EFFECT OF HEAT TREATMENT ON THE PROPERTIES OF ALUMINUM ALLOY AGS 6101 AFTER WIRE DRAWING

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Abstract

In this study, the evolution of some properties of the wire drawn alloy AGS 6101 will be followed and the effect of a heat treatment at high temperature will be analyzed.

OM (optical microscopy) and SEM (scanning electron microscopy) observations showed an homogeneous fibrous microstructure in the longitudinal cross-section. However, the EBSD (electron backscatter diffraction) analysis showed that the distribution of the two main crystallographic fibers <111> and <001> was not homogeneous through the cross-section of the wire. And as the deformation increases, it has been found that the fiber <111> tended to intensify at the wire core and the fiber <001> was distributed at its periphery. In our similar studies on wire drawn copper and steel, similarities in certain behaviors like hardening, recrystallization, have been found, but this phenomenon has not been observed yet. We have also found that the center of the wire stored less energy than the periphery during drawing.

A heat treatment at high temperature (400 °C during various holding times) for this alloy, which leads to recrystallization, never modified the texture established by drawing and the two fibers <111> and <001> remain predominant. More importantly, treatments beyond 20 minutes led to heterogeneity in recrystallized grain size between the core and the periphery of the wires due to the initial difference in terms of stored energy through the wire section.

Keywords: AGS 6101 alloy, wire drawing, metallic texture, crystallographic fiber, recrystallization

1. INTRODUCTION

This study relates to aluminum alloys type AGS 6101. According to the literature this alloy would be much more used in aeronautics and space, but in our case this alloy is intended for medium and high voltage electrical transport. In the literature there is a wide variety of works on aluminum and its deformed alloys, particularly on rolled aluminum alloys. But very few are those who focus on drawing and particularly for the 6101 alloy.

Thermal treatments are generally a necessary step after any shaping by plastic deformation. The main objectives are the elimination of hardened structures in order to obtain desired properties. In previous study, we treated the deformed state [1]. In this work, we will try to see the effect of the heat treatments on the evolution of the properties of drawn wire AGS alloy, in particular on its texture.

2. STUDIED MATERIAL

The studied material is the aluminum alloy type AGS 6101, supplied in the form of wires of different diameters. The associated deformations are presented in a previous study [1]. However, due to the variation in its chemical composition according to the suppliers and the arrivals, the recorded chemical composition is given in **Table 1**.

Table 1 Chemical composition of the AGS alloy 6101

Element	Fe	Mg	Si	Cr	Zn	Mn	Cu	Al and others
Content (% wt.)	0.73 - 0.86	0,6 - 0.97	0.52 - 0.7	0.26 - 0.34	0.02- 0.17	0.02 - 0.12	0.02 - 0.11	97 - 98.6

3. INITIAL STATE AND DRAWN STATE INITIAL

3.1. Texture And Acuity

The pole figures (**Figure 1**) reveal the presence of fibers parallel to the wire axis (ND) of wire rod. The analysis by EBSD of the dispersion of the fibers <111> and <001> parallel to the wire axis confirms this observation. This result indicates the presence of an established texture in the wire rod. This observation is still particularly what we usually see on the continuous casting rods whether on the mild steel [2], the perlitic steel [3] and wire copper [4].

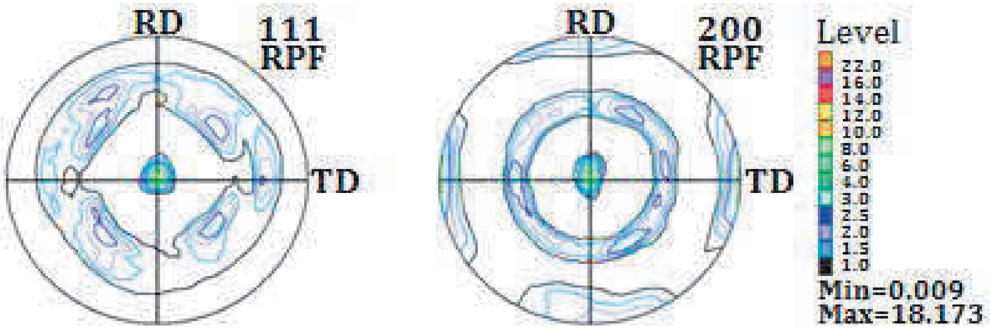


Figure 1 Pole figures of the initial state (wire rod). ND is the wire axis, normal to the pole figures.

For the drawn wire as predicted by literature [5], the EBSD analysis (**Figures 2** and **3**) reveals the presence of the two strong fibers <111> and <001>. During drawing the fraction of the fiber <111> increases more than of the minority fiber <001>. However, a closer examination of the core and the periphery of the wire drawn shows that the distribution of the two fibers is not homogeneous according to the cross-section of the wire. The <111> fiber tends to settle at the periphery of the wire, whereas the <001>fiber tends to occupy the core of the wire. This trend tends to be more established as the rate of deformation increases. This result is also different from what is usually seen in the drawn wires [2-4]. However, this behavior can be assimilated to that observed on rolled sheets of aluminum alloys [6-13].

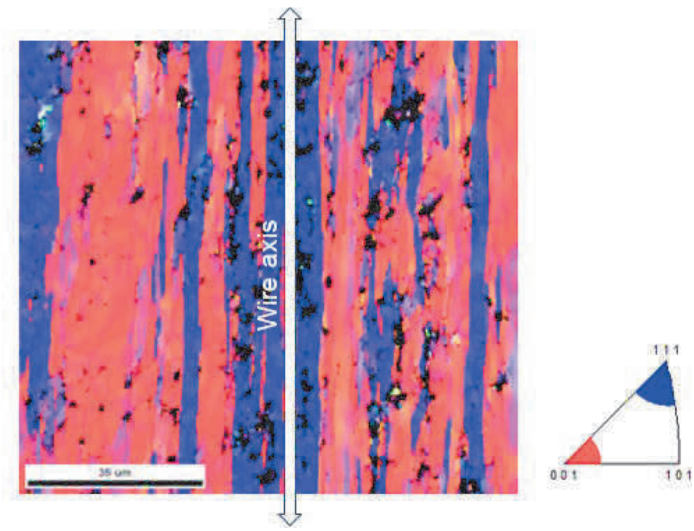


Figure 2 Microstructure characterized by EBSD of the center of the 86 % deformed wire. Crystallographic directions parallel to the wire axis

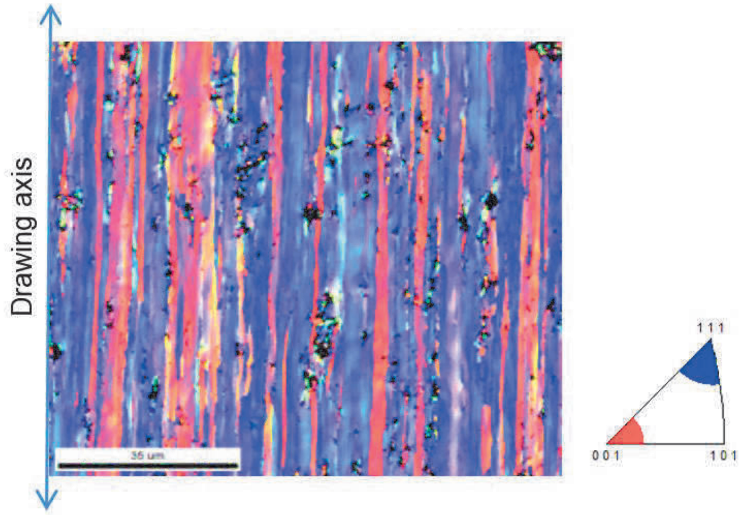


Figure 3 Microstructure characterized by EBSD of the periphery of the 86 % deformed wire. Crystallographic directions parallel to the wire axis

4. THE HEAT TREATED STATE

The samples (drawn to 22 %, 36 %, 51 %, 68 %, 75 %, 81 % and 86 %) were heat treated. The annealing was performed in the open air and at atmospheric pressure at different temperatures ranging from 170 to 400 °C during various holding times, and then they were cooled in the open air.

The various heat treatments carried out do not modify the mother texture composed of fiber <111> and <001>. We found that they only influence grain size and its distribution. A prolonged annealing at high temperature leads to a heterogeneous grain growth on the cross section of the wire.

At 170 °C for times up to 4 hours, the microhardness at the center (core) and the periphery was almost the same. So we concluded that the grain size does not vary between the core and the periphery. But beyond (06 h), we observed that the hardness of the core was slightly less than that of the periphery for deformations above 68%. So we established that the grain size at the core was slightly larger.

At higher temperatures (400 °C), the grain size at the center and the periphery was identical for 10 minutes of treatment, as we can see in **Figures 4** and **5**. But after 30 minutes of treatment the size of the grains of the core becomes greater for the deformations above 75% (**Figure 6**).

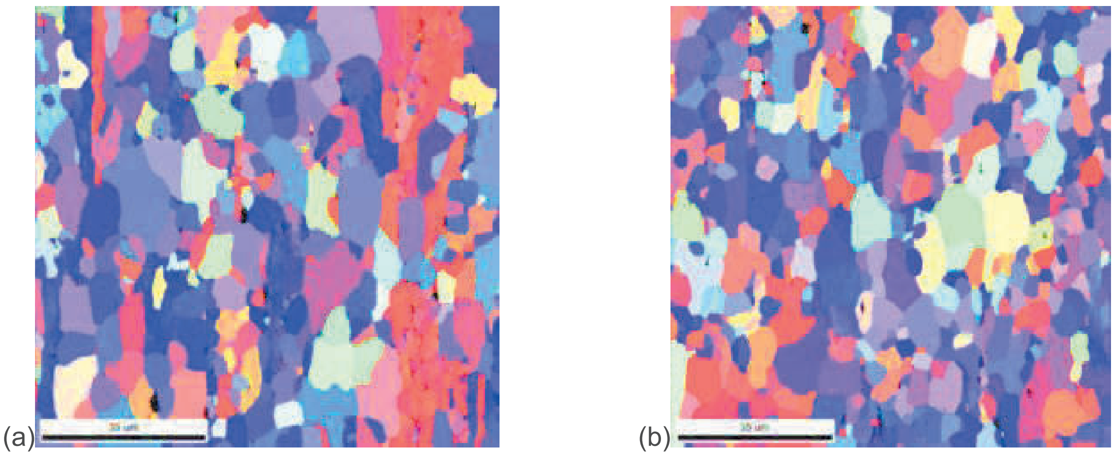


Figure 4 Microstructures characterized by EBSD at the center (a) and at the periphery (b) of the 86 % deformed wire annealed at 400 °C for 10 minutes

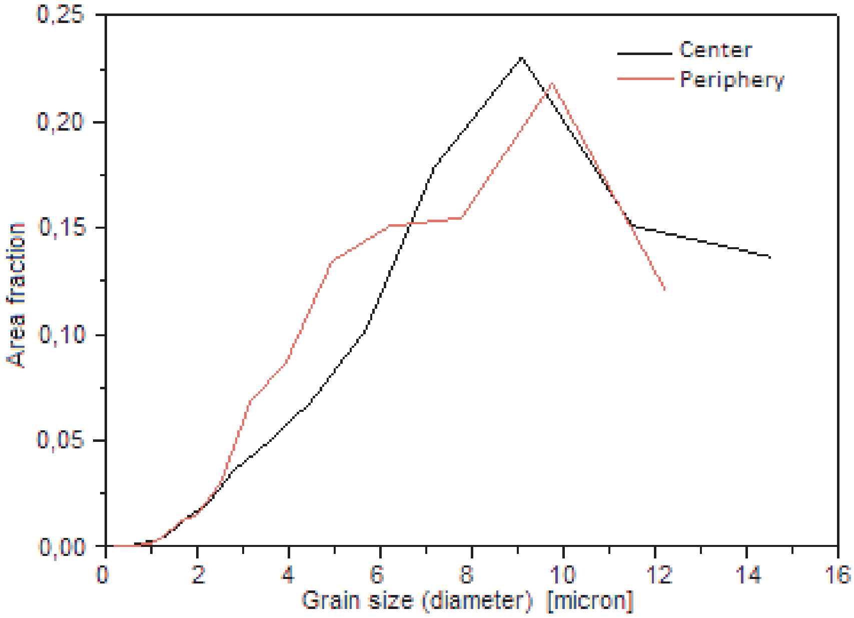


Figure 5 Distribution of the grain size at the center and the periphery of the 86 % deformed wire annealed at 400 °C for 10 minutes

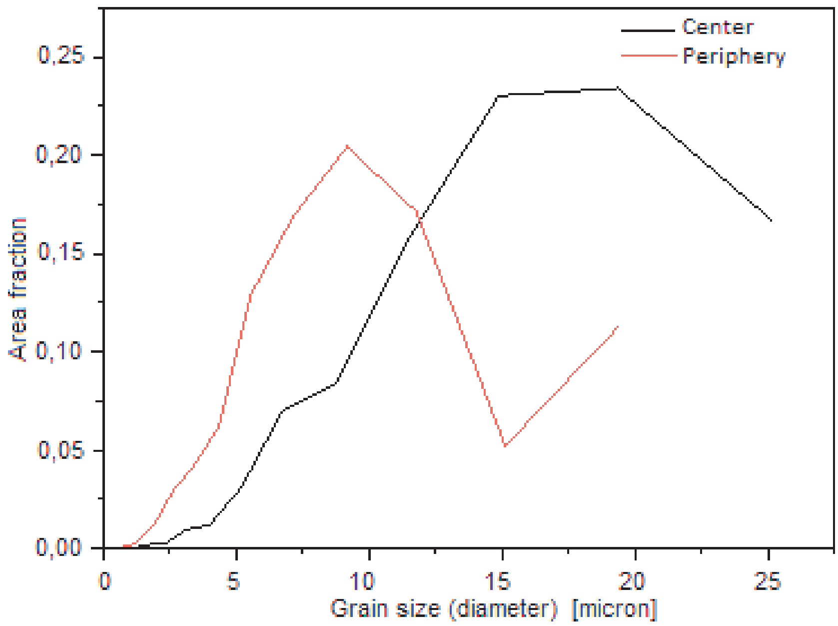


Figure 6 Distribution of the grain size at the center and the periphery of the 86 % deformed wire annealed at 400 °C for 30 minutes

4.1. Discussion

The analysis of the intragranular stored energy (through the Grain Orientation Spread - GOS) is shown in **Figure 7** after 10 minutes at 400°C. At this annealing time, microstructures are not completely recrystallized since it is assumed that GOS<1.5° corresponds to recrystallized grains. The stored energy at the periphery of the wire is greater than at the center, certainly due to shear strain induced by the cold drawing at the contact with the drawing machine.

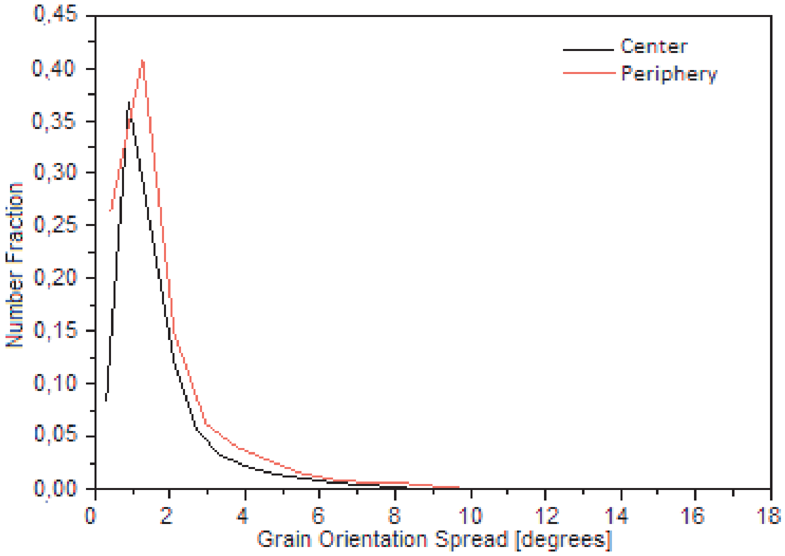
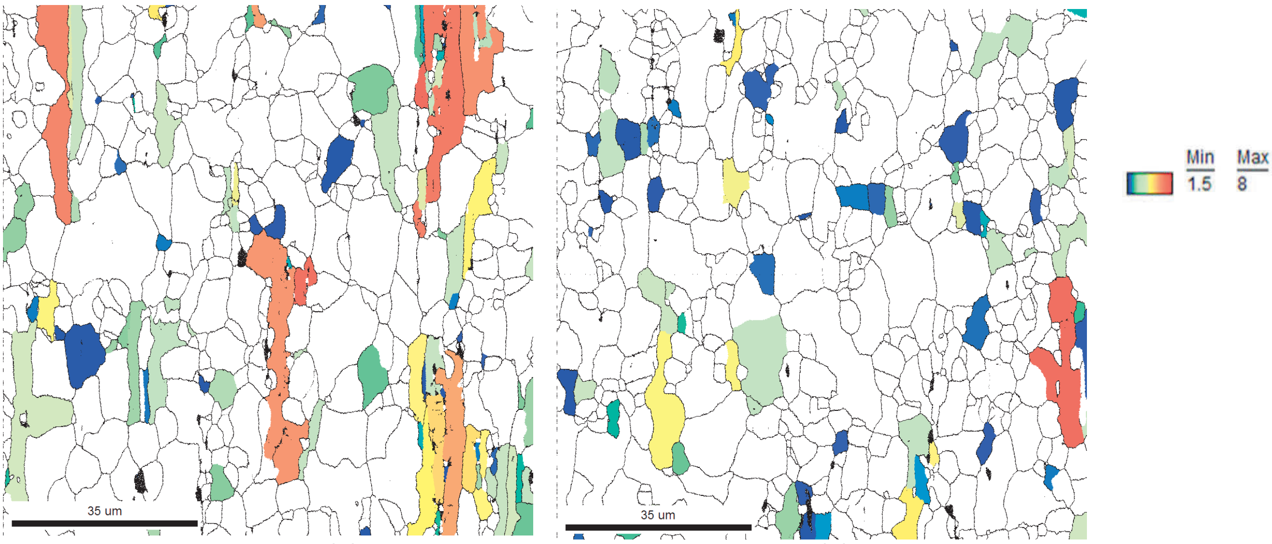


Figure 7 GOS through the wire cross section after 10 minutes at 400 °C

This difference between center and periphery explains why the periphery has an advantage to be recrystallized compared to the center as shown in **Figure 8** where it can be seen that after 10 minutes annealing at 400 °C, the non-recrystallized fraction is close to 25 % at the center while it is only about 15 % at the periphery.



(a) (b)

Figure 8 (a): center; (b): periphery; in color, grains with GOS>1.5°, = non-recrystallized grains after 10 minutes at 400 °C

Since the energy is greater at the periphery, the number of nuclei is also higher during recrystallization than at the center of the wire. As a consequence, grain size is smaller at the periphery as grain growth has occurred. This is in good agreement with **Figure 6.**

5. CONCLUSION

According to our previous results, the following points may be concluded:

- Contrary to what we usually see in the alloy studied AGS 6101, a preset texture can occur in wires produced by continuous casting.

- After cold drawing, the texture becomes composed of a majority fiber <111> and a minority fiber <001>.
- The <111> fiber tends to settle at the periphery of the wire while the <001>fiber occupies the core.
- The periphery microstructure contains more stored energy than the center due to shear strain.
- The heat treatments do not modify the mother texture but cause heterogeneity in the grain size beyond a certain deformation and after annealing during a sufficient time.

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