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Effect of heat treatments on the tensile strength and SCC-resistance of AA7050 in an alkaline saline solution

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Abstract

Effect of heat treatments (namely T6, T73, RRA, OP1 and OP2) on the tensile strength (TS) and stress corrosion cracking (SCC) resistance of aluminum alloy 7050 in 3.5% NaCl solution at pH 12 has been investigated using constant extension rate tester (CERT). T6 increases the TS but decreases the SCC-resistance. To the opposite, T73 (i.e., T6 + 160 °C/30 h) increases the SCC-resistance but decreases the TS. Retrogression and re-aging (RRA, i.e., T6 + 200 °C/10 min + water quench + 120 °C/24 h) increases both TS and SCC-resistance but this treatment confines only to thin and small specimens. Step-quench aging (SQA, i.e., 470 °C/1 h + step-quench to 200 °C/1 min + water quench/or air cooling + natural aging at room temperature/1 week + 120 °C/24 h) provides a relatively practical treatment to enhance both the TS and SCC-resistance even the specimen either having quenched in water (OP1) or cooled in the air (OP2) in the process. Through electrochemical testing and micro-structural examination, we found that both the TS and SCC-resistance of AA7050 is governed by the microstructures that depend on heat treatments.

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1. Introduction

Aluminum alloys of 7000 series (Al–Zn–Mg–Cu) have been introduced since 1943 and used extensively as airframe structures due to their highly specific strength [1]. It was reported that the mechanical strength of AA7075 could be increased through a T6 tempering (i.e., a solution treatment followed by a peak aging), and its resistance to stress corrosion cracking could be enhanced by T73 tempering (i.e., a solution treatment plus an over-aging) [2]. Unfortunately, treatment of T6 induces a huge diminish in SCC-resistance and T73 causes an expense of strength from 10% to 15% [3].

Many efforts have been made by a number of investigators to find out a tempering process that is eligible for enhancing the SCC-resistance of AA7075 without sacrifice its strength. In 1993, Cina [4] patented a retrogression and re-aging process and claimed this novel process is capable of increasing the SCC-resistance without expense the mechanical strength. He successively demonstrated the function of RRA with many examples. However, a short-term retrogression (at 200–280 °C in a few minutes) confines the RRA to specimens that are thin or in small size [5]. Kanno and coworkers proposed a process of step-quench (SQ) for getting rid of the disadvantage of RRA process [6]. Recently, Ou et al. [7] reported that step-quench and aging processes accomplish a practical treatment for AA7000 series with good strength and satisfactory SCC-resistance. The step-quench and aging process [7] was conducted including a sequence of stages. A specimen via water-quenched in this sequence is named OP1 and that via air-cooled is named OP2.

AA7050, with composition similar to AA7075 in major alloying elements (e.g., Zn, Mg and Cu) but 0.11% Zr in place of 0.20% Cr, is another popular airframe alloy. AA7050 is reported a superior material to AA7075-T6 in overall properties regarding a combination of strength, toughness and SCC-resistance [8]. This superiority may be ascribed to the presence of trace Zr that is responsible for the microstructure where the GP zone is stabilized in a wider range of temperatures. Consequently, the mechanical properties and SCC-resistance is improved [9]. However, no detailed electrochemical investigation has been reported.

Many authors [10–12] reported that the mechanical strength of AA7075 is predominated by the microstructure that is previously determined by the type of heat treatments. Some other authors [13–15] mentioned that the SCC behavior of AA7075 depends upon the environment, microstructure of specimens and their interaction. However, the SCC of AA7050 was seldom reported [16,17]. Lin and Yang studied [18] the fatigue behaviors of AA7050 under tempers of T6 and T73, in both air and saline environments. They found that T73 temper improves the resistance of corrosion-fatigue-cracking to a less extent than does the SCC-resistance. They concluded that the unpredictable result was beyond the rationalization simply on the aspect of microstructure but gave no reason.

The effect of heat treatment on the mechanical strength (in the air) and SCC-resistance (to the alkaline saline solution) of AA7050 was of interest. The electrochemical behavior of AA7050 undergone various heat treatments such as T6, T73, RRA, OP1 and OP2 was concerned. An attempt was made in this work to interpret the effect of heat treatment on the tensile strength and SCC-resistance of AA7050. Constant extension rate testing was