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Effect of aging time and aging temperature on fatigue and fracture behavior of 6063 aluminum alloy under seawater influence

R.A. Siddiqui, S.A. Abdul-Wahab *, T. Pervez

Department of Mechanical and Industrial Engineering, College of Engineering, Sultan Qaboos University, P.O. Box # 33, Al-Khod 123, Oman

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Abstract

This paper describes experimentally the effect of seawater corrosion, aging time, and aging temperature on the fatigue resistance property of 6063 aluminum alloy. The 6063 aluminum alloy that was used for the study was heat treated and soaked in seawater for different intervals of time between 2 and 30 weeks. It was found that the maximum fatigue resistance property in the 6063 aluminum alloy was observed when aged between 7 and 9 h and heat treated at temperatures between 160 °C and 200 °C. Generally at constant load, the results indicated that the number of cycles to fail the 6063 aluminum alloy decreased with increasing the soaking time in seawater. Moreover, fracture surfaces were considered and studied under a scanning electron microscope (SEM). The results showed that the brittle fracture pattern tended to occur with the increase in aging time and temperature. The fatigue striations were observed very clearly at low and peak aging temperature. The increase in the fatigue resistance property with aging time was linked with the vacancies assisted diffusion mechanism and also by the hindering of dislocation movement by impure atoms.

Keywords: Aluminum alloy; Fatigue resistance; Seawater corrosion; Aging time; Aging temperature

1. Introduction

Nakayama and Nakanishi [1] investigated the effects of the final-aging condition and the step quenching treatment on the two-step-ageing behavior of a 6063 aluminum alloy. In their study, they applied tensile test together with electrical resistivity and differential scanning calorimetry. The results showed that the clusters formed during the pre-aging treatment at a relatively low temperature for a long time had a marked effect on the tensile properties after the two-step-aging treatment.

Tokaji and Gashima [2] studied the fatigue behavior of the 6063 aluminum alloy in a corrosive environment. He performed the fatigue test in distilled water as well as in 3% sodium chloride (NaCl) solution. He noticed that the fatigue strength of the 6063 alloy decreased with increasing aggressive environments. Moreover, he found that the fatigue strength of the 6063 alloy was nearly the same as those of the 2024 and 7075 alloys in 3% NaCl solution. The 6063 alloy showed low susceptibility to corrosive environment, but fatigue cracks were initiated at the grain boundaries when the environment became more aggressive.

Artificial neural networks (ANNs) were used to search the optimum technology proper for pre-aged AA 6063 aluminum alloys [3]. The ANNs were used to compare experimental results. Moreover, test data were used for the training of the ANNs. The paper focused mainly on examining the changes in the hardness of AA 6063 alloys when heat treated at different pre-aging treatments. A significant correlation was found between experimental hardness and ANN hardness results.

Jiang et al. [4] investigated the influence of aging condition on the tensile and fatigue fracture behavior of the 6063 aluminum alloy. He examined the aluminum alloy 6063 that was heat treated in the under aged, peak aged and over aged conditions. Both fatigue and tensile tests were carried out. In addition, the fractured surfaces were investigated by

* Corresponding author. Tel.: +968 2414 1360; fax: +968 2414 1316.
E-mail address: sabah1@squ.edu.om (S.A. Abdul-Wahab).

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using SEM. The experimental results indicated different modes of fracture under different aging conditions.

Luo et al. [5] investigated the fatigue performance of hydro formed sections of 5754 and 6063 aluminum alloys. The results indicated that the hydro formed 5754 alloy had a higher fatigue resistance than the 6063 material. The higher fatigue lives of the 5754 alloy compared to the 6063 alloy in both the low and high cycle life regimes are due to the increased fatigue crack initiation and propagation resistance of the 5754 alloy, and its probable cyclic strain-hardening behavior.

Kumar and Garg [6] examined the fatigue cracks growth rate in a 6063 T_6 aluminum alloy under different stress ratios. They observed that the growth rate of fatigue cracks in a pre-strained material was more than that of as-received material. In addition, the crack opening displacement measurements showed that the crack closure occurred to a lesser extent in the pre-strained material. The increase in the yield strength of the 6063 T_6 alloy also increased the fatigue crack growth. However, the fatigue life of the alloy decreased with an increase in the percentage of pre-strain. Al–Mg–Si alloys 6063 and 6082 were heat treated in under aged and peak aged conditions [7]. The tensile and fatigue tests were performed and resultant fractured surfaces were studied under a scanning electron microscope. The alloys showed different tensile and fatigue properties, and different modes of fracture. The difference in fatigue and tensile properties were due to slip distribution.

The effect of grain refining master and heat treatment on the properties of 6063 aluminum alloys was investigated by Zhong and Liu [8]. Further, the effect of pre-aging temperature on the behavior in the early stage of aging at a high temperature for Al–Mg–Si alloy was studied by Saga et al. [9].

The effect of lubricating anodic files on the fretting fatigue strength of aluminum alloys was investigated for 6063 T_5 specimens [10]. It was observed that the plain fatigue strength of the specimens with a anodic film was lower than that of the specimens with a lubricating anodic film. This might result from the brittleness and tensile residual stress of the anodic film, which attributed to the cracking at a lower applied stress.

Jiang et al. [11] investigated the effect of different aging conditions with different chemical composition is and dispersoid content on fatigue fracture behavior of Al–Mg–Si alloys. It was found that the dispersoid phase could alter the mode of fatigue fracture by the influence on the deformation uniformity of the alloy.

The stress–strain response under cyclic loading at a fixed plastic strain amplitude condition was examined for cast alloys comprising age-hardenable aluminum, 7% Si and 0.4% Mg (A-356) [12]. Special attention was paid to the effect of solidification structure and aging condition on cyclic hardening behavior. It was found that cyclic hardening behavior was sensitive to the solidification structure. The refined grain size, DAS and unmodified acicular eutectic Si particles increased the stress level of the cyclic hardening curve. A drastic change in the cyclic hardening behavior was observed by the changing aging conditions.

Van Den Avyle and Sutherland [13] investigated the fatigue characteristics of typical materials including the 6063 Al–Si–Mg alloy used for vertical axis wind turbine blades. They measured two types of data: (a) stress versus number of cycles (S–N curve) and (b) fatigue crack growth rate. The S–N experiment was conducted on 6063 extruded material using 100 bend specimens cycled at a fine alternating stress amplitude. The cyclic crack growth rates were measured using three loading rates.

A search of the literature has identified that considerable work has been carried out on precipitation hardening of 6063 aluminum alloys. As relatively inconclusive work is available in the literature, work is needed to study the effect of aging time and temperature of Al–Si–Mg alloys on fatigue and fracture behavior under seawater influence. Therefore, this paper is conducted with the objective of investigating the effect of aging time and temperature on the fatigue fracture behavior of 6063 Al–Si–Mg alloys that are effected by seawater for variable duration. The present work is very important since its results will improve our common understanding of the effect of aging time and temperature on the fatigue fracture behavior of 6063 Al–Si–Mg alloys under seawater influence.

2. Methodology

The Al–Mg–Si alloy used in the experiments was prepared in Dubai in the form of billets. The 6063 aluminum profiles were rolled and fabricated by the Oman National Aluminum Company, Sultanate of Oman. The chemical composition of this alloy is illustrated in Table 1.

The standard fatigue specimens were prepared according to BSS specifications. They were fabricated at the Sultan Qaboos University in the College of Engineering Workshop. In order to preserve the super saturated solid solution at room temperature, the 6063 aluminum alloy specimens were soaked in a furnace for 2 h at 520 ± 5 °C followed by quenching in water at room temperature. This process is known as solution heat treatment. After solution heat treatment, all the 6063 Al-alloy specimens were kept in a freezer. This is very important to avoid the natural aging of the alloy at room temperature. The artificial age hardening of the specimens was carried out in a muffle furnace. In addition, SEM was used to observe the mode of fracture. The values of different parameters used in this study (aging time, immersion time, and age hardening temperature) are indicated as shown in Table 2.

Table 1
Chemical composition of 6063 Al-alloy

	Element					
	Al	Si	Mg	Fe	Mn	Cu
Wt.%	Balance	0.535	0.514	0.081	0.059	0.083