Aluminum-Lithium Alloys: Chapter 13. Fracture Toughness and Fracture Modes of Aerospace Aluminum-Lithium Alloys

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Aluminium-Lithium (Al–Li) alloys have been of interest since the 1950s when they were first used on a military aircraft. Having lithium as the main alloying element in Al alloys is attractive since (i) each 1 wt% Li reduces the density by ~3% and increases modulus by ~5%, and (ii) high strengths can be achieved by precipitation-hardening. During the 1980s, extensive research and development was carried out on alloys with high lithium contents (>2 wt%≡~8 at%) such as AA 8090 (Al 2.4 Li 1.2 Cu 0.7 Mg 0.12 Zr) (wt%). The mechanical properties of these 'second-generation' Al–Li alloys, however, did not match those of conventional Al (-Zn)-Mg-Cu alloys, and the lower fracture toughness of these alloys (for equivalent strengths was a particular problem. Thus, 2nd generation Al–Li alloys did not see widespread use. The experience with 2nd generation Al–Li alloys led to the development of '3rd generation' alloys with lower Li contents (0.75–1.7 wt%), and some of these alloys have a better overall balance of properties, including fracture toughness, than the best available conventional Al alloys. These 3rd generation Al–Li alloys should therefore see extensive use in future civil and military aircraft. This chapter on fracture toughness and fracture modes of aerospace Al–Li alloys outlines why fracture toughness is important for aerospace structures and components, and summarises testing procedures and terminologies in regard to plane-strain and plane-stress fracture toughness. The relationships between fracture toughness/fracture modes and microstructural features such as grain morphology, constituent particles, impurity phases, matrix precipitates, grain-boundary precipitates, and grain boundary segregation, are then discussed. Proposed explanations for the low fracture toughness of 2nd generation Al–Li alloys, associated with low-energy intergranular and transgranular shear fractures, are discussed in some depth, followed by a summary of the alloy-design principles behind the development of 3rd generation Al–Li alloys with a much improved resistance to low-energy fracture modes. Quantitative data for fracture toughness of 2nd and 3rd generation Al–Li alloys in comparison with conventional Al alloys are provided, showing that 3rd generation Al–Li alloys have outstanding combinations of toughness and strength combined with reduced densities. The superior toughness of 3rd generation Al–Li alloys compared with 2nd generation alloys is reflected in the differences in fracture-surface topography and fracture path. The chapter concludes with a summary of the current and proposed uses of 3rd generation Al–Li alloys in aircraft structures and components

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