Studying the Intermetallic Compounds in the Microstructure of the 8006 Aluminum Alloy Sheets and Foils

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Abstract

This research studies the microstructure of the 8006 alloys (AlFeMn), which is transformed into sheets and foils with different thicknesses during rolling. The 8006 alloys are mostly manufactured through a two roller casting process. The microstructure of the sheets produced by this method is fine and suitable. The chemical formula of the alloy includes 1.2%-2% Fe, 0.3%-1% Mn and a maximum of 0.3% Si. The experiments confirm the presence of iron, manganese, and silicon compounds in the 8006 alloy structure during casting and rolling. A scanning electron microscopy and EDS analysis were employed to examine the intermetallic compounds, and it was determined that the particles in the intermetallic compounds of AlFeMn in foils are smaller than the particles of these compounds in sheets.

1. Introduction

Composite materials and aluminium alloys are currently exceedingly attractive due to their substantial strength to weight ratio and anti-erosion properties for industrial applications such as aero-plane body manufacturing and hydrogen storage system [1-3]. Composite panels have been used for many mechanical engineering applications due to their resistance against static and buckling loads [4].

Aluminium panels are vastly used during the last century due to their lower weight than steel and relatively high strength [5]. In this study, the microstructure of the 8006 aluminium alloy microstructure is investigated. The 8006 alloys are produced mostly through the two roller casting process used in household foils and packaging industries. The main obstacle in using aluminium foils is the expensive cost of producing these sheets. The two roller casting process has been suggested as an alternative to direct chill casting to reduce production costs. The high freezing speed and hot rolling are combined [6-8]. The two roller casting process has advantages such as investments and low operating costs. The sheets produced by this process have a fine and suitable microstructure, and this process is excellent and efficient both metallurgically and economically [9, 10].

<table>
<thead>
<tr>
<th>Table 1. Reactions in the ternary system of Al-Fe-Mn [11]</th>
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<tbody>
<tr>
<td><strong>Reaction</strong></td>
</tr>
<tr>
<td>(FeMn)Al → Liq+FeAl3+MnAl3</td>
</tr>
<tr>
<td>Liq→ (FeMn)Al3+FeAl3+Al</td>
</tr>
<tr>
<td>L→ AL+ AL3Fe</td>
</tr>
<tr>
<td>L→ AL+ AL3(FeMn)</td>
</tr>
</tbody>
</table>

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The 8006 alloy has a ternary system of Al-Fe-Mn, and the chemical formula consists of 1.2%-2% iron, 0.3%-1% manganese and a maximum of 0.3% silicon. In the phase diagram of Al-Fe-Mn (see Figure 1), only the binary phases present at the corner of the diagram are rich in aluminium: FeAl₃, MnAl₆ MnAl₄. Liquid phase design and isotherm section at 627°C are shown in Figure 1(b), and invariable reactions of the 8006 alloy are shown in Table 1 [11-13]. Figure 2 shows the AL₆ (FeMn) initial crystals and AL₃Fe phase in the binary diagram of the 8006 alloys. These phases can be formed when the iron is highly concentrated.

Factors that affect the intermetallic compounds in the alloy microstructure are:

1- The cooling speed during freezing
2- Presence of fine additives
3- Amounts of iron, manganese, and silicon
4- Adding nucleate

That is how the type of intermetallic compounds significantly impact the produced foil and sheet [11].

2. Research Method and Materials

This study examines the 8006 alloy foil and sheet microstructure that the two roller casting process has produced. The chemical formula of the mentioned alloy is shown in Table 2. The samples of rolled sheets with the thicknesses of 230μm and 130μm and foils with the thicknesses of 68μm and 35μm were examined by the scanning electron microscopy and EDS analysis after metallography treatment and electro etching the samples with the Berker solution (with a 20V voltage and a duration of 90 minutes) with the solution.

<table>
<thead>
<tr>
<th>Element</th>
<th>Weight Percent %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td>1.2-2</td>
</tr>
<tr>
<td>Manganese</td>
<td>0.3-1</td>
</tr>
<tr>
<td>Silicon</td>
<td>max 0.4</td>
</tr>
<tr>
<td>Copper</td>
<td>max 0.1</td>
</tr>
<tr>
<td>Zinc</td>
<td>max 0.1</td>
</tr>
<tr>
<td>Titanium</td>
<td>0.012-0.025</td>
</tr>
</tbody>
</table>

Figure 1. Ternary diagram of the Al-Fe-Mn system a) The liquid mode b) The isothermal section at 627°C [11]
3. Results and Discussion

The microstructure of the rolled sheets with the thicknesses of 230μm and 130μm and foils with the thicknesses of 68μm and 35μm were examined. Figures 3 and 4 show the analysis of the images of the 8006 alloy in 230μm and 130μm thicknesses. In these figures, we can see the structure, fine particles, and their relatively uniform dispersion. In sheets that have a 230μm, the size of the intermetallic compounds varies between 20μm to 44μm, whereas the size of these particles in sheets with a 130μm thickness reach 18μm-33μm. We can see that in both thicknesses, the intermetallic compound particles depend on the rolling direction. By analyzing the scanning electron microscopy, it was determined that these intermetallic compounds are of the AlFeMn and FeAl₃ types.
In the sample with a 130μm thickness, the image of the electron microscopy confirms the presence of some compounds based on the analysis of iron (Figure 5A), manganese (Figure 5B), silicon (Figure 5C), and aluminium (Figure 5D) compounds and the presence of polyhedral compounds of Al-Fe-Mn. The Al-Fe-Mn compounds present on the sheet surface were confirmed by the Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray (EDAX) analysis and shown in Figure 6 and Table 3.

![Figure 4. The microstructure of the 8006 alloys with a 130μm thickness [15]](image)

<table>
<thead>
<tr>
<th>Element</th>
<th>Iron</th>
<th>Manganese</th>
<th>Aluminium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight Percent</td>
<td>17.5</td>
<td>7.06</td>
<td>75.44</td>
</tr>
</tbody>
</table>

Table 3. The chemical formula resulting from the EDS analysis in Figure 6.

![Figure 5. Image of the 8006-alloy sheet compound with a 130μm thickness of (a) iron (b) manganese (c) silicon (d) aluminum (e) x-ray image of iron and (f) manganese; 600 times [15]](image)
Foils with 35μm and 68μm thicknesses were analyzed. The microstructure is shown in Figure 7 (a and b). The size of the AlFeMn compounds is between 4μm and 13μm and they are uniformly distributed. The presence of some pores on the foil surface can include AlFeMn oxides or aluminium boride. Agglomerate oxides or oxide compounds are seen in some areas. Regarding the foil with a 35μm thickness, it has been shown that the AlFeMn compounds have been distributed in the same structure. The microstructure of the 35 μm thickness foil includes rough and large agglomerate compounds, and the brittle particles of AlFeMn and large particles of AlFeMnSi can be observed (see Figure 7 (c and d)). In the centre of the foil, the brittle particles of AlFeMn and AlFeMnSi have been shown that can break the foil (compare Figure 8 and Table 4). The SEM analysis confirms this statement (compare Figure 9 and Table 5).

![Figure 6](image)

**Figure 6.** (a) The SEM image of the 8006 foil with a 130μm thickness, (b) EDS analysis

<table>
<thead>
<tr>
<th>Element</th>
<th>Iron</th>
<th>Manganese</th>
<th>Silicon</th>
<th>Aluminium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight Percent</td>
<td>17.38</td>
<td>8.03</td>
<td>0.35</td>
<td>74.24</td>
</tr>
</tbody>
</table>

![Figure 7](image)

**Figure 7.** The optical microscope image of the 8006 foil with a 68μm thickness. (a) 50 times magnification, (b) 100 times magnification. The optical microscope image of the 8006 foil with a 35μm thickness. (c) 50 times magnification (d) 100 times magnification
4. Conclusions

The 8006 alloy foils and sheets were subjected to metallography treatment, and then the microstructure of the alloy was examined using the scanning electron microscope and EDS analysis. Based on the examinations on the intermetallic compounds of the 8006 alloys, the following statements are concluded:

- The size of the intermetallic compound particles in the foils was smaller than that in the sheets. Such that the size of the particles varied from 4μm to 13μm in the foils and 20μm to 40μm in the sheets.
- The nature of the particles of the intermetallic compounds was analyzed by the scanning electron microscope (SEM), and it was demonstrated that it is of the AlFeMn type. In some areas, the placement of these particles together will cause a break in the foil.
- Regarding the foils, the microstructure has a relatively uniform distribution of AlFeMn intermetallic particles. In some of these areas, these particles were large and brittle, which will cause a break in the foil.

Table 7. The chemical formula resulting from the EDS analysis in Figure 9

<table>
<thead>
<tr>
<th>Element</th>
<th>Iron</th>
<th>Manganese</th>
<th>Aluminium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight Percent</td>
<td>18.5</td>
<td>6.59</td>
<td>74.9</td>
</tr>
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</table>

References


