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Stress Corrosion Cracking of AZ91 + *x*Ce Alloy Using Proof Ring Test in ASTM D1384 and NaCl-K_2CrO_4 Solutions

S. Manivannan, S. Senthil Kumaran, A. Vallimanalan, R. Mahendran, and S.P. Kumaresh Babu

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The effect of cerium addition on AZ91 magnesium alloy and its influence on stress corrosion cracking (SCC) were studied using constant load proof ring testing NaCl-K_2CrO_4 and ASTM D1384 solutions at 70 and 80% of yield stress, respectively. The investigation revealed that the optimum grain refinement of desired phases occurred with 0.5% addition of cerium. The addition levels of cerium above 1.5 wt.% to AZ91 alloy resulted in premature failures due to poor SCC resistance in both solutions (K_2CrO_4 and ASTM D1384 solutions). The microstructural studies of the experimental alloys were characterized by using optical and scanning electron microscopy. The elemental compositions of cerium-added AZ91 magnesium alloys were studied by energy-dispersive spectroscopy. The results indicate that the mode of SCC failure was found to be transgranular in nature along with secondary cracks containing cleavages which resulted from the hydrogen embrittlement and anodic dissolution phenomena. The AZ91 alloy with 0.5 wt.% cerium exhibits better mechanical properties and high stress corrosion resistance.

Keywords AZ91, cerium, cleavage, embrittlement, fractography, transgranular

1. Introduction

Magnesium alloys have been widely employed in automotive and aerospace application because of their low density, as well as high (excellent) specific strength, good dimensional stability, high damping capacity and good castability (Ref 1-4). It is well established that the use of magnesium alloys can increase the efficiency, thereby decreasing the fuel consumption and CO_2 emissions especially/particularly in transportation industries (Ref 5). The HCP structure of magnesium results in low ductility and low strength (Ref 6). However, they are susceptible materials when they are sensitized to the extent due to continuity of β-($Mg_{17}Al_{12}$) precipitate phase along α-grain boundaries. The as-said intermetallic β-($Mg_{17}Al_{12}$) phase is more anodic when compared to α-matrix, and it is electrochemically more active (Ref 7). To overcome these problems, addition of rare earths (RE) like cerium enhances the mechanical and corrosion properties by changing the morphology and by formation of intermetallic strengthening phase along the grain boundaries acting as corrosion barrier (Ref 8). Haitao Zhou et al. (Ref 9) studied the effect of cerium on hot-extruded AZ91 and found that Ce refines $Mg_{17}Al_{12}$ particles and a new rod-like Al_4Ce phase is formed. Also it is reported that (Ref 10, 11) the addition of cerium can enhance the mechanical properties of AZ91 alloys by grain refinement. According to Yu Fan et al. (Ref 12), addition of 2 wt.% Ce to magnesium alloy decreased the corrosion rate to 21.8%. As many magnesium alloy components are used in automobiles, they are often susceptible to stress corrosion in various corrosive environments. Many researchers reported that stress corrosion cracking becomes a serious problem for engineering components and structures. Failure due to SCC cannot be easily interpreted in its early stage, and the components did not show any deformation. Three conditions are required for SCC such as a susceptible material, a tensile stress and a corrosive environment. If any of the above conditions are not effective, the SCC will not happen (Ref 13). Sometimes corrosion pits can also result in initiation of SCC as stated by Parkinset al. (Ref 14). The threshold stress of a material is specific to its corrosive environment. So determining the value of threshold stress will give an insight on the safe service stress of the material in that particular environment without SCC. In this study, the alloys are prepared by casting route and it is aged. Heat-treated alloys were performed to study the effect of cerium on mechanical properties of AZ91 alloy and also to study the stress corrosion behavior of cerium-added AZ91 alloy in ASTM D1384 (Ref 15, 16) solution and 3.5% NaCl + 2% K_2CrO_4 solution (Ref 17) at 70 and 80% yield strengths, respectively. Time to failure and approximate threshold stress of the AZ91 alloys are evaluated, and optimum composition of cerium in AZ91 alloys showing better stress corrosion resistance and good mechanical properties is also studied. The present study discusses the stress corrosion behavior of cerium-added AZ91 in two different solutions.

S. Manivannan, Department of Mechanical Engineering, Karpagam Academy of Higher Education, Coimbatore, Tamil Nadu 641 021, India; **S. Senthil Kumaran**, Department of Mechanical Engineering, VIT, Vellore, Tamil Nadu 632014, India; and **A. Vallimanalan, R. Mahendran,** and **S.P. Kumaresh Babu**, Department of Metallurgical and Materials Engineering, National Institute of Technology, Tirchirappalli, Tamil Nadu 620 015, India. Contact e-mail: manivannan.s@kahedu.edu.in.

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