

Materials Science & Engineering Doctoral Defense

Corrosion and Corrosion-Fatigue Behavior of 7075 Aluminum Alloys Studied By In Situ X-Ray Tomography

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abstract

7XXX Aluminum alloys have high strength to weight ratio and low cost. They are used in many critical structural applications including automotive and aerospace components. These applications frequently subject the alloys to static and cyclic loading in service. Additionally, the alloys are often subjected to aggressive corrosive environments such as saltwater spray. These chemical and mechanical exposures have been known to cause premature failure in critical applications. Hence, the microstructural behavior of the alloys under combined chemical attack and mechanical loading must be characterized further. Most studies to date have analyzed the microstructure of the 7XXX alloys using two dimensional (2D) techniques. While 2D studies yield valuable insights about the properties of the alloys, they do not provide sufficiently accurate results because the microstructure is three dimensional and hence its response to external stimuli is also three dimensional (3D). Relevant features of the alloys include the grains, subgrains, intermetallic inclusion particles, and intermetallic precipitate particles. The effects of microstructural features on corrosion pitting and corrosion fatigue of aluminum alloys has primarily been studied using 2D techniques such as scanning electron microscopy (SEM) surface analysis along with post-mortem SEM fracture surface analysis to estimate the corrosion pit size and fatigue crack initiation site. These studies often limited the corrosion-fatigue testing to samples in air or specialized solutions, because samples tested in NaCl solution typically have fracture surfaces covered in corrosion product. Recent technological advancements allow observation of the microstructure, corrosion and crack behavior of aluminum alloys in solution in three dimensions over time (4D). In situ synchrotron X-Ray microtomography was used to analyze the corrosion and cracking behavior of the alloy in four dimensions to elucidate crack initiation at corrosion pits for samples of multiple aging conditions and impurity concentrations. Additionally, chemical reactions between the 3.5 wt% NaCl solution and the crack surfaces were quantified by observing the evolution of hydrogen bubbles from the crack. The effects of the impurity particles and age-hardening particles on the corrosion and fatigue properties were examined in 4D.

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