

THE COMPARISON OF AA1060 AND AA3003 ALUMINIUM ALLOYS BY THEIR CRYSTALLOGRAPHIC TEXTURE

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Abstract: In this research the AA1060 and AA3003 alloys were compared by their crystallographic texture, hardness and earing. Both alloy sheets were rolled, and heat treated by the same manufacturing route. The cold rolled samples had the strain of 1.94, then the subsequent heat treatment was carried out between 190 °C and 380 °C. The annealing temperatures were chosen in respect to the industrial annealing temperatures. After the experiments XRD evaluation was carried out to determine the crystallographic texture of the sheets. The XRD results were compared with the industry-known earing test's and hardness test's results. The results can be applied in the industry for the optimization of a given technology.

Keywords: AA1060, AA3003, crystallographic texture, earing

INTRODUCTION

In most cases the aluminium sheets are semi-products, meaning that after the rolling and annealing steps, these sheets are deep drawn. In order to define the deep-drawability of the sheets prior to the operation, crystallographic texture needs to be defined. The crystallographic texture describes the degree of anisotropy by defining the crystallographic orientation of all grains within the material [1]. In most industrial environments, the deep-drawability is described by the hardness of the sheet, but that does not give an adequate answer to the deep-drawability.

The two alloys studied are the AA1060 and the AA3003. The AA1060 is low on alloying elements, but the AA3003 alloy's main alloying component is manganese [2]. Manganese in aluminium alloys, depending on the temperature, could dissolve from the solid solution and form compounds [3]. These compounds influence the recrystallization of the AA3003 alloy [4]. The aim of this research is to compare the recrystallization kinetics of the two alloys based on crystallographic texture, earing and hardness.

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1. MATERIALS AND METHODS

1.1. Experimental route

During the examinations the as-received hot rolled 7 mm thick sheet was cold rolled to 1 mm thickness. Subsequently the heat treatments were carried out at 190 °C, 280 °C and 380 °C for 1, 2, 3, 4 and 5 hours. On *Figure 1* the experimental route is displayed. The heat treatments were done in an air furnace, and the samples were inserted when the furnace was heated to the annealing temperature. The samples cooled down in air. The earing examination was carried out by ARCONIC-Köfém Kft. The interpretation of the earing values is as it follows: positive values refer to 0/90° earing of the deep-drawn sheets, which is defined positive (recrystallized); negative values refer to the 45° earing of the sheets, which is defined as negative (rolled) [5]. The hardness tests were carried out with the Tukon 2100B.

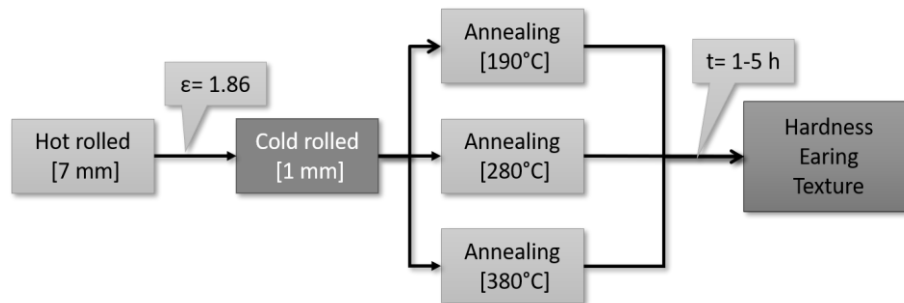


Figure 1
Route of the examinations

1.2. XRD measurements

The texture examinations were carried out with the Bruker D8 Advance X-ray diffractometer equipped with a Eulerian cradle. The measurement parameters: 40 mA, 40 kV, CoK α . The {111}, {200}, {220} lattice planes were measured, with the corresponding pole figures recorded. The pole figures were recalculated, then used for Orientation Distribution Function (ODF) synthesis. ODF cuts were made at 5° steps of the φ_2 values. The texture components are defined by the three Eulerian angles and were measured from the ODF. The texture components are specific Eulerian angle triplets which are characteristic of the manufacturing steps or physical processes (rolling, recrystallization...etc.).

2. RESULTS

2.1. Hardness results

The hardness test results can be seen on *Figure 2*. The 0-hour sample (not annealed, just rolled) is shown on the left. It can be seen that both alloys exhibit the same behaviour. The samples annealed at 190 °C did not change their hardness significantly due

to annealing. At 280 °C the first 2 hours show rapid decrease in hardness, but after 3 to 5 hours, the decrease has already reached its plateau. That is backed up by the fact that after the 380 °C annealing, all samples have around the same hardness value.

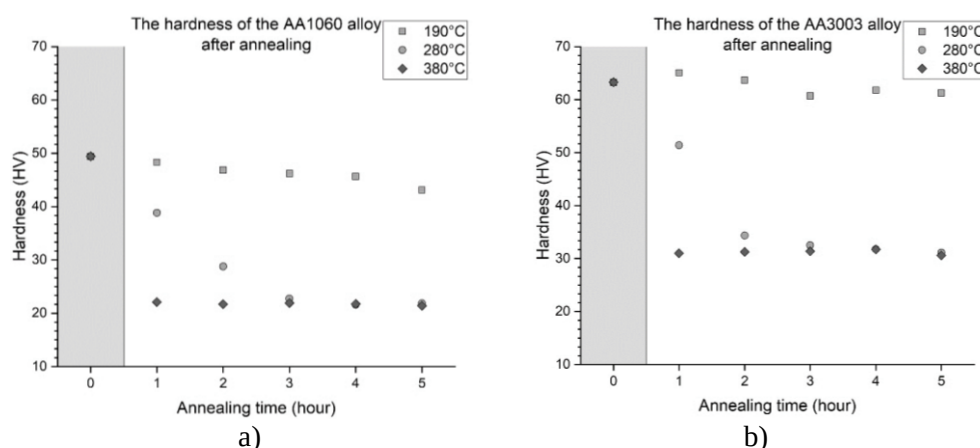


Figure 2

Hardness of the alloys after annealing: a) AA1060; b) AA3003

2.2. Earing results

The results of the earing tests can be seen on *Figure 3*. As in the case of hardness, the earing values seem to follow a similar trend for both alloys (in the opposite direction). The 190 °C annealing did not change the earing notably. The annealing at 280 °C between 1–3 hours increased the earing value sharply. The highest annealing temperature, 390 °C, shows increased earing values even after the 1-hour heat treatment. Through the trends are the same for both alloys, the AA1060 has more optimal earing values than AA3003 (closer to 0).

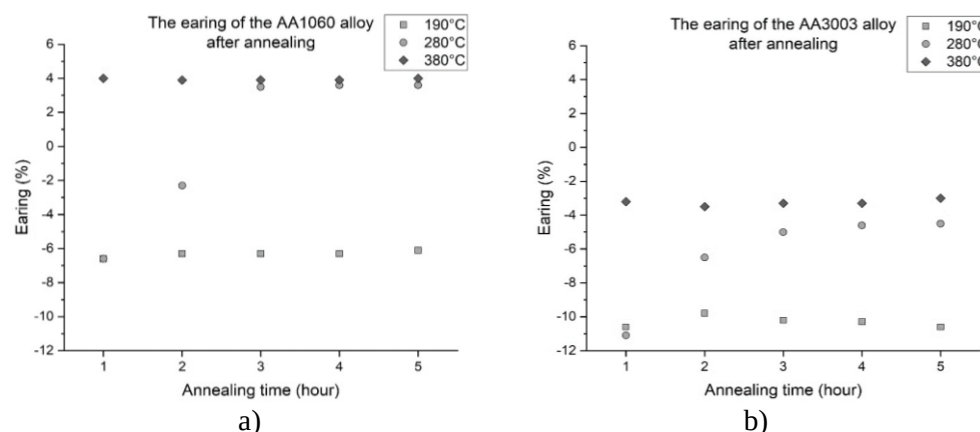


Figure 3

Earing of the alloys after annealing: a) AA1060; b) AA3003

2.3. Texture results

The texture components and their volume percentage can be seen on *Figure 4*.

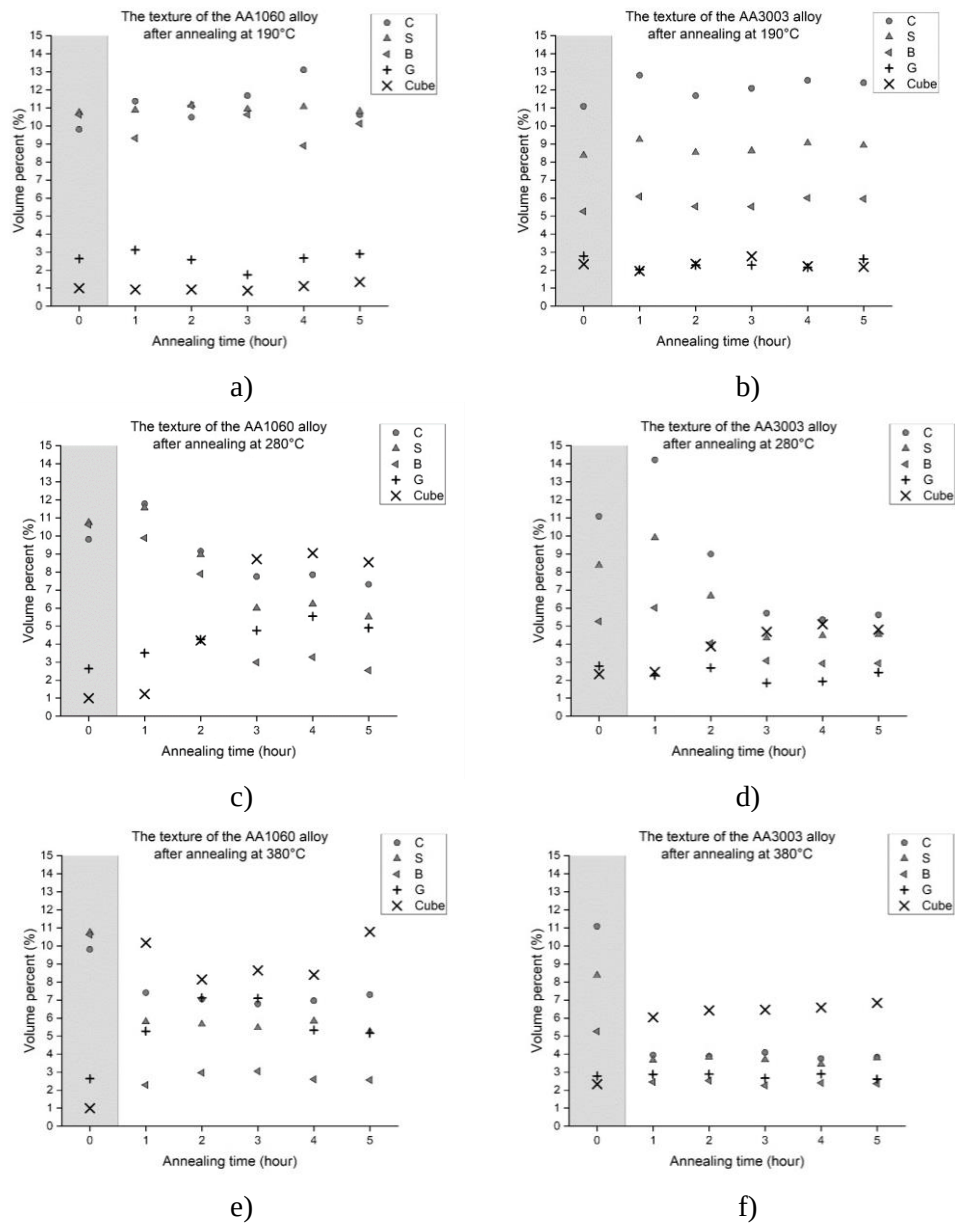


Figure 4

Texture of the alloys after annealing: a) AA1060-190 °C; b) AA3003-190 °C; c) AA1060-280 °C; d) AA3003-280 °C; e) AA1060-380 °C; f) AA3003-380 °C

Both alloys are paired up by their annealing temperature for easier comparison. In all cases the 0-hour state (cold rolled) is displayed in grey. The texture components representing plastic formation (rolling) are displayed with grey markings (C, S, B) and the texture components representing the recrystallization and its processes (G, Cube) are displayed line-based markings.

The texture results after annealing at 190 °C can be seen on *Figure 4a)* and *b)*. Basically, no change in the texture can be seen. The C, S, B components are much higher than the annealing components and the annealing time had no effect on the crystallographic texture. The AA3003 alloy has its C, S, B components more scattered by volume percent, but it is due to the 0-hour sample's state.

After annealing on 280 °C several effects can be seen (*Figure 4c)* and *d)*). In the case of both alloys, after 1 hour of heat treatment, recovery occurs, which increases the texture components referring to rolling. This is due to the fact that during recovery, only the subgrains are ordered, but no grain boundary movement occurs, therefore there will be more volume within the sheet with the same orientation than before annealing [6]. Between 2 and 3 hours of annealing the recrystallization texture components increase and the rolling components decrease. Between 3–5 hours the AA1060 alloy recrystallizes. Due to the fact that the Cube component has the highest values, it refers to recrystallization, but after the Cube, the rolling components are the highest. This indicates that a mixed recrystallization took place, both the classic high angle boundary movement related recrystallization, and the particle stimulated nucleation (PSN). In the case of the AA3003 alloy between 1 and 3 hours of annealing, all things written above are the same, but between 3 and 5 hours entirely PSN recrystallization takes place. This is backed up by the almost equal values of both the rolling and recrystallization components and the fact that the AA3003 is filled with precipitations containing Mn.

AT 380 °C IN THE CASE OF BOTH ALLOYS CLASSICAL RECRYSTALLIZATION OCCURRED, THIS CAN CLEARLY BE SEEN ON THE *FIGURE 4E)* AND *F)*. THE CUBE COMPONENT IS THE HIGHEST IN ALL STATES. THIS MEANS THAT THERE IS NO POINT IN ANNEALING FOR MORE THAN 1 HOUR AT THIS TEMPERATURE.

CONCLUSIONS

In this research the comparison of aluminium sheets with different composition and same processing parameters were carried out. The comparison is based on hardness, earing and texture results. The following can be concluded:

- a) In both alloys the earing and hardness results indicate that at 190 °C no significant change occurred, at 280 °C between 1 and 3 hours of annealing there is a considerable drop in hardness, and a notable increase of earing, indicating that recrystallization took place.
- b) The texture results are in good agreement with the hardness and earing results; however, they are more precise when describing the recrystallization process. The data reveals that at 280 °C mixed recrystallization took place in AA1060 and PSN-type recrystallization took place in AA3003.

- c) The experiments clearly outline the optimal parameters for the studied alloys. In the case of AA1060, at 280 °C the optimal annealing time between 2 and 3 hours could result in 0% earing.

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