EVOLUTION OF DEFORMATION AND RECRYSTALLIZATION TEXTURES
OF A STEEL DRAWN WIRE

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Abstract

The aim of this work is the understanding of the microstructure and the texture evolution during the cold deformation of a wire drawn steel intended for industrial applications. In parallel, we tried to better apprehend the influence of the deformation amount on the recrystallization kinetics of drawn wires. The study was undertaken on an initial wire low carbon steel (0.06% C) used by the Tréfisoud firm (Algeria). The texture characterization of the reference state (initial wire) revealed an isotropic state (without texture). After wire-drawing, the texture presents an a fiber (<110>// ND, the wire drawing axis). The temperature effect is studied below the eutectoid level, at 500°C and 600°C. The appearance of an homogeneous recrystallization is noted over the section of the wire. The first grains such as the complete recrystallized microstructure keep the same orientation as the deformed state.

The experimental techniques used in this study are: The Optical microscopy (OM), the Scanning Electron Microscope (SEM), the Electron Back Scattered Diffraction (EBSD), the X-ray diffraction and the Vickers microhardness.

Key Words: Steel, Wire drawing, Recrystallization, Texture, Ferritic grains.

1. INTRODUCTION

The wire-drawing is an industrial process which provokes the structure hardening by increasing the dislocation density. When the deformation amount is very important, the microstructure presents a morphological texture where the grains are lengthened along the wire-drawing axis [1-3]. A heat treatment provokes a microstructural transformation and modifies its physical and mechanical properties. The microstructural transformation takes place in three essential stages: recovery, recrystallization and grain growth. The influence of the deformation texture on the recrystallization texture will be examined in the present paper on a steel (F10) with a weak carbon rate (0.06% C) provided by Tréfisoud firm (Algeria).

2. MATERIAL

The studied material is a commercial low carbon steel wire of 0.06 wt% of carbon (initial section $S_i = 6.00$ mm); it has been provided to us by the Tréfissoud. The deformation level of wire drawing is:

$$\varepsilon = \frac{S_f - S_i}{S_i} \times 100$$

(Equation 1)
S, and Sf designate respectively the initial and the final sections of the wire. For this work, a large number of drawn wires specimens were chosen (from 27 to 88 % of section reduction).

Different techniques have been used for this investigation: Optical Microscopy (OM) and Scanning Electron Microscopy (SEM) observations of the wire were made along the longitudinal section after etching with Nital. In order to evaluate the mechanical properties of the wire, microhardness measurement (with a force of 300g) were applied. Specimens were prepared for Electron Back Scattered Diffraction (EBSD) analysis in the standard manner. A Zeiss 940 SEM with a tungsten filament was used. The SEM device is coupled with the automatic OIM™ (Orientation Imaging Microscopy) software, from the TSL Company. X-ray diffraction (FDP and ODF) was used to examine the change in preferred grain orientation.

3. RESULTS AND DISCUSSION
3.1. Drawn wire stage
3.1.1 Microstructure

The metallographic analysis of the as received wire reveals a ferrito-perlitic microstructure; the ferritic grains are equiaxe with an average size of 10 µm (Figure 1a). The pearlite has a lamellar structure (Figure 1b). SEM observation shows elongation of colony of pearlite and ferrite grains along the drawing axis. (Figure 1c). The cold wire drawing provokes the hardness of wires (Figure 2). This hardening is interpreted by the deformation mechanism inducing a very strong dislocation density and the reduction of the interlamellate pearlite spacing [4-5].

![Figure 1: (OM and SEM) microstructures of (a) as-received low carbon steel wire and (b) drawn wire: ε =47.44%](image1.png)

![Figure 2: Vickers micro-hardness curve of low carbon steel wire after cold wire drawing](image2.png)
3.1.2. Textures of drawn-wires

Figure 3 presents the \{110\} pole figures measured by X-ray diffraction. In the case of the initial wire (non-deformed) (Figure 3a), the intensity of the pole figures is weak (Max=1.2 for the \{110\} pole figure), then the texture is nearly isotropic. On the contrary, the texture acuity increases with the deformation level (Figure 3b) [6]. These results are consistent with works done by Gangli et al. [7] on the wire drawn textures of low carbon steels.

![Figure 3: \{110\} pole figures (X-Ray diffraction): (a) of as-received wire and (b) after reduction by wire drawing: $\varepsilon = 47.44\%$](image_url)

The figure 4 shows the $\Phi_2 = 45^\circ$ plot section of the Orientation Distribution Function (ODF) of the drawn wire. The quantitative analysis shows the development of the fibre $<110>/\text{ND}$ (ND // wire drawing axis) [8]. This fibre presents however a main $\{111\}<110>$ reinforcement corresponding to the maximum of the FDOC (Max=6.00). The $\{001\}<110>$ is also present with the same ODF acuity (Figures 4a and 4b). This texture has been observed by Langouche and al [9], in steels in general and by Montesin et al. [10] in perlitic steels intended to the manufacture of pneumatic wires. In our case, the $<110>$ fibre is majority on the whole section of the wire for the different level of deformation.

![Figure 4: $\Phi_2 = 45^\circ$ plot section of the ODF: (a) of the wire after deformation ($\varepsilon = 47.44\%$) by cold wire drawing and (b) position of ideals orientations.](image_url)
3.2. Annealing stage

3.2.1. Microstructure and texture evolution during isothermal annealing

The temperature effect is studied below the eutectoid transformation between 200°C and 680°C, for variable maintained times (5mn to 20h). These tests of isothermal annealing made it possible to determine the critical temperature of recrystallization estimated just above 450°C [11], for all the deformation amounts. The $\varphi_2 = 45^\circ$ plot section of the ODF (from X-ray diffraction measurements) after 80 minutes of annealing at 500°C is shown on figure 5. The texture is similar to the deformation one.

Figure 5: EBSD microstructure and ODF plot sections ($\varphi_2 = 45^\circ$) (X-ray) of wire after deformation ($\varepsilon = 47.44\ %$) and isothermal annealing during 80 mn at 500°C

The first recovered and/or recrystallized grains characterized from the highest quality index of the Kikuchi patterns measured by EBSD shows still the same texture (Figure 6). This texture is the conserved after complete recrystallization and more marked so after an annealing at 600°C during 20 hours (Figure 7) [12]. The EBSD characterizations of wires (periphery and core) after annealing at 600°C during 20 hours show practically homogeneous microstructures, where the recrystallized grain sizes similar for these two observations, but it differs from drawn-wire to another, this depends on the level of deformation, the finer grains are obtained for the strongly drawn wire [6].

Figure 6: EBSD microstructures and ODF plot sections ($\varphi_2 = 45^\circ$) of wire after deformation ($\varepsilon = 47.77\ %$) and isothermal annealing during 80 mn at 500°C
Figure 7: EBSD microstructures and ODF plot sections (φ2 = 45°) (X-ray) of wire after deformation (ε = 47.44 %) and isothermal annealing during 20 hours at 600°C

4. CONCLUSION
Our investigation represents a contribution to the study of the microstructure and the texture evolution after deformation and recrystallization during different isothermal annealings applied to industrial low carbon steel drawn-wires. The recrystallization texture is composed of the same components as the deformation texture of drawn wires i.e the a fibre and the {001}<110> component. It was noticed that the acuity of this fibre increases according to the deformation level and the annealing temperature.

5. REFERENCES