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EVOLUTION OF THE TEXTURE IN STEELCORD

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Tyre industry wishes always wires with best mechanical performances. This continuous improvement of the performances needs the knowledge and the understanding of the deformation process of the wire. To reach this goal, it is useful to know the cristallographic texture and its evolution during the drawing process.

The depth of penetration of X Ray not being very important (about some tens of micrometers or more in metal, depending on the absorption [1]), the X Ray examination can be considered as a superficial one for large wires (about a millimeter diameter or more).

On the other hand, if we consider thin wires, it can be said that X-ray can penetrate deeply and even reach the core of the wire. In this case the information we get from the diffracted intensities is a mean orientation factor $K(\varphi\psi)$ [2] subject to modification caused by the absorption and the diffracting volume effect. This mean factor will be closer than that of the surface, especially when the wire becomes larger or the texture gradient gets lower.

To measure with accuracy the texture of steelcord and its change, we have developed a X-ray diffraction procedure to obtain the texture evolution across the wire radius for each important step of the drawing process [2,3]. This evolution is studied according to some drawing parameters.

I) EXPERIMENTAL PROCEDURE

To describe the evolution of the texture across the radius, the wires are thinned by successive chemical attacks. Each attack is stopped at a desired diameter. After each attack the texture is measured. This procedure is used to test larger wire.

For thinner wires, however, to obtain better values of the $K(\varphi,\psi)$ orientation factor, we must refine the analysis of the diffracted intensity, because in such wires, a non negligeable part of the intensity comes from their inner side. For this purpose, we keep the same sample preparation as cited previously and use the results of the two mean values $K(\varphi,\psi)$ (K_i and K_{i+1}) of the same wire before and after the i^{th} chemical attack.

1.1) Calculus

Let us suppose that the wire is constituted of two parts :

- a) a cylindrical shell whose thickness is what has been removed by the chemical attack.

- b) the core of the wire.

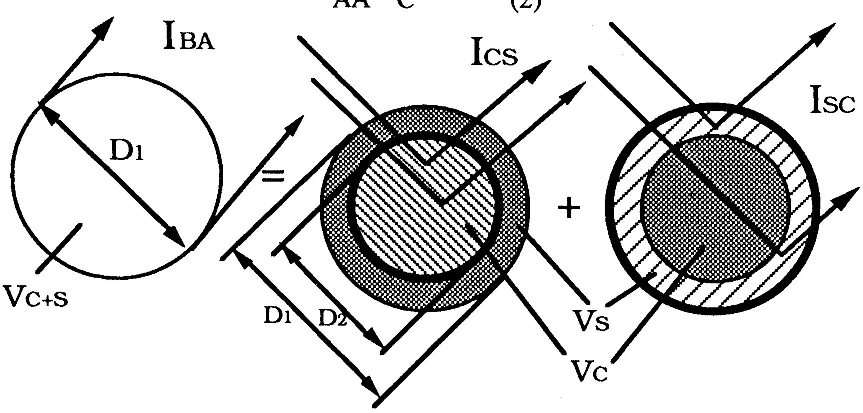
The cylindrical shell has an homogeneous texture in its volume V_S . The core has another homogeneous texture in its volume V_C. The diffraction experiment gives us :

- Before attack : the whole intensity diffracted I_{BA} by the wire (shell+core) can be written as follows : the diffracted intensity by the shell attenuated by an ideally isotropic core I_{SC}, increased by the diffracted intensity by the core attenuated by an ideally isotropic shell I_{CS} (figure 1)

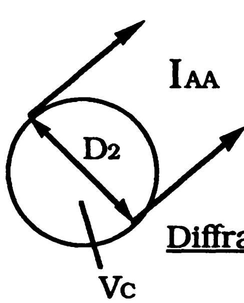
$$I_{BA} = I_{SC} + I_{CS} \qquad (1)$$

- After attack : the whole intensity diffracted by the core alone without attenuation by the shell (I_C) :

$$I_{AA}=I_C \qquad (2)$$



Diffracted intensity Before Attack IBA



Diffracted intensity After Attack IAA

By using the relations 1 and 2 and the general theory of X rays absorption presented in an other Icotom paper :

$$dI(\varphi,\psi) = i \,.\, K(\varphi,\psi) \,.\, e^{-\mu t(\varphi,\psi)} dV$$

we obtain the following expression :

$$i \cdot K_S(\varphi,\psi) \cdot D(\varphi,\psi) = I_{BA}(\varphi,\psi) - \frac{I_{AA}(\varphi,\psi) \cdot B(\varphi,\psi)}{A(\varphi,\psi)} \qquad (3)$$

Where

- $Ks(\varphi,\psi)$ is the orientation factor of the shell only
- $D(\varphi,\psi)$, $B(\varphi,\psi)$ and $A(\varphi,\psi)$ are correcting factors depending on the irradiated volume and the absorption phenomenon, and defined in [2 and an other Icotom paper].

1.2) Example :

We present several pole figures coming from a 175µm diameter steel wire drawn by the SODETAL company, to illustrate the way to obtain the texture evolution across the wire diameter.

With the iron wave length used, the penetration of X-rays is about 50µm in the steel wire.

One of the caracteristics of these kinds of wire is a <110> fibrous texture located in the core and a <110> circular texture located under the surface (2).

With the procedure described previously, it is possible to know the texture of a 10µm thick shell located anywhere in the wire. To illustrate the ways of measurement and calculus, the area chosen is located between the diameter 110µm and 90µm. The successive step in the samples preparation are :

- a thinning down of the wire from 175µm to 110µm by a chemical attack; followed by the making of the set of adjoining 110µm diameter wires for X-ray diffraction examination (sample 1).
- a thinning down of the wire diameter from 175µm to 90µm by a chemical attack; followed by the making of 90µm diameter wires set for X-ray diffraction examination (sample 2).
- the sample 1 gives $I_{BA}(\varphi,\psi)$; the sample 2 gives $I_{AA}(\varphi,\psi)$.
- the calculus of the corresponding $A(\varphi,\psi)$, $B(\varphi,\psi)$ and $D(\varphi,\psi)$ are done with a microcomputer.
- and finaly, the calculus of the expression (3) give us $Ks(\varphi,\psi)$

On the fig. (1) we present the pole figure of the 110 µm wire, with the core influence, corrected by absorption and diffracting volume effects. On fig. (2) we show the pole figure of the 90 µm wire, corrected by absorption and diffracting volume effects. On fig. (3) we show the pole figure of the shell alone. On fig. (4) we present the pole figure of the intensities coming from the core attenuated by the shell and corrected by absorption and diffracting volume effects.

1.3) Observations

One can remark that the pole figure of the 110µm wire $I_{BAcorrected}(\varphi,\psi)$ corresponding to the whole diffracted intensity (shell+core) shows a texture close to a fibrous texture. Whereas the pole figure coming from the shell alone shows a circular texture. This procedure allows to distinguish several areas of different textures in an heterogeneous textured material and gives the possibility to know with a good precision the texture evolution across the wire diameter.

II) EVOLUTION OF TEXTURE INDEX IN STEEL-CORD

The texture variations in the wire are described by the evolutions of :

- the corrected pole figures, wich define the local orientation of crystallites in the drawn material.
- the texture index (Ti), defined as the arithmetic average of all the absolute differences between the measured pole figure and the pole figure of a geometricaly identical but isotropic sample of the same material.

$$Ti = \frac{\sum_{k=1}^{n} \left(\left| I_k^{measured} - I_k^{isotropic} \right| \right)}{n - \frac{m}{2}}$$

where : - n is the number of intensity measurements in one pole figure,
- m is the multiplicity of the measured lattice plane.

Ti varies from 0 to 2, it is characteristic of each pole figure, it reflets the texture sharpness and can be evaluated during the drawing process accross the wire section. Its values are 0 when the wire is isotropic, and 2 when the wire is perfectly oriented.

2.1) Evolution of the texture index in a 0.25 mm drawn wire (steel-cord)

The texture index evolution accross the wire section (0,25 mm diameter) after the last die (fig 5) shows an extremely well oriented ferritic matrix in the core of the wire (Ti=0.9); whereas the orientation is unsharp (Ti=0.2) at the surface. This comes from the plastic flow distribution of the metal through the die.

The more the ferrite is close to the core of the wire, the more the <110> directions of the ferrite are oriented towards the wire axis .

2.2) Influence of the die angle.

Three wires have been drawn with different die angles (9°, 12°, 17°). The fig. (6) shows that the smaller the angle, the more the core is oriented. The orientations at the surfaces are equivalent even if the skin friction on the die is not the same.

III) CONCLUSION

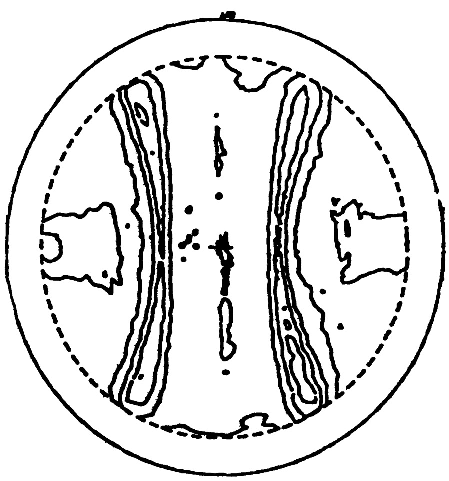
The <110> orientation of the ferrite is always observed at all the steps of the drawing process. The sharpness of this orientation depends on the location of the ferrite in the wire, and on drawing parameters mentioned above.

The texture index is a very sensitive parameter of the cold drawing process, it changes more than the parameters resulting from mechanical tests.

The texture parameters (pole figure and index) show that there is room to improve orientation homogeneity and therefore to give more deformation possibilities.

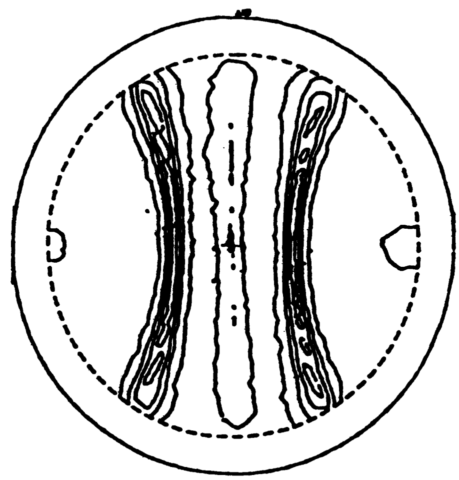
1. A. Guinier, *Théorie & technique de la radiocristallographie* (Paris: Dunod 1956).
2. T. Montesin & J.J. Heizmann, *Mém. Et. Scient. Rev. de Mét.*, April 1990.
3. T. Montesin & J.J. Heizmann, *J. Appl. Cryst.*, to be published.

Fig. 1



IBA = corrected intensity
110μm diameter steel wire

Fig. 2



IAA = corrected intensity
90μm diameter steel wire
The CORE of the 110μm wire

IS = calculated intensity
The SHELL of the 110μm
wire

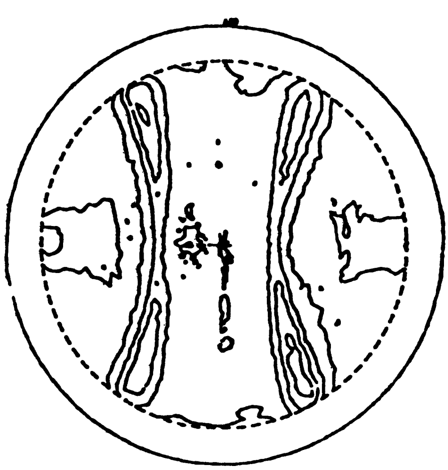


Fig. 3

ICS = calculated intensity
The CORE (90μm)
attenuated by the SHELL

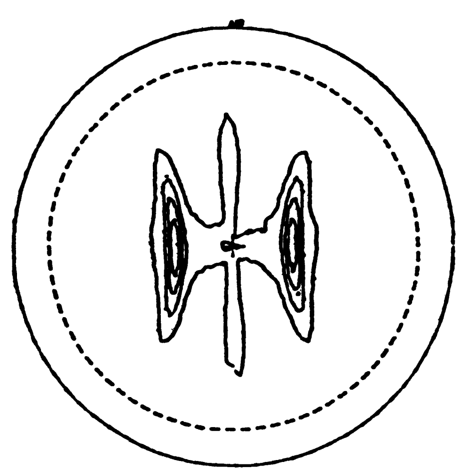


Fig. 4

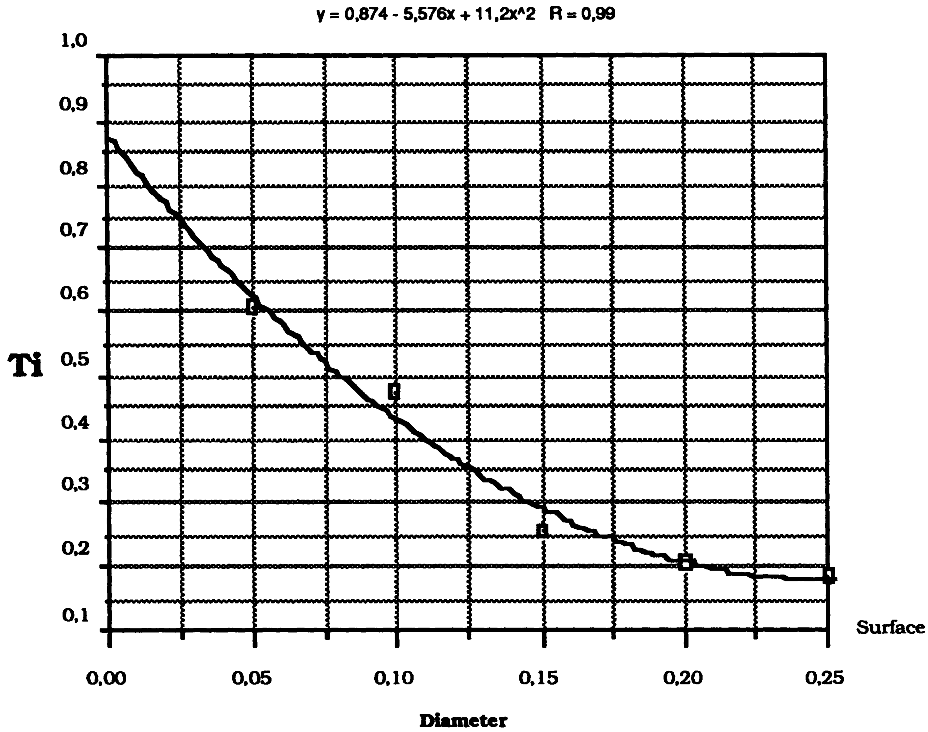


Fig. 5 : Evolution of the texture index in a 0,25 mm diameter wire

Fig. 6 :
Influence of the die angle on the crystallographic texture of a thin wire