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The Crystallographic Texture in The Medium Carbon Steel Wires: From The EBSD to The OIM^{TM} Analysis Software

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Abstract

This study falls within the framework of a scientific collaboration with the national wire drawing and manufacturing company of welding products TREFISOUD JSC, specialized in the manufacturing of long type steel products. The TREFISOUD today offers a varied range of solutions for different sectors such as industry, agriculture, construction and public works. Indeed, whether it is drawn wires, steels for the manufacture of mattress springs, strand cables and welding products. The company covers a wide variety of applications through the production of drawn wires by single-pass and multi-pass type machines

The medium-carbon steel is mong steels of wide use. During this study, a medium-carbon steel wires produced by the national drawing and welding products manufacturing company (Algeria) was characterized by two analytical techniques. One is scanning electron microscopy (SEM) to monitor the microstructure evolution and the second is electron back scatter diffraction (EBSD) for the crystallographic texture analysis. The EBSD results are processed with OIM (Orientation Imaging Microscopy) analysis software.

Keywords: Medium-carbon steel, Wire drawing, Microstructure, Texture, OIM Analysis.

1. Introduction

Carbon steels remain the most used materials in drawing industries because of their excellent price-performance ratio. They offer a wide range of usage properties deriving from their numerous microstructure and texture variants. The microstructural behaviour of these steels present themselves as a powerful solution to adapt them to the many implementation processes and the various service requests. This explains the huge amount of research being done on the microstructure of carbon steels in general [1] [2] [3] [4].

The progressive anisotropy of the crystallographic texture or of the elongation of the grains (morphological texture) induced in the material by cold drawing as a consequence of significant changes at the microstructural level. Thus, although it is clear that cold drawing improves the microstructural modifications during wire drawing can produce an anisotropic microstructure [5].

The objective of this work is to follow the evolution of the microstructure and the crystallographic texture of D45-2 drawn medium carbon steel wires intended for the manufacture of spring mattresses.

2.Material and methods

2.1. Material

The present study was carried out on medium carbon steel wires provided by TREFISSOUD JSC,. Algeria. The chemical composition of steel is listed in Table 1.

Table 1. Chemical composition of medium carbon steel D45-2 (wt %)

C	Mn	Si	P	S	Cr	Ni	Cu
0.465	0.653	0.152	0.009	0.013	0.069	0.039	0.054

D45-2 steel is an non alloyed steel with 0.45 % (average) carbon content and is intended for the wire drawing process for special applications (Fig. 1) [6]

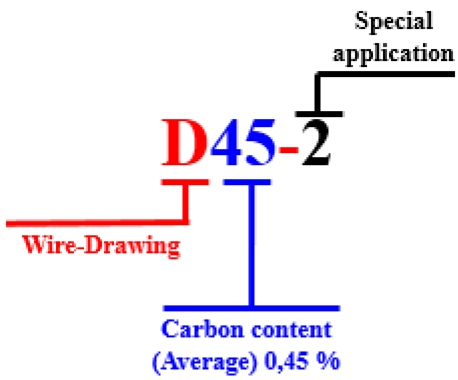

Fig.1. Standardized designation of D45-2 steel [6].

For observation of the microstructure by SEM microscopy, all the samples were subjected to mechanical polishing performed on SiC abrasive papers of different grain sizes (P100, P180, P240, P400, P600, P800, P1000, P1200, P2400 and P4000) with oil-based diamond. After the mechanical polishing, the samples were chemically etched with Nital 3% (3 ml of nitric acid with 97 ml of ethanol) to reveal microstructure.

For the crystallographic texture characterization, the samples were subjected to mechanical polishing on granulometry paper (1200, 2000 and 4000) followed by diamond polishing (3 µm and 1 µm) and then electro-polishing to remove the mechanical polishing layer.

2.2. Characterization technics

The evolution of the microstructure and the texture in D45-2 medium carbon steel wires were characterized by scanning electron microscopy FEI quanta 250, TSL EDAX electron backscatter diffraction in the scanning electron microscopy Zeiss 940 equipped with OIM^{TM} software.

2.2.1 Basic principle of EBSD

When by focusing an electron beam on a grain which one wishes to know the crystallographic orientation, the electrons backscattered in Bragg incidence with the reflecting crystallographic planes will diffract according to two diffraction cones for each reflecting plane (Fig. 2). The intersection of the diffraction cones with a detector screen forms hyperbolas resembling lines. The set of lines constitutes the Kikuchi diagram.

Indexing by reference of different lines makes it possible to know the crystallographic orientation of grain, knowing its crystal structure. This indexing is by OIM software (Imaging Orientation Microscopy) which gives the crystallographic orientation by the poles figure (PF), the individual orientation maps and the orientation distribution functions (ODF).

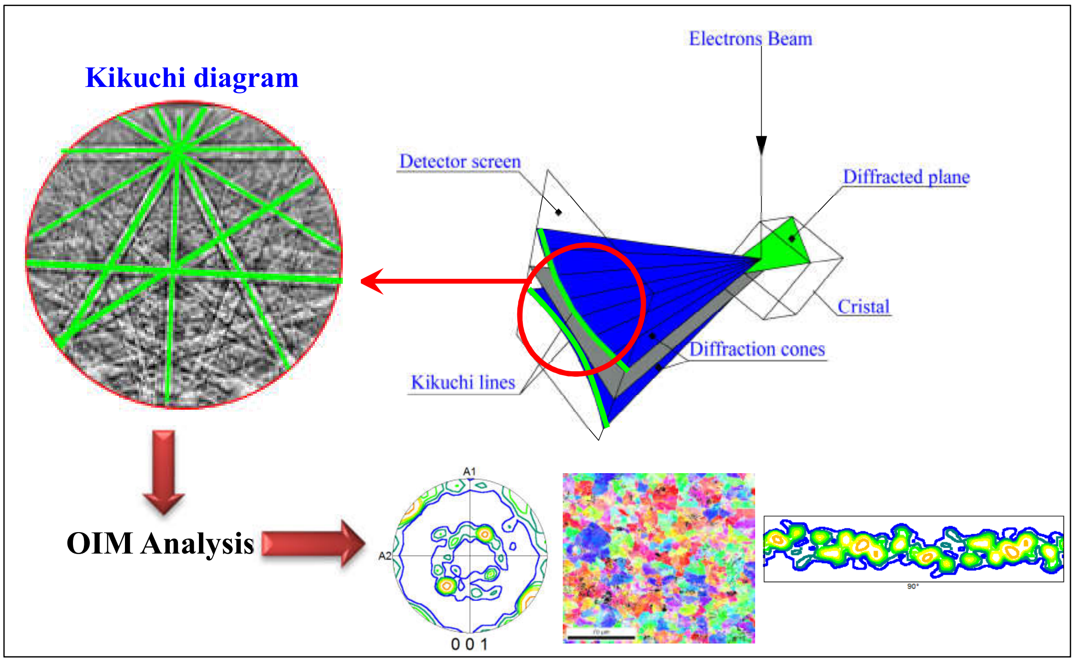

Fig.2. Basic principle of EBSD

3. Results and discussion

3.1. SEM Characterization

Figure 3 presents a SEM micrograph of the D45-2 wire rod. We can notice that the microstructure is composed of two phases (ferrite (F) and pearlite (P)). Each perlite colony (PC) has its own lamellar direction. The cementite lamellae are presented by the light color and the ferrite by the dark color. Two morphologies of perlite can be observed, one with straight lamellae (SPL) predominant and the other with curled lamellae (CPL) (Fig.3-A). The overall microstructure is homogeneous without any sign of plastic deformation and the grains are equiaxed with a random crystallographic texture and orientations of the cementite lamellae.

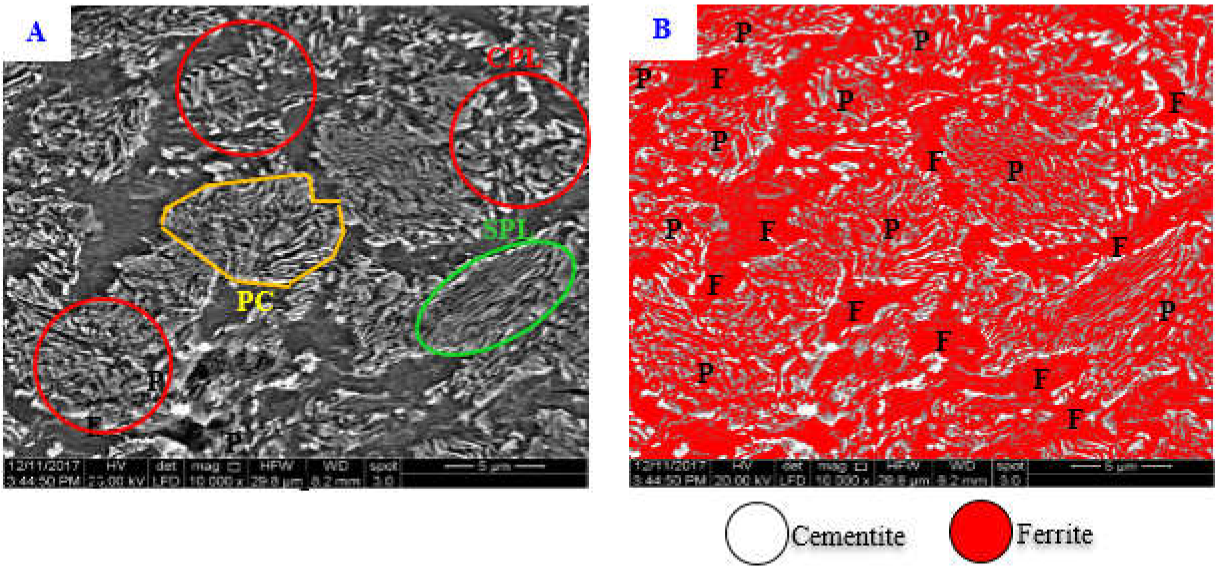

Fig.3 SEM micrograph of the longitudinal section of D45-2 steel wire rod (Ø 5.5 mm) A) SEM micrograph, B) Illustration of the compounds (processed by ImageJ)

In the same way, we present on figure 4, the SEM images relating to two different deformation rates by drawing (57.27% and 74.5%) of steel D45-2. We can notice three types of cementite lamellae are clearly identifiable: aligned with the wire axis (WA), folded and sheared at 57.27% deformation rate and aligned with the DD direction at 74.5%. The microstructure has become fibrous and the grains are strongly elongated in the direction of wire drawing DD.

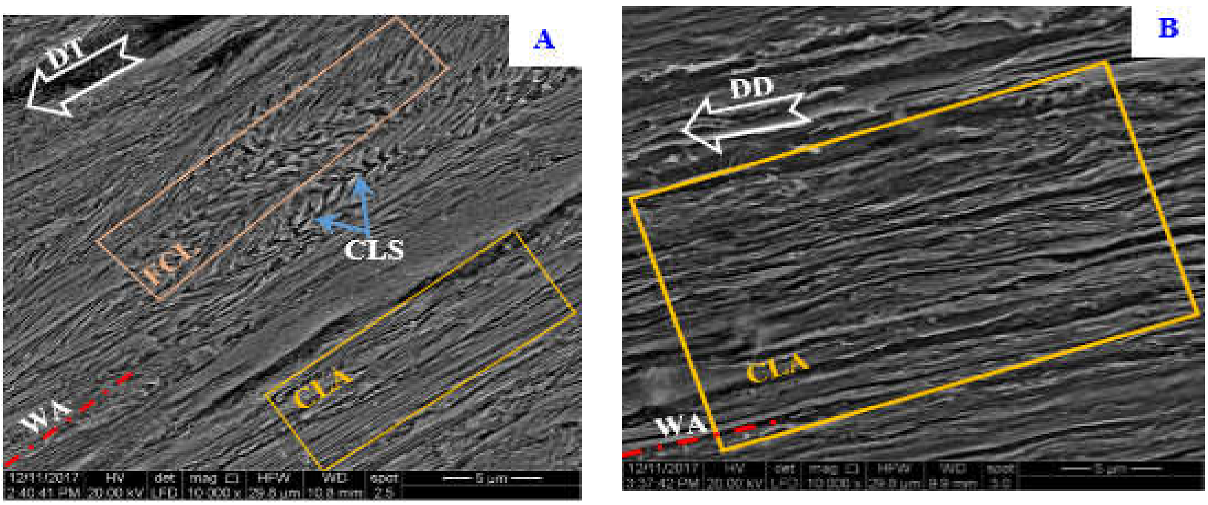

Fig.4 SEM micrographs of the longitudinal section of the drawn steel wire D45-2 drawn.
a) ε = 57.27% and b) ε = 74.5%.

3.2. EBSD Characterization

3.2.1. Poles figure (PF)

First of all, we can see on the poles figure of drawn wires (Fig.5) the presence of the fiber texture <110> parallel to the direction A1 (drawing direction) [7] and then this fiber texture is developed during deformation and reinforced with the maximum intensities of 15.378 for ε = 57.27 % and 14.603 for ε = 74.5 %.

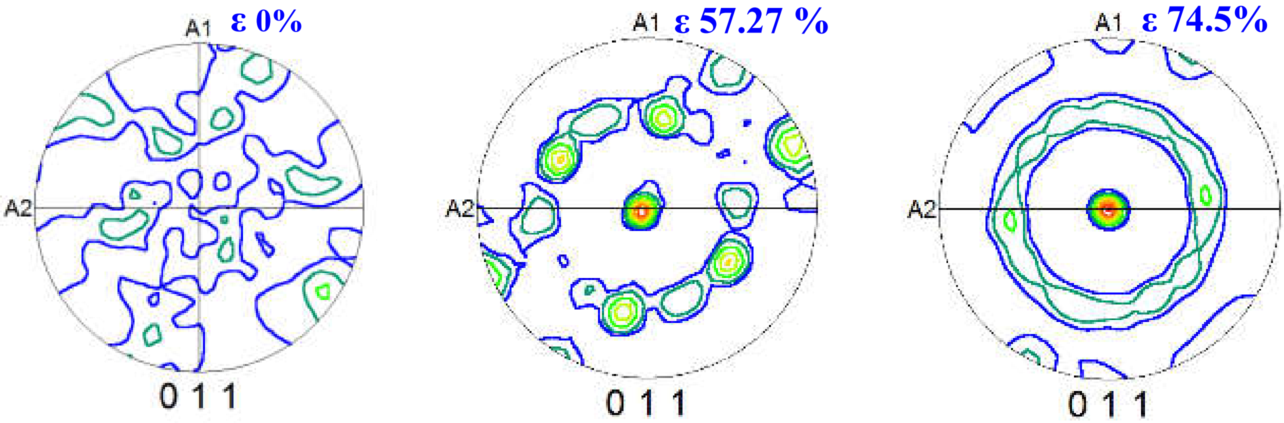

Fig.5 Poles figure {110} of D45-2 steel wires.

3.2.2. Orientation distribution functions (ODF)

In Figure 6, only a development of the <110> // DD fiber texture appears at ε = 57.27 %. This fiber is in the majority and reinforced at ε = 74.5 % .

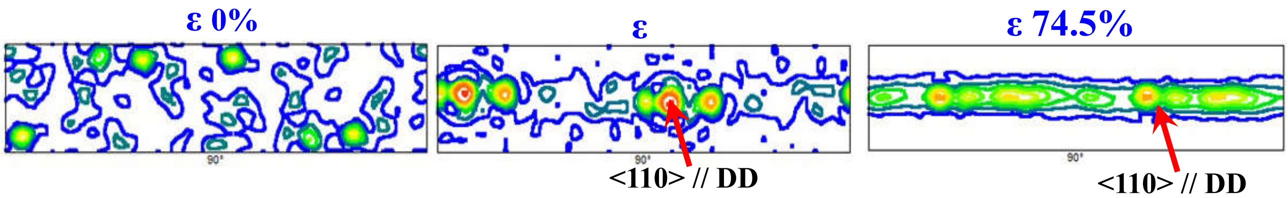

Fig.6 Orientation distribution functions of D45-2 steel wires.

4. Conclusion

Scanning electron microscopy allowed us to analyze the grains morphology. During wire drawing, the cementite lamellae orient towards the wire drawing direction and the microstructure with a morphological texture parallel to the wire axis. Two different forms of cementite lamellae are observed: folded (FCL) and aligned cementite lamellae (CLA).

EBSD analysis has shown us the evolution of the crystallographic texture as a function of the deformation rate. The development of a fiber texture <l l0> comes from the drawing effect.

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