Influence of aging on quench sensitivity effect of 7055 aluminum alloy

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ABSTRACT

The influence of aging on quench sensitivity effect of 7055 aluminum alloy was investigated by means of tensile properties and electrical conductivity tests. The microstructures were characterized by optical microscopy (OM) and transmission electron microscopy (TEM). Compared with single aging, duplex aging led to higher mechanical properties and lower electrical conductivity of the air quenched alloy, thus reduced the quench sensitivity effect. This was attributed to the elimination of negative effects due to loss of vacancies during slow quenching by duplex aging, which resulted in a higher density of stable G.P. zones in the matrix. Within the studied temperature 20–100 °C, a higher temperature pre-aging was favorable for reducing the quench sensitivity effect and the optimal duplex aging was 100 °C/24 h + 121 °C/24 h in this work.

1. Introduction

7xxx aluminum alloys are quench sensitive because inadequate quenching after solution heat treatment leads to drop in strength after aging. This problem is especially critical for thick plates or heavy forgings as slower quenching in the center section results in inhomogeneity and drop in properties [1,2]. For its practical importance, many attempts have been made to understand the mechanisms responsible for quench sensitivity and to reduce it [3–11]. Generally for 7xxx aluminum alloys, quench sensitivity is primarily caused by loss of solutes due to heterogeneous precipitation during slow quenching, which is often associated with dispersoid particles and (sub)grain boundaries [3,4]. Furthermore, the decreased vacancy concentration after slow quenching plays a part in quench sensitivity [7,8]. According to some investigations [2,6,8,11], many parameters, for instance, the total amount of alloying elements, Zn:Mg ratio, the trace elements(Cr, Mn or Zr) and degree of recrystallization, exert influence on quench sensitivity.

Improvements in aircraft structure, which demand a superior combination of high strength, fracture toughness and stress corrosion cracking resistance, have led to the development of 7055 aluminum alloy. 7055-T77 alloys provide higher strength about 10% than 7150-T6 and 30% than 7075-T76 with high fracture toughness and good resistance to corrosion and to the growth of fatigue cracks, and these attractive properties are attributed to the high Zn/Mg and Cu/Mg ratios [12]. This alloy contains more amount of (Zn + Mg + Cu) elements, which may promote precipitation of equilibrium phases during slow quenching [13], thus leading to large quench sensitivity. Few investigations on the problem of this alloy have been reported in the literatures. The authors have investigated the TTP (time–temperature-properties) diagrams for this alloy [14], which was indeed found to be more quench sensitive than some other 7xxx aluminum alloys. Slow quenching definitely leads to drop in the mechanical properties of the alloy after aging, which often occurs in the middle of thick plates. In practice, it is desirable to reduce the drop percentage in the mechanical properties caused by slow

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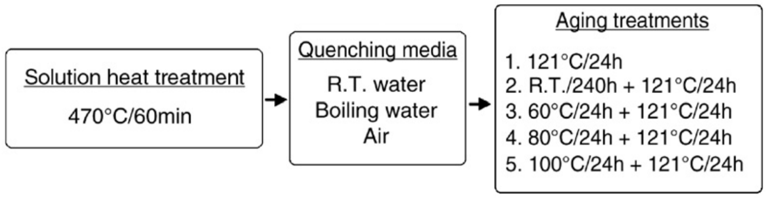

Fig. 1 – Experiment scheme carried out in this work.

quenching, namely reduce the quench sensitivity effect, so as to decrease differences in the properties between the middle and the surface part of thick plates. The quantification of quench sensitivity effect may depend on the temper of the alloys, so this effect may be reduced by modification of aging treatments [6,15].

In this work, the influence of aging parameters on the microstructures and mechanical properties of 7055 aluminum alloy subjected to different quenching rates was investigated with the purpose of reducing the quench sensitivity effect by aging.

2. Experimental

The nominal chemical compositions of the studied 7055 type aluminum alloy were Al–8.0%Zn–1.8%Mg–2.1%Cu–0.18%Zr (wt.%). The amount of Fe + Si was kept below 0.15%. The ingots of 20 mm × 150 mm in cross section and 200 mm in height were made by an induction furnace. The ingots were homogenized by heating to 465 °C with 0.8 °C/min and holding for 24 h, and then cooled in air. After preheating at 420 °C for 2 h, the homogenized ingots were rolled to a sheet of 2.2 mm in thickness with 10 passes.

The samples with the size of 70 mm length × 20 mm width × 2.2 mm thickness were cut from the sheet and solution heat treated at 470 °C for 60 min. Three quenching media, R.T. (room temperature) water, boiling water and air were used to obtain different cooling rates, which were measured by embedded thermocouple at the center of the sample. This was carried out on a Geeble1500 machine. The average cooling rates through the critical temperature range 420–210 °C were found to be about 1510 °C/s, 72 °C/s and 3 °C/s for R.T. water, boiling water and air quenching respectively. After quenching, the samples were aged immediately with details indicated in Fig. 1.

The Vickers hardness of the aged samples was tested on a HV-10B machine with a load of 3 kg, and 5 measurements were made on each sample to obtain an average value. The ambient tensile properties were tested with a CSS-44100 testing machine. Electrical conductivity was measured with an eddy current conductivity meter and then converted to a % IACS. The microstructures were observed by optical microscopy (OM) and TecnaiG^2 20 transmission electron microscopy (TEM) operated at 200 kV. Samples of 3 mm in diameter, 0.08 mm in thickness for transmission electron microscopy observation were electropolished using 30% HNO_3 + 70% CH_3OH solution below −20 °C.

3. Results

3.1. *Properties of the Alloy*

The mechanical properties and electrical conductivity of the aged alloy are indicated in Fig. 2. Slower quenching rate led to lower mechanical properties but higher electrical conductivity after the same aging treatment.

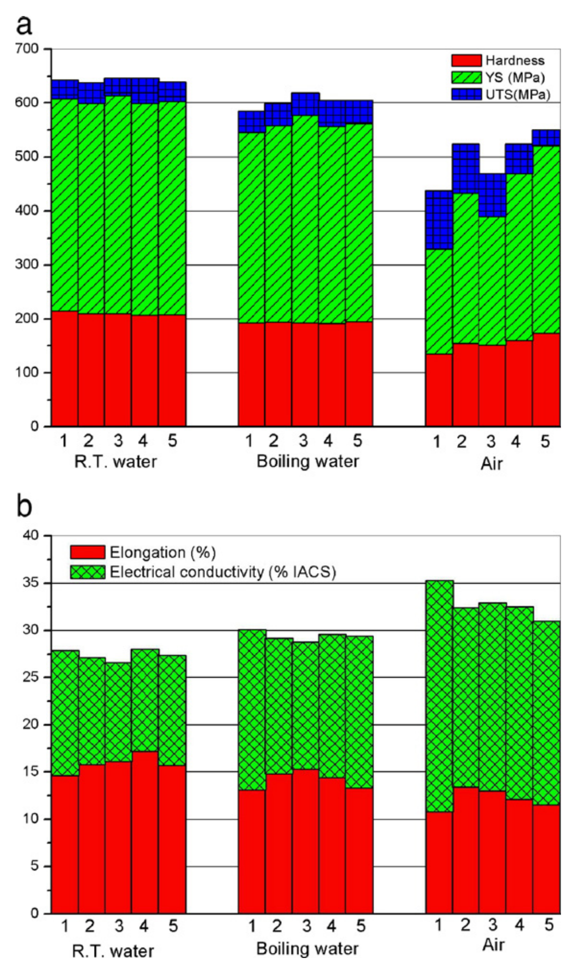

Fig. 2 – Mechanical properties and electrical conductivity of the aged alloys (a) hardness, yield strength (YS) and ultimate strength (UTS) (b) elongation and electrical conductivity; details of aging treatments 1–5, see Fig. 1.