MECHANICAL BEHAVIOR AND TEXTURE EVOLUTIONSTUDYOF MEDIUM CARBON STEEL WIRES DURING INDUSTRIAL WIRE-DRAWING PROCESS

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Abstract

The medium carbon steel drawn wires are used in wide variety of applications, such as bridge cables, tire cord and springs. Wire drawing is a cold working process. It issued for reducing the cross-section (the diameter) of a wire by plastic deformation, in the presence of a dry lubricant powder, called soap. An electron backscatter diffraction (EBSD) was developed which allow non-destructive evaluation of crystallographic orientation distribution in materials has been used in this study.

This present research paper focuses on the characterization of the texture, microstructural evolution and mechanical properties behaviour (hardness and torsion) of medium carbon steel wires obtained by wire drawing process at Tréfissoud (Company used for the manufacturing of the spring mattress). The study was carried out respectively on the two states of the wires, wire rod and drawn wire (47 % and 56 % of deformation level), using the scanning electron microscopy (SEM) for examination of the microstructure, the electron backscatter diffraction (EBSD) for crystallographic orientation distribution analysis, the hardness and torsion to follow the curing of the studied wires.

Keywords: Medium carbon steel, drawn wire, spring mattress, texture, microstructure, hardness, torsion

1. INTRODUCTION

Wire drawing process has an important role in the industrial production of carbon steel products. It is a manufacturing method used for reducing the diameter of wires by pulling the wire through a die. The wire is pulled through a conical aperture called a die to reduce its diameter [1,2]. During this process, the microstructure of steel material changes which affect its mechanical properties [3,4]. Generally, wire rod is made from carbon steel. The carbon steel wires are used as a product at cables, electrodes and springs [5].

2. EXPERIMENTAL PROCEDURE

Medium carbon steel wires used in this study produced by Tréfisoud Company, JSC from Algeria. The chemical composition of the wires was shown in **Table1**.

Firstly, mechanical surface cleaning has been done to remove oxide layer on wires. Following this process orderly chemical pickling, washing, lime bath and drying processes were applied and then the drawing process is carried out at room temperature.

Table 1 Chemical composition of medium carbon steel (wt%)

C	Mn	Si	P	S	Cr	Ni	Cu
0.675	0.649	0.18	0.008	0.017	0.051	0.036	0.048

Two types of wire are studied (wire rod (0 %) and deformed wires with two different reduction (47 % and 56 %). The deformation level is calculated from the equation [6]:

$$\varepsilon = \frac{(S-s)}{S} \cdot 100 \quad (\%) \qquad (1)$$

Where:

S is the section of wire rod and *s* is the section of deformed wire.

To observe the microstructure by SEM, the samples were subjected to mechanical polishing performed on SiC abrasive papers of different grain sizes with oil-based diamond. After the mechanical polishing, the samples were chemically etched with Nital 3 % to reveal microstructure.

Microstructural and textural analyzes were done using scanning electron microscopy FEI quanta 250 and TSL EDAX electron backscatter diffraction in the scanning electron microscopy Zeiss 940 equipped with OIMTM. The Vickers hardness measurement was carried out by applying 500 g load, according to NF EN ISO 6507-1:2005 standard. The number of twist was determined by torsion tests according to ISO 18338:2015 standard.

3. RESULTS AND DISCUSSION

3.1. Microstructure

Figure1 presents the microstructure wire after successive cold drawing, all in longitudinal section.

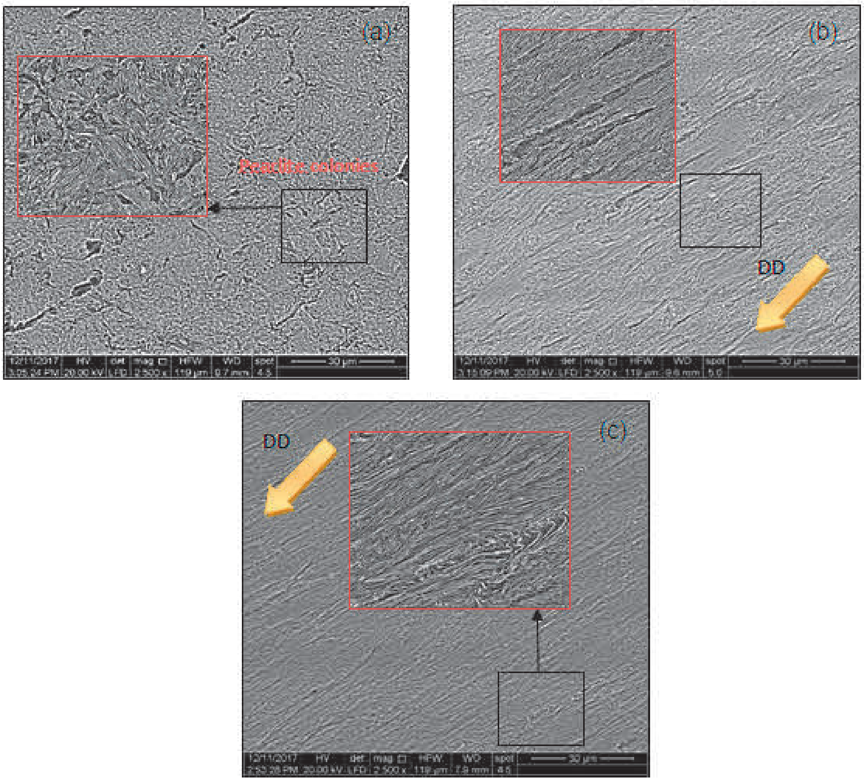

Figure 1 Scanning electron micrographs for the wire samples drawn to different levels: (a) 0 %, (b) 47 % and (c) 56 %.

The microstructure of steel wire rod (**Figure 1-a**) shows a random distribution (isotropy) of the pearlite colonies. After drawing (**Figure 1-b** and **Figure 1-c**), microstructures are significantly different and very fine grains are oriented in the drawing direction, the cementite lamellae are elongated in the drawing direction (DD). This elongation is the result of the development of fiber texture <110>in the drawing direction (DD) [7,8].

3.2. Texture

Deformation textures are also shown in the ODFs plots (φ2 = 45°) for the wire rod and drawn wires in **Figure 2**, respectively.

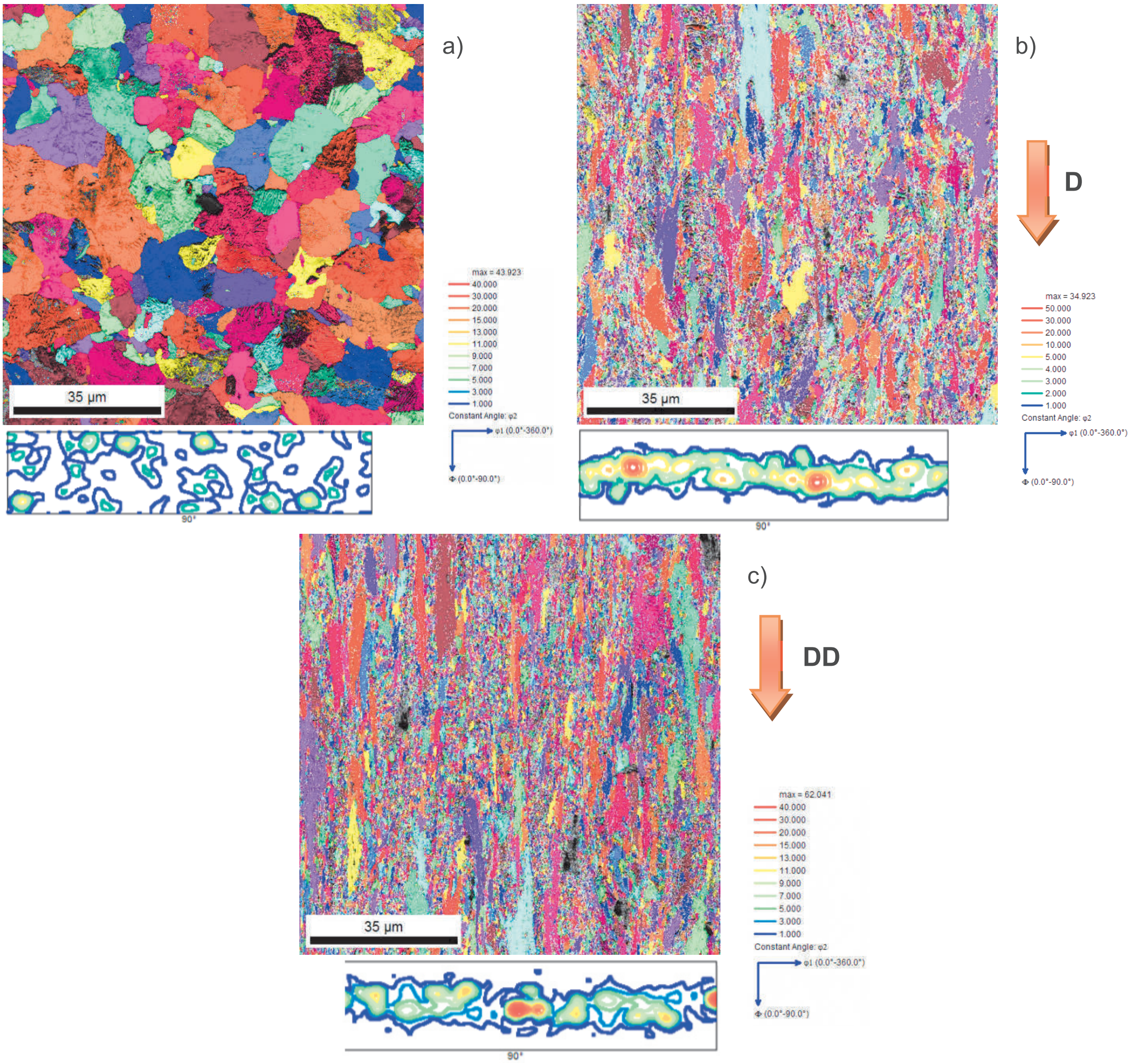

Figure 2 Electron backscatter diffraction microstructure and orientation distribution function calculated by EBSD of the medium carbon steel wire samples drawn to different levels:
(a) 0 % (b) drawn wire at 47 %and (c) 56 %.

The quantitative analysis show the development of the fiber<110>//DD (DD = drawing direction) with the maximum ODF density with 34.923 and 62.041 for the 47 % and 56 % drawn sample, respectively. The principal component ({111} <110>) of the fiber increases with the increasing of the deformation level [9].

3.3. Hardness

Figure 3 shows the effect of wire drawing level on the hardness. After the drawing process, the generation of high dislocation density in the crystal structure of medium carbon steel and the refining of inter-lamellar spacing leads to the increase in hardness [10,11].

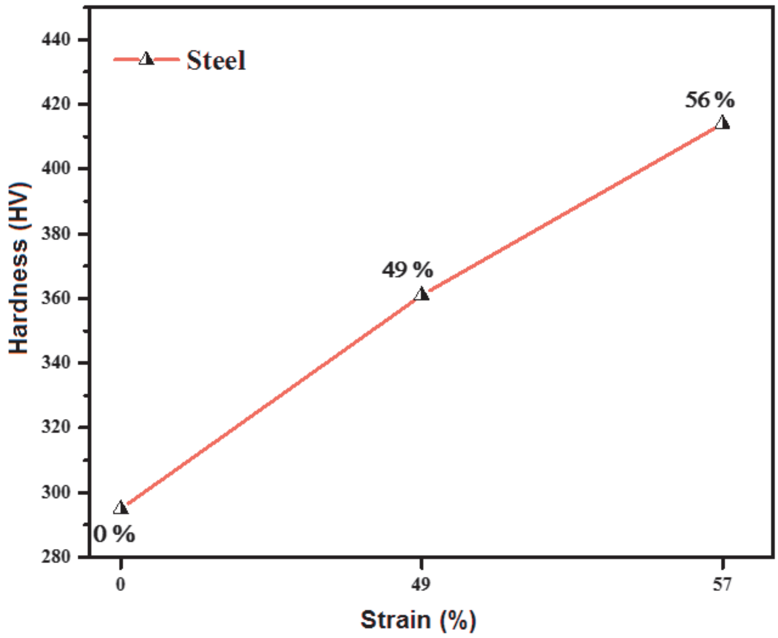

Figure 3 Hardness evolutions of medium carbon steel wires

3.4. Torsion testing

The torsion properties of the medium carbon steel wires are shown in **Figure 4**. It is observed that number of twist to failure during torsion testing of medium carbon steel increase with increasing of drawing level.

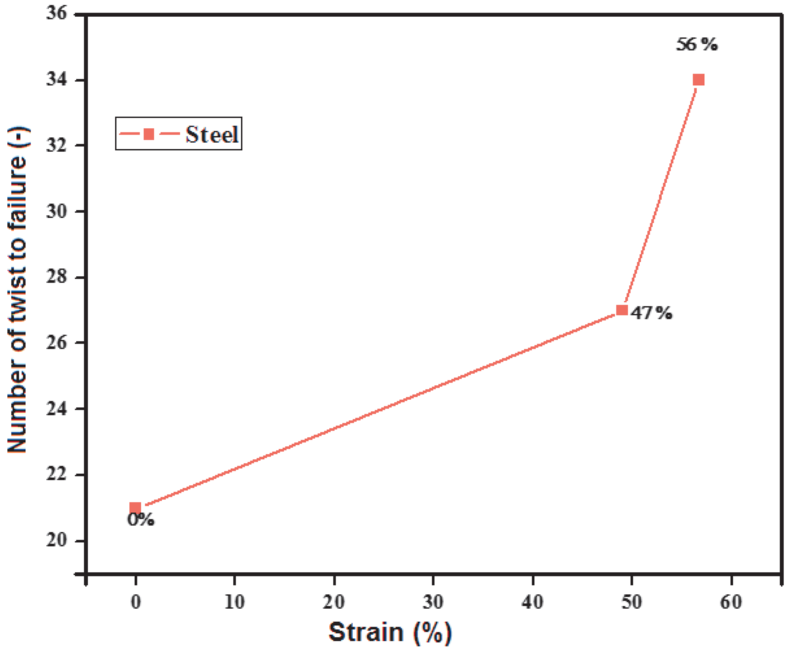

Figure4 Influence of number of twists to failure on deformation level of medium carbon steel wires

4. CONCLUSION

The wire drawing process of medium carbon steel wires has been studied. This study aims to the know of some processes that affect microstructure, texture, hardness and torsion properties of drawn wires which appeared during the drawing process. The following conclusion can be done from this study:

- The drawing produces microstructural orientation in medium carbon steel, so that cementite lamellae orientate in the drawing direction (DD), while its inter-lamellar spacing decreases during process.
- The drawing causes the development of majority fiber texture <110> // DD (DD = drawing direction). The principal component ({111} <110>) of the fiber increases with the increasing of the deformation level.
- The hardness test shows that wire drawing increases hardness by generating new dislocations in the crystalline structure and by decreasing of inter-lamellar spacing.
- The experiments have shown that the torsion twist increase when reduction level is increased.

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