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ScienceDirect

Procedia Engineering 160 (2016) 158 – 166

Procedia Engineering

www.elsevier.com/locate/procedia

XVIII International Colloquium on Mechanical Fatigue of Metals (ICMFM XVIII)

Electrochemical-Controlled Characterization of the Corrosion Fatigue Behavior of Creep-Resistant Magnesium Alloys DieMag422 and AE42

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Abstract

Magnesium alloys offer a high potential for lightweight construction, however their application range is limited due to their low corrosion resistance. In the present study the corrosion fatigue behaviors of the creep-resistant alloys DieMag422 and AE42 were characterized and compared. In this context, fatigue properties of specimens in sodium chloride solutions as well as under simultaneous galvanostatic anodic polarization were assessed in constant amplitude tests. The results were correlated with the corrosion behavior of the alloys, which was investigated in instrumented immersion tests. Corrosion- and deformation-induced changes in microstructure were observed by light and scanning electron microscopy, yielding a structure-property relationship for a comprehensive understanding of corrosion fatigue processes. The reduction of the corrosion fatigue strength with increasing corrosion impact could be quantitatively correlated with the adjusted corrosion rates. However, different corrosion morphologies between both materials were found, leading to varying influence on the corrosion fatigue behavior.

Peer-review under responsibility of the University of Oviedo

Keywords: Magnesium alloy, DieMag422, AE42, corrosion fatigue, instrumented immersion

1. Introduction

Due to their low density, beneficial strength to weight ratio and good castability, magnesium alloys are very attractive for lightweight applications, e.g. in automotive applications [1]. However, their application range is strongly limited due to their low corrosion resistance, especially in chloride containing electrolytes [2,3], which also

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Peer-review under responsibility of the University of Oviedo
doi:10.1016/j.proeng.2016.08.876

impairs the fatigue properties under combined corrosive and fatigue load [4]. For automotive applications, such as gearboxes and crankcases, materials have to withstand loadings at temperatures up to 200 °C, which additionally requires a good creep resistance. Currently available alloys for application temperatures up to 300 ° C often contain rare earths as alloying elements and are therefore relatively expensive. As a result, extensive research has been carried out over the last years to develop creep-resistant magnesium alloys free from rare earths [5,6].

In the present study, the influence of corrosion on the microstructure and the dependent mechanical properties under cyclic load for the newly developed creep-resistant magnesium alloy DieMag422 (Mg-4Al-2Ba-2Ca) and the rare earth containing alloy AE42 was characterized and compared. The investigations aimed at a mechanism-oriented description of the interdependency of corrosion and fatigue effects on the corrosion fatigue strength. For this purpose, the corrosion fatigue behavior was investigated at equivalent corrosion rates, which were adjusted using different environments and targeted polarization of the alloys, which exhibited actually different corrosion resistances.

2. Experimental procedure

2.1. Materials

The experiments were conducted with the magnesium alloys DieMag422 and AE42. Chemical compositions of the materials, which were cast using a permanent mould direct chill casting process, are given in Table 1.

Table 1. Chemical compositions (wt.-%) of DieMag422 and AE42.

Element	Al	Ba	Ca	Ce	Fe	Mn	Nd	Pr	Mg
DieMag422	4.6	1.6	1.8	-	0.02	0.13	-	-	bal.
AE42	3.8	-	-	1.2	0.02	0.013	0.29	0.07	bal.

SEM micrographs (Fig. 1a) and EDX analyses of DieMag422 indicate the texture to consist of three phases. At the grain boundaries of the primary α-Mg phase a compact Ba-rich phase ($Mg_{21}Al_3Ba_2$) and a lamellar Ca-rich phase (Al_2Ca) precipitate [6]. In case of AE42 a two-phase texture was found (Fig. 1b) with a lamellar $Al_{11}RE_3$ phase between the primary Mg phase [7].

a) b)

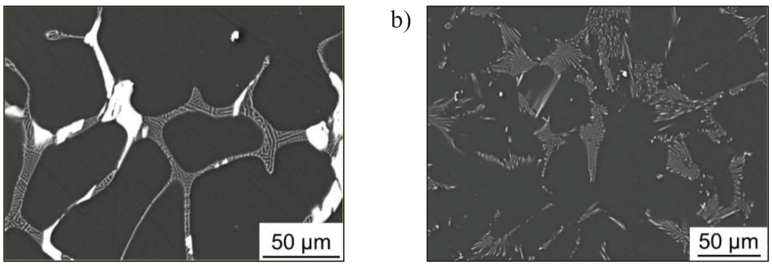

Fig. 1. SEM images of DieMag422 (a) and AE42 (b) in initial states.

2.2. Corrosion tests

Aim of corrosion tests was to adjust equivalent corrosion rates for both investigated materials, which were determined by means of instrumented immersion tests. Since both materials exhibit different corrosion resistances, various media were used and partially additional anodic polarization of the specimens was necessary to adjust similar corrosion rates. Eventually, DieMag422 was tested in distilled water (i.e. 0 mol L^{-1} NaCl solution) and