Abstract

2048 aluminum alloy is a heat treatable wrought alloy with good corrosion resistance, high specific strength and high fracture toughness. Although various thermomechanical treatments exist in the case of AA2024, no such treatment for AA2048 has been determined in the literature, to the best of our knowledge. Therefore, the aim of this study is to analyze the effect of thermomechanical treatment on aging characteristics of AA2048. Since the data on artificial aging behavior of AA2048 was not established well in literature, the first step of this study includes the determination of aging curve by hardness measurements. Thermomechanical treatment, on the other hand, is an effective method to increase the rate of precipitation. After obtaining the hardness variation with aging time, the effect of deformation on aging behavior was analyzed. With this aim, cold-rolling up to 20% was applied after solutionizing at 500 °C, followed by aging up to 6h at 200°C. Hardness measurements were employed to observe the effect of cold-rolling on aging behavior.

1. Introduction

Aluminum alloys are the most commonly used alloys among the non-ferrous systems because of their superior properties in combination with relatively low cost. They are commonly used in aviation industry because of their good formability, high corrosion resistance at atmospheric conditions, high specific strength, relatively good fracture toughness and low density [1-2].

2XXX series aluminum alloys are among the high strength aluminum alloys due to their ability to be heat-treated. Most of the studies in the literature on 2XXX series focus on 2024 alloy [3,4,5,6,7,8]. However, 2048 alloy is thought to be a better alternative to 2024 since it has higher ductility and fracture toughness [1].

The strength of the age-hardenable alloys can be further increased with the aid of thermomechanical treatments.

There are studies on the thermomechanical treatment of age-hardenable aluminum alloys in the literature, which employ cold deformation methods such as rolling, extrusion, equal channel angular pressing (ECAP) [9,10,11,12]. Thermomechanical processing of age-hardenable alloys has commonly conducted by introduction of cold-deformation between the solutionizing and aging steps of the aging heat-treatment. Since the increased dislocation density enhances the precipitation, peak-aging time can be reduced, and even higher strength values can be obtained with this type of treatment. Accordingly, the aim of this study is to analyze the effect of thermomechanical treatment on the strength of 2048 alloy. With this aim, cold-rolling up to 20% was applied after solutionizing at 500°C, followed by aging at 200°C. Hardness measurements were employed to observe the effect of thermomechanical treatment on the strength of 2048 alloy.

2. Experimental Procedure

Commercial 2048-T351 alloy has been purchased from Seykoç Altiminyum Paz. ve San. Tic. Ltd. Şti. in the form of plates with a length of 100 mm, width of 50 mm and thickness of 10 mm. Elemental analysis of the plates (Table 1) has been conducted by UV-VIS Spectrometer (SPECTROMAXx, Spectro Analytical Instruments GmbH, Germany).

Table 1. Quantitative analysis result of 2048 plate (values are given in wt%).

<table>
<thead>
<tr>
<th>Al</th>
<th>Cu</th>
<th>Mg</th>
<th>Mn</th>
<th>Fe</th>
<th>Si</th>
</tr>
</thead>
<tbody>
<tr>
<td>94,1</td>
<td>3,44</td>
<td>1,43</td>
<td>0,502</td>
<td>0,12</td>
<td>0,0494</td>
</tr>
</tbody>
</table>

The transformation temperatures of as-received AA2048 (Figure 1) were determined by differential scanning calorimeter (DSC) (Q2000, TA Instruments, U.S.A.) with a heating rate of 10°C/min. The analysis was performed under nitrogen atmosphere in a temperature range of 50°C to 400°C. According to DSC curve, three exothermic and one endothermic reaction have taken place. Similar to
2024 aluminum alloy, 2048 alloy has displayed two small exothermic peaks around 60°C and 80°C, respectively. These peaks were attributed to the formation of GPB (Guinier-Preston-Bagaryatsky) zones [12]. The endothermic peak between 160°C and 210°C was believed to be due to the dissolution of GPB zones. The third exothermic peak at around 240°C, on the other hand, was believed to be due to S-type precipitate formation.

Figure 1. DSC curve of as-received plate.

2.1. Heat Treatment

Solutionizing of 2048 plates was conducted at 500°C for 16 hours (ST). After solutionizing, artificial aging was performed at 200°C for 6 (ST-6), 12 (ST-12), 18 (ST-18) and 24 hours (ST-24), respectively.

2.2 Thermomechanical Treatment

In order to analyze the effect of deformation, 10%, 15% and 20% deformation have been applied by cold rolling before aging (ST-C10, ST-C15, ST-C20). The artificial aging temperature was kept constant at 200 °C.

2.3 Characterization Studies

X-ray diffraction (XRD) analyses were conducted using a conventional diffractometer (MiniFlex600, Rigaku, Japan) with Cu-Kα radiation, operating at 40 kV and 15mA. The measurements were performed at 2θ interval of 30°-90° with a scanning speed of 2°/min. Moreover, hardness values were measured with Vickers micro hardness (MIC 010, EMCO-TEST, Austria) after each treatment by application of 5 kg. load for a holding time of 10 seconds. The average values of at least five measurements were used to determine the hardness values.

3. Results and Discussion

XRD results of artificially aged (ST-6) and thermomechanically treated (ST-C15) 2048 alloys are given in Figure 2. Although, there is slight evidence of Al2Cu and Al2CuMg precipitate formation after artificial aging and thermomechanical treatment, respectively, it was hard to deduce any certain conclusion since the peaks of the precipitates either coincide with that of α-Al peaks or they have very low intensity making them hardly be differentiable from the background noise [13,14].

Figure 2. XRD results of a) ST-6 and c) ST-C15.

The effects of both aging and thermomechanical treatments were more recognizable from the hardness test results. The hardness was increased from 106 HV (after solutionizing) to 146 HV after aging at 200 °C for 18 hours (Figure 3). The prolonged aging up to 24 hours has resulted over-aging and accordingly lower hardness.

Figure 3. The effect of artificial aging time on hardness.
The hardness was further increased by the applied cold-rolling before aging. As it is obvious from Figure 4, the maximum hardness of 153 HV was obtained after 15% deformation even though the aging time was reduced to 6 hours.

Further increase in the amount of deformation up to 20% has caused a decrease in hardness, which was believed to be due to either over-aging of 2048 alloy or increase of the recovery rate before the nucleation of precipitates.

Since the peak hardness was achieved at 15% deformation, the effect of aging time on the hardness of thermomechanically treated 2048 alloy has been investigated by varying the aging time. As it was given in Figure 5, increased aging time at 200°C has led to a decrease in the hardness. Accordingly, it can be said that the peak aging condition after 15% cold deformation has been attained by 6 h aging at 200 °C.

4. Conclusions

In the present work, the artificial aging conditions of 2048 aluminum alloy as well as the effect of deformation on the aging behavior has been investigated and following results are obtained:

1) The peak hardness of 146 HV was obtained by aging at 200 °C for 18 h.

2) Artificial aging time has been decreased from 18 hours to 6 hours by applying cold rolling prior to aging.

3) Hardness has been increased from 131 HV to 153 HV with cold rolling before aging while keeping aging time constant at 6 hours.

4) It was observed that, increasing deformation amount from 10% to 15% led to an increase in hardness from 149 HV to 153 HV. However, further increase in deformation up to 20% has caused a decrease in hardness, which was believed to be due to either over-aging of 2048 alloy or increase of the recovery rate before aging.

References