MONITORING THE EVOLUTION OF THE PROPERTIES OF ALUMINUM AGS ALLOY WIRE DURING DRAWING

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Abstract

The main purpose of this work is to meet the need of an electrical cable manufacturer on the breaking of the wire aluminum AGS alloy. And also answer the question of the misfit properties prescribed by the provider to the final properties of the wire drawn.

In this study we tried to follow the evolution of the properties of wire alloy during drawing. On the DL wire (wire for medium and high voltage line), it was found that the wire properties were very close to that recommended by the provider. However, the ML wire (wire for medium voltage line), for which the problem of rupture appeared, it was found that the differences were consistent between the properties of drawn wire and data prescribed by the supplier; these differences may vary from one arrival to another.

Micrographic analysis by optical microscope revealed that there is no difference between the microstructure of the two wires; both have the same microstructure and acquire an elongated grain microstructure along the axis of the deformation during drawing. It should be noted that there was still a slight difference between a grain-size of both initials wires. The measurement of the microhardness showed a greater hardening of the DL wire compared to ML wire, during drawing. However, the electrical resistivity of ML wire is greater than the DL wire.

Keywords: AGS alloy, wire drawing, porosity alloy, texture, recrystallization

1. INTRODUCTION

This work has been undertaken with an industrial company manufacturing electrical cables. The company imports its first material rod wire rod from different suppliers. It turns out that on one of the imported wires, the company meets the breakage problems at drawing chain causing him significant losses in time. It has also found that the final product did not fit the prescribed provided by the supplier, this may harm the company's image as a leader in the national market.

The 6061 AGS is a commercial alloy widely used in industry for the qualities he possesses, such as light weight, good corrosion resistance, malleability and good electrical and thermal conductivity. These qualities, he owes much of its ability to form precipitates, a phenomenon that is very common in these alloys [1-6] even after deformation and heat treatment [7-13]. But its use in electrical cabling is much more linked to its low cost and its fit in high voltage underground.

In this study we specifically treat the drawn state and we will monitor some properties of wire, during drawing.

2. THE LOCATION OF THE BREAK

The information provided by the company on this issue fails to locate the passes where breaking occurs or to identify the operative causes (drawing speed, lubrication) break. We regard the drawing speed and lubrication, they were identical to those applied to other wires but the rupture was minimal on these wires compared to DL wire. So we have tried to locate the place over break. Monitoring the break on the drawing chain enabled us to locate one can more clearly the places of rupture. Indeed, the break occurs on the whole chain of the drawing, however, statistical monitoring shows that 65% of ruptures occurred between the first and the third pass and the remaining on the fourth to eighth passes. This result shows that there is a variation in mechanical properties of the DL wire beyond the third pass which is more favorable to the drawing of this alloy.

3. STUDIED MATERIAL

The studied material is an aluminum alloy of international trade designation AGS 6061, it is destined for the manufacture of electrical cables and wires. It is supplied in the form of rod wire of different diameters and for each diameter we associated the corresponding deformation noted ε_i (**Table 1**) calculated by the following relation:

$$\varepsilon_i = \frac{s_i - s_f}{s_i} \qquad (1)$$

Where: S_i designates the section of the initial state and S_f designates the final sections of the wire.

Table 1 Values of the studied strain

Noted deformation	ε_0	ε_1	ε_2	ε_3	ε_4	ε_5	ε_6	ε_7	ε_8
Value (%)	0	23	37	51	59	68	75	80	86

Wire rod arrives at the business after two to four months of its production; we also receive the drawn wire after a long time after its deformation. According to the literature [8, 11], this may induce some change in the initial microstructure of the rod wire and drawn wire.

In examining **Table 2**, there is a difference in the chemical composition of the material studied between the values prescribed by the supplier and the measured values. Measured values of the basic elements: magnesium and silicon are similar to those required, but for iron, the value is three times that specified by the supplier. Note also the presence of other elements such as chromium, manganese and zinc.

Table 2 Chemical composition of the AGS alloy (wt.%)

Element	**Al**	**Cu**	**Fe**	**Mg**	**Si**	**Cr**	**Mn**	**Zn**	**Others**
Prescribed	98.45	0.014	0.215	0.653	0.595	-	-	-	-
Measured	97.26	0.02	0.73	0.61	0.58	0.27	0.02	0.02	0.48

4. PHASE ANALYSIS AND MICROSTRUCTURE OBSERVATION

4.1. Analysis of microstructure

Micrographic analysis of the wire rod (initial state **Figure 1**) and draw wire (**Figure 2**) show a microstructure consisting of a single phase α of aluminium. These two micrographs do not distinguish the presence of any precipitate as expected by the literature [8, 11] for the deformed AGS alloys that can undergo natural aging (precipitation). However, we note the presence of numerous voids (cavities) in the microstructure (**Figure 1**). Certainly the material is soft; these defects can be confused with polishing cavities. However, an examination of the microstructure by SEM of a sample deformed to 86% (**Figure 2**) confirms the presence of porosity in the wire rod. This porosity, of different size, appears to be associated and adopts an elongate voids morphology imposed by the deformation mode.

And at first sight it can be concluded that the wire breakage during drawing is certainly due to the presence of the micropores in the alloy.

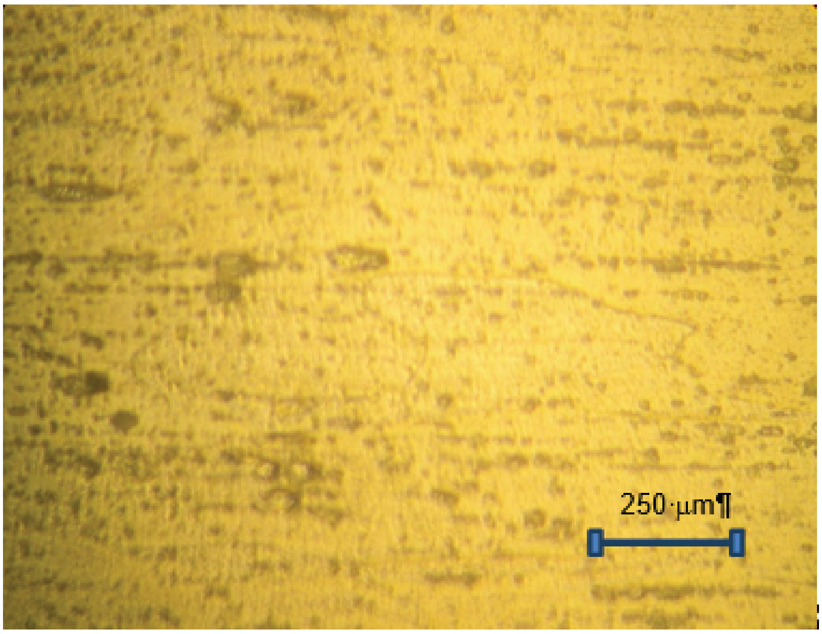
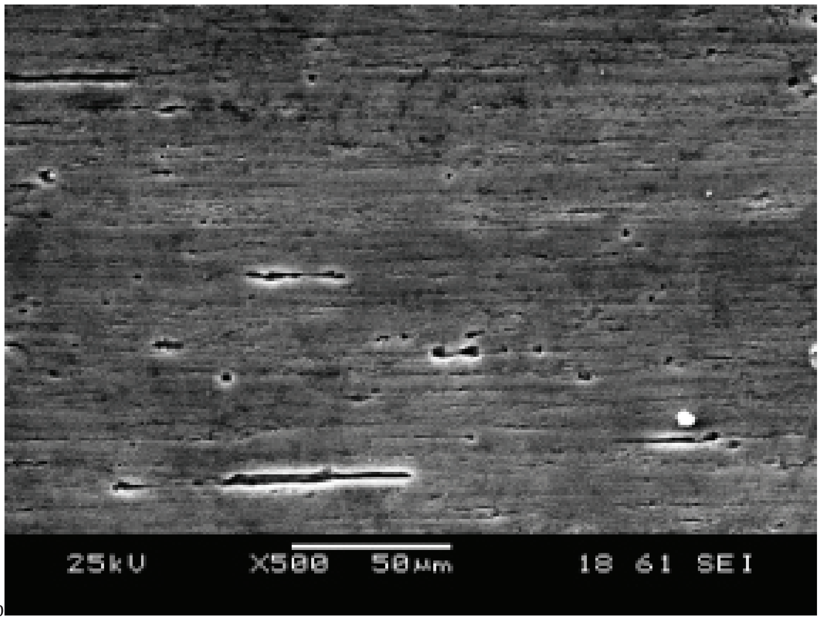


Figure 1 Optical micrograph of the of wire rod



$\varepsilon_8 = 86\%$

Figure 2 SEM micrograph of a wire drawn to

4.2. X-ray diffraction

The observation by OM and SEM did not seem satisfactory, so we proceeded to analyze phase by the technique of X-ray diffraction. And effectively it was found that for the last (largest) deformation there has taken Al_2Cu forming precipitates (see **Figure 3**). Certainly the friction force during drawing led gradually to the temperature rise of the wire which had the effect of heat treatment on the wire and caused precipitation of this new phase Al_2Cu.

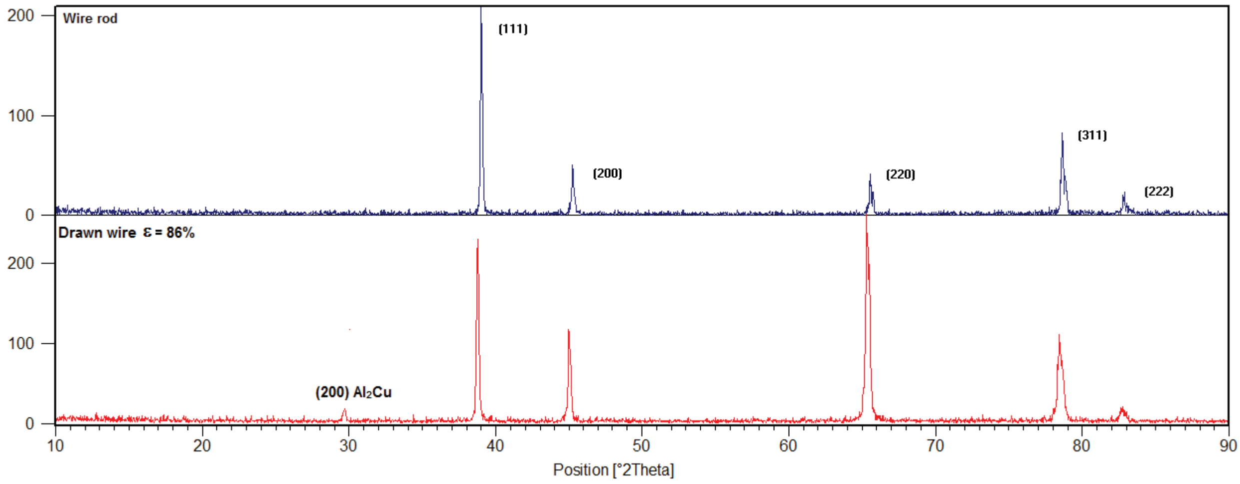


Figure 3 X- ray diffraction diagrams of wire rod and wire drawn to

5. EVOLUTION OF WIRE PROPERTIES DURING DRAWING

5.1. Microhardness Measurement

Note that the measurements of the microhardness were very difficult because of fluctuating results. Such fluctuations may be attributed to the presence of both porosity and small amount of precipitates. The accuracy of the measurement is estimated at ±3.26 Hv for the ML wire and ± 4.42 Hv for the DL wire.

Figure 4 shows the evolution of the microhardness of two types of wire depending on the degree of deformation. It is very clear that the ML wire has a higher microhardness than the DL wire during the step of drawing. It turns out that this is the DL wire which poses the most out of the problem. This result proves that the break of the latter wire is not directly caused by the phenomenon of hardening induced by deformation. In the case of this alloy, the hardening is caused not only by the hardening (presence of high dislocation density) but also to the presence of precipitates [12].

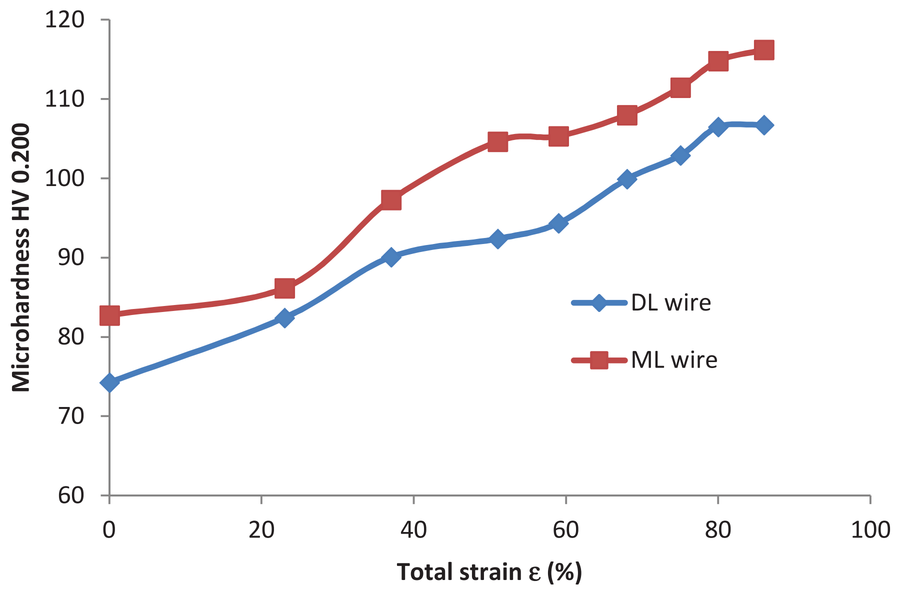


Figure 4 Microhardness evolution according to the degree of deformation

5.2. Load at break

An examination of **Figure 5** shows the ML wire much more resistant to breakage than the DL wire. This result once again confirms that the hardening is not the direct cause of the rupture of DL wire.

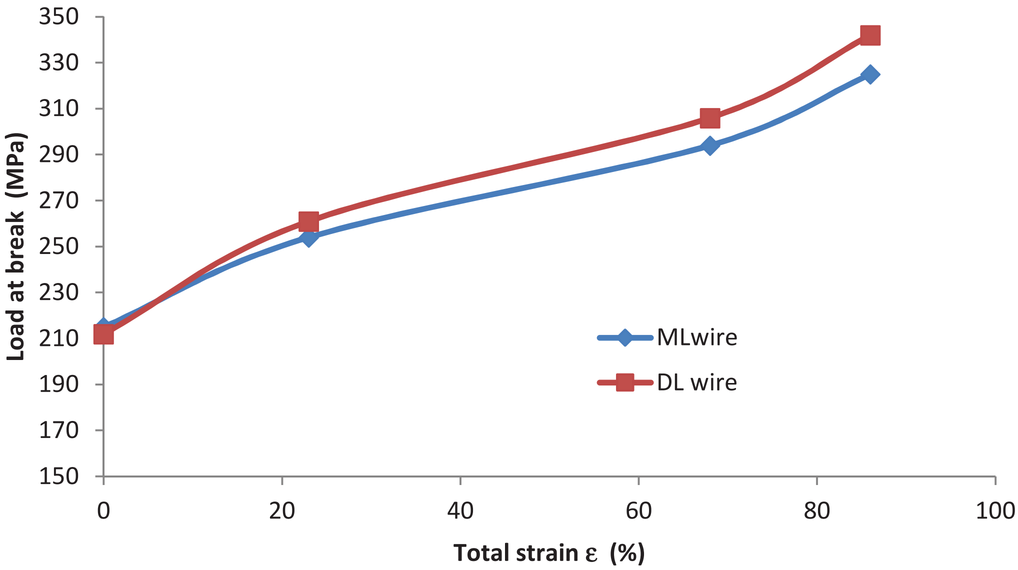


Figure 5 Load at break evolution as function of the degree of deformation

5.3. Electrical resistivity

In **Figure 6** we also find that the drawing causes an increase in the electrical resistivity of both wires. It is very clear on the graph that the electrical resistivity of the wire LD is higher than the ML wire throughout the drawing step. This result indicates that the DL wire has in its structure more defects which act as barriers to the passage of electric current than the ML wire.

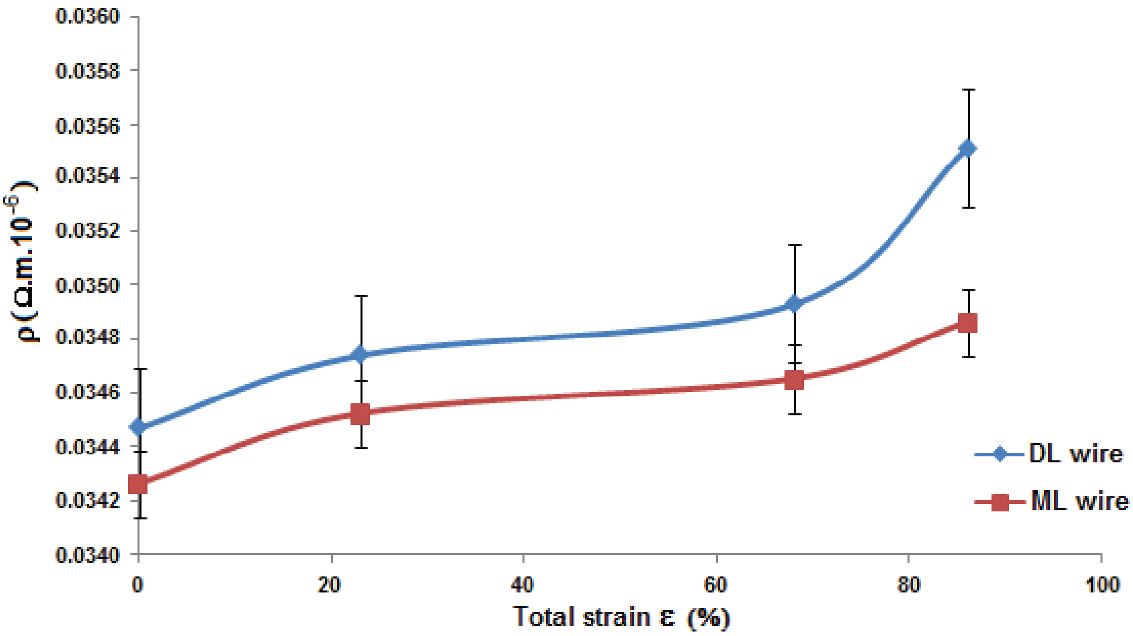


Figure 6 Electrical resistivity evolution as function of the degree of deformation

6. CONCLUSION

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

- The drawing can produce precipitation in AGS alloy 6061 beyond a certain deformation
- In the case of wire drawing an AGS 6061 alloy, the hardening of the structure can not only be assigned to strain hardening but also to the formation of precipitates.
- The drawing causes hardening of the structure by strain hardening which may be a break crack trigger source. But in our case, breaking the DL wire is not directly linked to the strain hardening alone but to a combination of hardening and porosity.

For the study to be more complete, it also suggests to examine the fracture surface, measuring the degree of porosity in the wire and see the state of roughness DL wire rod.

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