THE DRAWING PROCESS OF THE WIRES OF COPPER AND ALUMINUM: EVOLUTION OF THE MICROSTRUCTURE AND (MECHANICAL/ELECTRICAL) PROPERTIES

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Abstract

In this research we studied the evolution of the microstructure of the two wires used in the manufacture of electric energy transportation. The first wire is an aluminum alloy of A 6101 type (or AGS) and the other is a pure copper (Cu-Ducab 98.33 %). The two wires are cold drawn in three passes (same deformation level) for a objective to make a comparative study and understand of the link with the mechanical and electrical properties, for the drawn state. In this study it was found an increase in hardness, mechanical strength and electrical resistivity of the two wires (copper / aluminum) with the level of deformation by drawing

Keywords*:* aluminum alloy, copper, deformation level, cold drawn

1. INTRODUCTION

During a cold deformation of a steel structure, the microstructure changes based on the deformation level Zidani et al [1]. During the first stage of deformation, the grains are divided, change shape and elongate in the direction of stress Hughes and Hansen, 1991, Hughes, 1995 [2, 3]. The plastic deformation also creates a large amount of point defects (vacancies) Jakani [4]. During plastic deformation of a material, a certain amount of energy input (1 - 10 %) is stored in the deformed microstructure, mainly in the form of dislocations Humphreys and Hatherly, 1995 [5]. It is well known that energy plays an important role in the mechanisms of recrystallization Bensaada [6]. Practically this structure disrupted cannot be adjusted to a general industrial use, since the working properties of metals are determined in most cases by the size, grain morphology and crystallographic orientation of the latter. A definite contribution of thermal energy is required to restore the physical structure and the metal had before deformation (strain hardening) [6] properties. At present, electricity and information are very important in our daily lives and making a performance to carry this energy and information tool effectively becomes a major necessity. The material most known for its reliable electrical contact, its high ductility and availability is copper. These properties are the reasons responsible for the widespread use of copper son in the industry such as: electrical construction, distribution of electrical energy, the manufacture of electrical and electronic equipment. By cons, for reasons of energy saving cost in service life, there is a direct industrial importance of aluminum and its alloys used as conductors in electrical power lines transport. Benefits by wire brass report are: lightness, good mechanical strength and low cost. But they have a lower electrical conductivity - conductivity wire AAC (All aluminum conductor) is about 61 % IACS (international annealed copper standard) and aluminum conductor AAAC (all aluminum alloy conductor) alloy is between 52.5 - 53 % IACS. The challenge for manufacturers and scientists is the control of the mechanical and electrical characteristics of the wire obtained. For this purpose we studied the evolution of the microstructure as-received copper and aluminum alloy AA 6101 cold drawn in three passes for objective to understand the relationship between microstructure and mechanical behavior electrical and after drawing

2. MATERIAL AND ANALYSIS TECHNIQUES

Our study focused on copper as-received "Ducab" 98.33 % Cu initial diameter 8.08 mm and aluminum alloy "AGS" Al 98.46 % of initial diameter 9.46 mm (see **Table 1**) and three wires of various diameters that represent three different deformation level for each machine wire (Copper / Aluminium) (ε_1 = 40.55 %, ε_2 = 67.31 % and ε_3 = 90.58 %) from a range of drawing eleven pathway (see **Fig. 1**). All these wires were provided by the company ENICAB (Enterprise industries cables Biskra - Algeria). Characterization methods used in this study to identify the evolution of the microstructure, mechanical and electrical properties of the wire drawn are: Optical and Electronics Microscopy, Microhardness, The tensile test and the electrical resistivity test.

Table 1 Results of chemical analysis determined wire studied in the laboratory (AML) company ERIS (SERIANA-Batna)

Elements «**DUCAB**»	Fe	Zn	Ni	Pb
Results (% Max)	0.021	0.003	<0.0044	<0.04
Elements « **AGS** »	Fe	Si	Mg	Cu
Results (% Max)	0.211	0.589	0.687	0.020

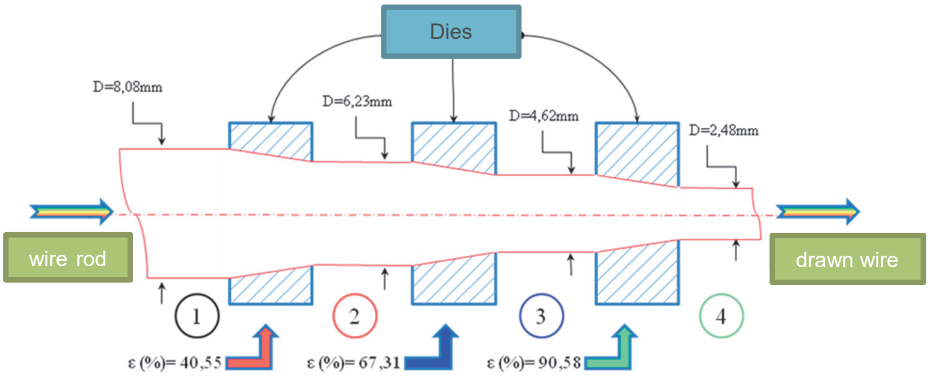

Fig. 1 The four stations of wire to examine experimentally

3. STUDY OF THE STATE DRAWN

The microstructures (**Fig. 2** a and c) show equiaxed grain shape particular to the copper as-received. As against the microstructures of the wire of two shades drawn machinery (Cu / Al) with ε_2 = 90.58%, there is a microstructure of elongated grains along the axis of the drawing (**Fig. 2** b and d). This flow grains is very important for the aluminum alloy. According Zidani et al [8, 9] when the deformation level increases, the drawn wire acquired a textured microstructure (fiber texture). Microhardness measurements show an increase in hardness drawn wires (Cu / Al) with increasing of deformation level (**Fig. 3**). This increase is very important for the wire of drawn copper. This hardening material is interpreted by the hardening mechanism causes a very high dislocation density in the deformed material

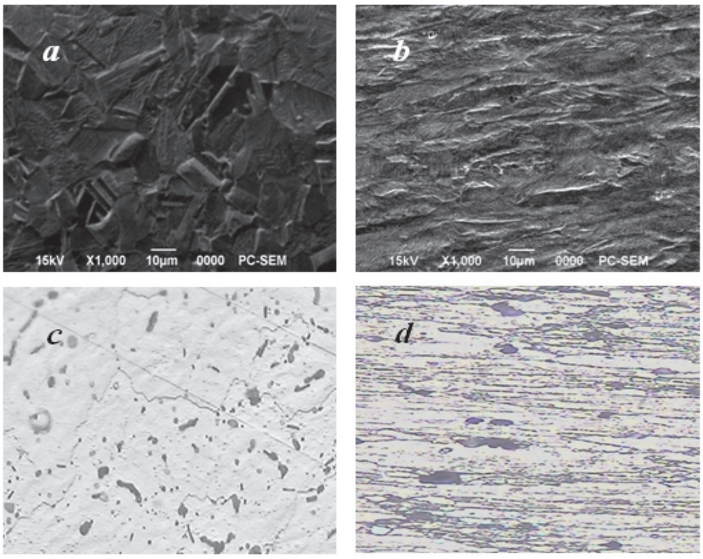

Fig. 2 SEM microstructures of as-received copper wire (a) and drawn wire (b) (ε_2 = 90.58%), OM Microstructures of as-received AGS wire (c) and drawn wire (d) (ε_2 = 90.58%).

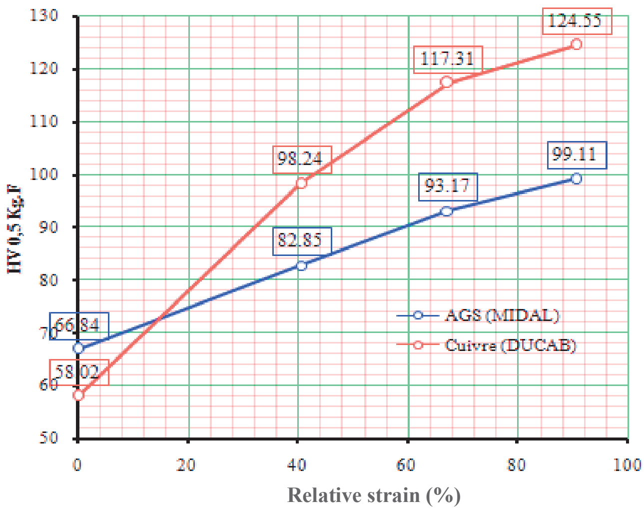

Fig. 3 Evolution of the mean value in microhardness according to deformation level

4. EVOLUTION OF PROPERTIES (MECHANICAL / ELECTRICAL)

4.1 Mechanical properties

The results of the tensile test (as-received wire / wire drawn) for two materials presented in **Table 2** and **3**, **Fig. 4** clearly show that the breaking strength increases as the deformation level increases by drawing against the elongation fall with deformation level (**Fig. 5**). Studies have shown that the mechanical properties of the wires drawn are influenced by impurities trapped in the first or added matter Jakani 2004 [4]. Note that the breaking strength of copper wire is higher by a port that of aluminum.

Table 2 Results of tensile tests for Ducab copper (Physics Laboratory-ENICA-Biskra)

ε (%)	A (%)	Rm(N/mm²)
0	39	325
40.55	4.0	322
67.31	2.5	414
90.58	2.0	464

Table 3 Results of tensile tests for AGS aluminum (Physics Laboratory-ENICA-Biskra)

ε (%)	A (%)	Rm(N/mm²)
0	11	215
40.55	3.5	273
67.31	2.0	304
90.58	1.6	328

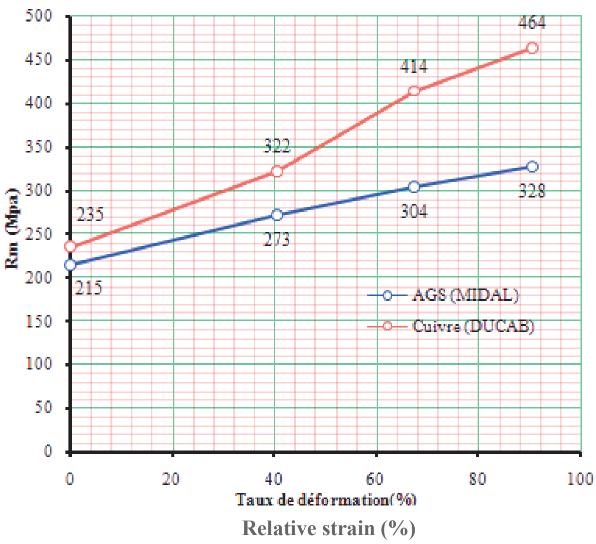

Fig. 4 Evolution of the breaking strength of the two materials as a function of deformation level (Physics Laboratory-ENICA-Biskra)

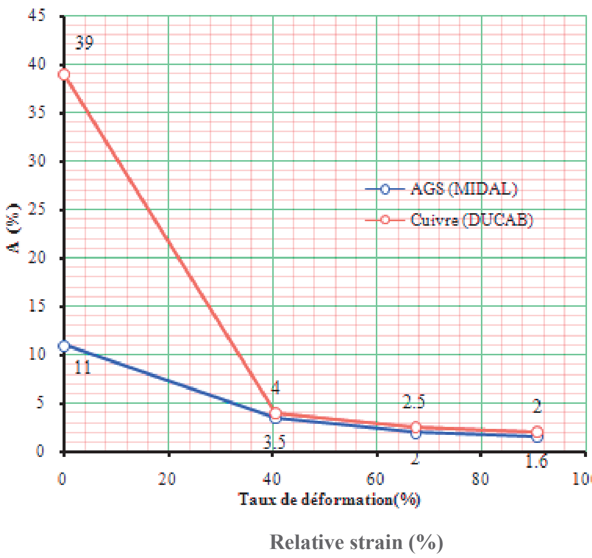

Fig. 5 Evolution of the elongation of the two materials as a function of deformation level (Physics Laboratory-ENICA-Biskra)

4.2 Electrical properties

The results of the electrical resistivity as a function of reduction level are illustrated in the figure (**Fig. 6**). We note a clear increase in the resistivity with increasing of reduction level by drawing for the two materials. Furthermore by this electrical characterization confirmed that copper is more conductive (electrical conductivity) than aluminum. Studies have shown that the electrical resistivity increases with impurity content, and linearly for very low levels up to 0.2% Pops 1997 [12]. According to the work of Pops, the electrical conductivity increases with the addition of oxygen to a level of 200 ppm by weight, and then decreases for higher levels Pops 1997 [12].

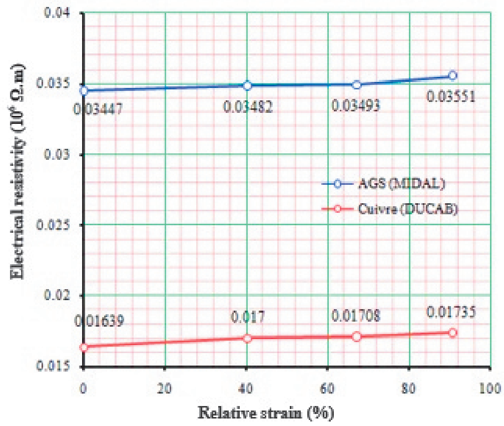

Fig. 6 Evolution of the electrical resistivity of two materials according of deformation level (Physics Laboratory-ENICA-Biskra)

CONCLUSION

This comparative study of two industrial wire of copper and AGS has allowed us to draw the following conclusions:

The drawing of copper and AGS wires causes development of a fibrous texture accompanied by an increase in hardness with increasing deformation level A decrease in elongation with the reduction level by drawing. An increase of the electrical resistivity and mechanical strength with the deformation level by drawing. The copper has (mechanical/electrical) properties higher by a port of aluminum. Against aluminum is more deformable than copper.

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