fatigue crack propagation.

1. Introduction

Al-Cu-Mg alloys have been widely used in aerospace areas due to their excellent combinations of moderate strength and good plasticity, especially employed in aircraft lower-wing panels [1-4]. Pre-strain is usually applied to relieve the residual stress which is induced by quenching. In this case, a mechanical property combination of high strength and low fatigue damage resistance can be created due to significant strain hardening led by pre-straining. This suggests pre-strain has a great effect on mechanical properties of age-hardened aluminum alloys.

Compared to the alloy without pre-strain, the pre-strained alloy possessed higher yield strength [5-7]. Specifically, Schijve's work [5] revealed that the FCP rate of AA2024-T3 plate was about twice as large as that without pre-strain. The observed increment in FCP rate was attributed to the small crack closure in pre-strained sample. For Al-Zn-Mg-Cu alloys, Al-Rubaie et al. [7,8] concluded that fatigue life and FCP resistance got worse with an increase of pre-strain level. In their work, an increase of pre-strain level had no considerable influence on fatigue region I and II, but it had a remarkable effect on fatigue region III [8]. Similarly, Froustey et al.'s [9] work on 2017A-T3 alloy revealed that an increase in pre-strain led to a large decrease in fatigue performance by promoting the formation of micro-cracks. Several studies [5,10] indicated that an increase in strength was accompanied by degrading fatigue damage resistance. The increasing