STUDY OF GRAIN STRUCTURE AND CRYSTALLOGRAPHIC ORIENTATION OF EXTRUDED 6xxx SERIES ALLOY PROFILES

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Abstract: Electrolytic etching of aluminium using Barker’s solution reveals the grain structure due to the resulting differences in the grey scale contrast for each individual grain. In this study, a correlation between grey scale grain contrast and texture properties is observed, using the techniques of Optical Microscopy and EBSD, therefore promoting Barker’s etch as a convenient method of producing an initial estimation of the attained texture properties of extruded profiles.

Keywords: ALUMINUM 6xxx SERIES, MICROSTRUCTURE, CRYSTALLOGRAPHY, OPTICAL MICROSCOPY, EBSD

1 Introduction

The microstructure of 6xxx series extruded profiles has been extensively studied with optical and electron microscopy. A thorough study is needed as the microstructure is directly related with the mechanical properties of the final product. Barker’s etch is the most common practice for revealing the grain structure, but differences in etching response may be observed in different samples. In our study texture analysis of several profiles is presented following grain structure examination. This offers useful information regarding formability properties of the manufactured parts and, therefore, unveils the crashworthiness. The occurrence of high contrast grains on the surface zones is also examined.

2. Experimental Procedure

Optical microscopy examination was performed on longitudinal and transverse sections in 6063 alloy hollow profiles in various cross-sections. Grain structure was revealed after Barker’s electrolytic etch. The optical, gray scale contrast of the grains was quantified using image analysis software by measuring the very bright and dark colour grains. For electron backscatter diffraction (EBSD) analysis the samples were electrolytically polished using Struers LectroPol-5 solution. Analysis was performed with an EDAX Hikari XP high-speed camera (rolling direction coincided with TD and normal direction with ND coordinates for longitudinal sections) [1], [2]. Calculation of recrystallization percentage was performed according to reference [3] based on grain orientation spread (GOS) criterion – which requires a value of GOS<2° for fully recrystallized grains.

3. Results

The microstructure of four samples was examined and results regarding the percentage of the area covered by Al grains with high grey scale contrast after Barker’s etch ranged between 8.9% and 25.9%. In the sample with the lowest value (sample 1) a separate Figure 1: Optical micrographs from longitudinal and transverse sections of extruded profiles showing the obtained grain structure with a different grey scale contrast, Barker’s electrolytic etch. (a) Sample 1 surface layer, (b) sample 1 mid-thickness, (c) sample 2 mid-thickness, (d) sample 3 and (e) sample 4 mid-thickness.
measurement including only the surface layer was performed, where the highest value of contrast was found (26.5%, see Table 1). Typical optical micrographs of the samples are given in Figure 1. EBSD mapping from mid-thickness areas revealed that the large majority of the equiaxed, recrystallized grains were oriented in all samples with the [001] crystal direction parallel to the sheet normal (note the reddish colour in the IPF maps). Quantification of these grains ranged from 7% to 28%, indicating a not very clear tendency of [001] crystal direction being respective to the calculations of contrast measurements. A lot clearer ratio was anticipated for the percentage of recrystallization calculated by the GOS 2° criterion and the percentage contrast of the same areas, with recrystallization values ranging between 82% and 100%. In the case of sample 4, which was observed transverse to extrusion direction, the highest relative intensity was found for directions [5 2 20] while a high intensity for [737] was also found (corresponding to light blue color grains).

![Figure 2](image-url)

**Figure 2**: EBSD IPF maps showing the grain orientation of (a) Sample 1 surface layer, (b) sample 1 mid-thickness, (c) sample 2 mid-thickness, (d) sample 3 mid-thickness and (e) sample 4 mid-thickness.

**Table 1**: Percentage of the grains with high optical contrast, the percentage of grains in which the [001] direction is normal to the maps plane and the percentage of recrystallized grains, in each examined area

<table>
<thead>
<tr>
<th>Sample</th>
<th>% area covered by grains with high grey scale contrast</th>
<th>Prevailing crystal direction</th>
<th>% area with [001] // to sheet normal</th>
<th>ReX (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (surface layer)</td>
<td>20.3</td>
<td>[0 0 1]</td>
<td>16</td>
<td>100</td>
</tr>
<tr>
<td>1 (mid-thickness)</td>
<td>8.9</td>
<td>[0 0 1]</td>
<td>14</td>
<td>82</td>
</tr>
<tr>
<td>2 (mid-thickness)</td>
<td>21.1</td>
<td>[0 0 1]</td>
<td>28</td>
<td>90</td>
</tr>
<tr>
<td>3 (mid-thickness)</td>
<td>14.8</td>
<td>[5 2 20]</td>
<td>7</td>
<td>90</td>
</tr>
<tr>
<td>4 (mid-thickness)</td>
<td>26.0</td>
<td>[0 0 1]</td>
<td>27</td>
<td>92</td>
</tr>
</tbody>
</table>

**4. Discussion & Conclusion**

Electrolytic etching of aluminium using Barker’s solution is a suitable method for revealing grain structure due to the resulting differences in the grey scale contrast for each individual grain. From the above findings, it is assumed that this contrast could be
directly related to the recrystallization percentage. Examination of a transverse section revealed that it is not safe to consider a direct relation between the % contrast obtained from Barker’s etch and the % of area covered by grains with the [001] direction aligned with the plane normal. Besides there seems to be also no correlation with grain size or morphology.

Extrusion conditions result in the occurrence of surface layers in the profiles with a higher recrystallization %, which is accompanied by additional high intensity of crystal orientations other than the common [001], such as the observed [101] and [112] in the case of sample 1.

Barker’s etch is therefore convenient as an initial estimation of the attained texture properties of the extruded profiles, information which is needed by automotive industries for the evaluation of formability.

As a conclusion, response of a metallographic specimen to Barker’s etch will depend other than the alloy, etching and sample preparation conditions, on the resulting texture. This is the reason why in the same specimen it is very common from the etch to produce a different image near the surfaces and in mid-thickness locations.

Additional tests are currently carried out in order to reach safer conclusions on this behavior including also an examination of the metallurgical condition and the chemical composition.

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Selected References

