Abstract

The susceptibility of high strength 7xxx aluminium alloys to environmentally assisted cracking (EAC) in humid air remains a matter of concern, given their widespread use in structurally critical aerospace applications. These alloys, particularly the new-generation variants with high zinc, are prone to hydrogen embrittlement in moist environments, commonly referred to as hydrogen environmentally assisted cracking (H-EAC). The embrittlement mechanism is generally attributed to hydrogen generation from alloy–moisture interaction, leading to grain boundary (GB) decohesion under the stress field at a crack tip. Despite decades of study, key questions remain poorly understood regarding the role of grain structure, grain boundary chemistry, and alloy composition (particularly zinc concentration) in governing EAC crack initiation and propagation.

In this study, the influence of partially recrystallized grain structures on H-EAC behaviour of AA7085 aluminium alloy thick plate was examined in humid air. Re-processing by hot rolling at 300–470 °C produced different fractions of recrystallized grains, and in-situ optical monitoring during four-point bend tests in warm-humid air (70 °C, 50 % RH) enabled high-resolution measurement of crack growth rates. Crack propagation was found to be highly sensitive to the degree of recrystallization. At a low recrystallized fraction of about 2%, the microstructure provides a relatively linear crack path, leading to higher crack growth rates. In contrast, increasing the recrystallized fraction from 2% to 20% promotes greater crack path tortuosity, thereby reducing crack growth rates. At higher recrystallization (~40 %), cracks advanced more rapidly by following interconnected bands of recrystallized grains, resulting in reduced crack growth rate. A mechanistic link between recrystallization, grain boundary morphology, and H-EIC crack growth resistance in AA7085 is proposed.

The influence of quench-induced (Q-GBPs) and age-induced (A-GBPs) η-phase grain boundary precipitates on H-EAC in AA7085 was studied by varying quench rate (6–200 °C s^{-1}). High cooling rates suppressed Q-GBP formation, producing uniform A-GBP coverage, which accelerated crack initiation and resulted in the highest growth velocities. In contrast, low cooling rates generated coarse, Cu-rich Q-GBPs with solute-denuded zones and reduced A-GBP coverage, which delayed initiation and suppressed growth. Intermediate cooling produced finer, more numerous Q-GBPs, giving initiation times comparable to slow cooling but with elevated growth rates. Control of GBP distributions through quench rate selection, therefore, offers a viable route to mitigate H-EAC in 7xxx alloys.

Finally, the effect of Zn concentration on microstructural evolution and hydrogen environment-induced cracking (H-EIC) behaviour of overaged 7xxx alloys was examined using laboratory-cast Al–xZn–2Mg–1.76Cu compositions (x = 5.7–10.3 wt.%). Increasing bulk Zn content enhanced hardness and also promoted the greater Zn segregation to grain boundaries, , and increased Zn levels in η-phase precipitates. In humid air tests, initiation and growth rates accelerated markedly with Zn, with the 10.3 wt.% alloy failing within 14 h compared to >80 h for the 5.7 wt.% alloy. Fractography revealed a shift from intergranular fracture at low Zn to mixed intergranular–quasi-cleavage at high Zn, with the highest Zn alloy also exhibiting mechanical decohesion in dry air. These results indicate that while Zn additions strengthen 7xxx alloys, it critically reduces EAC resistance by coupling hydrogen-assisted and mechanically driven fracture processes.

Keywords: Environmentally Assisted Cracking (EAC) / Environmentally Induced Cracking (EIC); High strength aluminium alloy; Hydrogen Embrittlement; Recrystalized grain; Grain boundary precipitate; quench-induced grain boundary precipitates (Q-GBPs); age-induced phase grain boundary precipitates (A-GBPs); Intergranular Fracture (IGF); Quasi cleavge fracture (QCF).