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THE EFFECT OF CROSS ROLLING ON TEXTURE AND MAGNETIC PROPERTIES OF NON ORIENTED ELECTRICAL STEELS

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ABSTRACT

The texture change due to a change of cold rolling direction and annealing temperature in the production of 0.6% Si steel sheet is described. Cross rolling results in a very strong (001)<110> component, causing soft magnetic properties in a direction at 45 degrees of the rolling direction. The texture governing mechanism of the primary and secundary recrystallization was oriented growth. The influence of texture on magnetic properties could be shown by measuring the directional properties of the sheet. The correlation between hysteresis losses and induction with texture and grain size was quantified.

INTRODUCTION

Non oriented electrical steels are used for the production of rotors and stators of small electric motors. High permeability and low core losses are the most important demands concerning the magnetic properties of the material. The total core loss consists of two components: the hysteresis losses P_H which is equal to the surface surrounded by the hysteresis loop, and the eddy current losses P_T. The eddy current losses are correlated to the resistivity and hence mainly influenced by the composition. Microstructure and texture have a decicive impact on the hysteresis losses and the permeability. Because of the specific nature of the magnetic anisotropy of the single crystal (1), the best texture for the non oriented steel sheets will be a <100> // ND fibre texture.

The purpose of this paper is double. First, the texture development of the material is described as a function of the successive processing steps and secondly, a study is presented in which the magnetic properties (permeability and hysteresis losses) are correlated with the texture data and the grain size.

MATERIALS AND EXPERIMENTAL PROCEDURE.

The experiments were carried out on industrial hot rolled material. The composition is shown in table 1. The processing parameters are schematically presented in figure 1.

Tabel 1: Composition in 10^{-3} wt.%

C	Mn	Si	P	S	N_2	Al
40	152	572	9	3	4.5	305

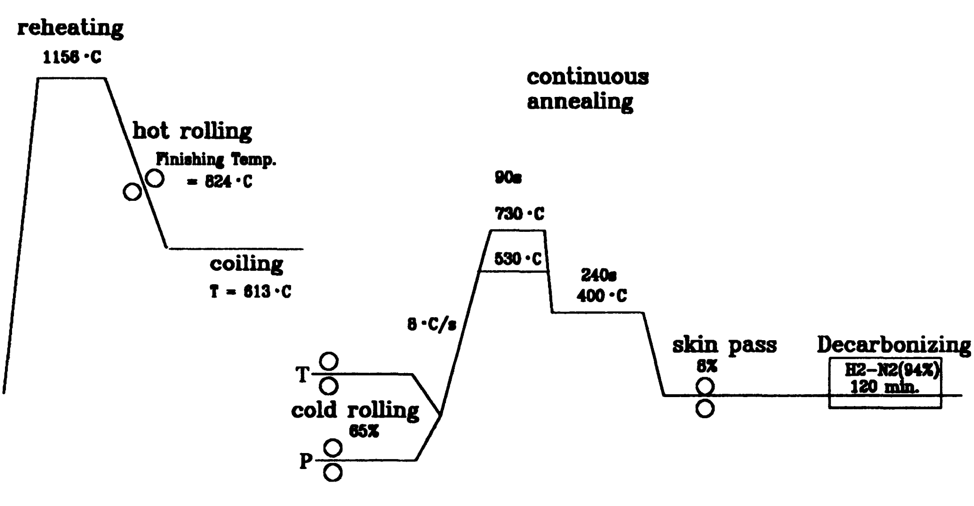

Figure 1: The schematical presentation of the processing parameters

Magnetic properties, P_H, P_T and induction B, and the grain size of all decarbonized samples were determined in the hot rolling direction (0°), the transverse direction

(90°) and 45° direction.

After each production step the texture was evaluated with a Siemens X-ray texture goniometer. From four incomplete pole figures the orientation distribution function (ODF) could be calculated, applying Bunge's method (2). The texture results are presented in a $\varphi_2 = 45°$ section of the Euler space.

In order to correlate texture data with magnetic properties a texture parameter A was defined. The A parameter of a crystallite with orientation g is the absolute value of the angle between the direction in which the magnetic properties are considered and the nearest <100> direction of the crystallite. This parameter is then averaged over all g using the ODF as weighing function. This averaged parameter, termed "A parameter", is calculated for the directions at 0°, 45° and 90° of the rolling direction. To account for the texture gradient accross the sheet's thickness, texture measurements and A parameter calculations were carried out in the mid plane (50% of depth) as well as on 15% depth. All A parameters mentioned next, are arithmetic thickness averages for 15% and 50% depth.

RESULTS AND DISCUSSION

The texture evolution

The middle plane's texture evolution throughout the production process is shown in figure 2.

The hot rolling texture in the middle of the sheet consists of a partial <110> // RD fibre and a (332)<113> component. These orientations are related to the austenite rolling and recrystallization components through a Kurdjumov-Sachs relationship. This type of texture is introduced by a transformation induced recrystallization taking place at the end of the intercritical hot rolling (3).

During cold rolling, the hot rolling components rotate as expected (4). Cross rolling results in a very strong (001)<110> component because the <110> // TD fibre rotates entirely to this component.

Annealing and decarbonization produces textures, strongly dependent on the annealing temperature and the starting texture. Whereas for the longitudinal rolled samples the texture governing mechanism is oriented nucleation as usually met in steels, in the cross rolled samples oriented growth becomes dominant (5). Annealing and decarbonization of the cross rolled material results in a switch of the texture following a 30° rotation around a <110> direction.

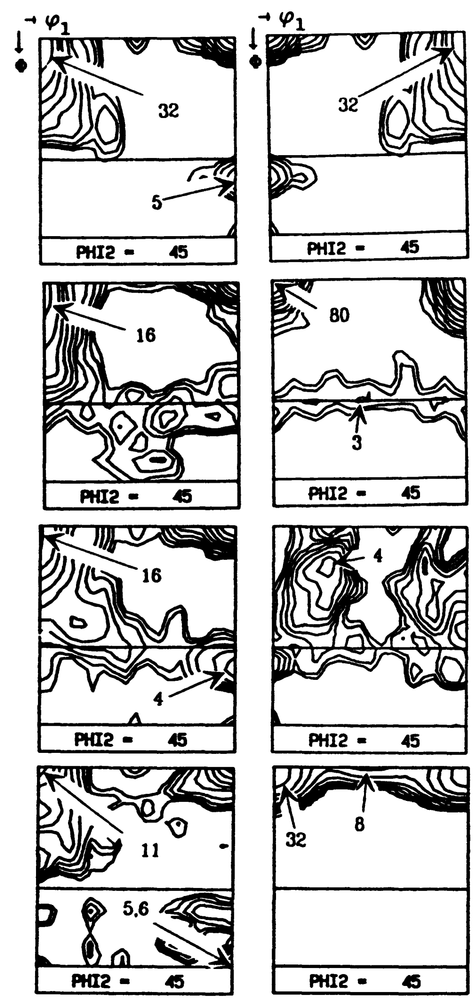

Figure 2: The texture evolution of the steel sheet through cold rolling, annealing and decarbonization annealing

Correlation with magnetic properties

A multiple regression method was used to correlate the magnetic data of the decarbonized samples with the grain size and texture parameter A as independent input variables. The results are represented by eqs. 1-2:

$$B(T)=2.164-(0.023\pm0.030)D(mm)-(0.016\pm0.001)A(^{\circ}) \qquad (1)$$

$$P_H(W/kg)=-0.869-(4.0\pm0.9)D(mm)+(0.15\pm0.04)A(^{\circ}) \qquad (2)$$

The multiple correlation coefficient are 0.924 and 0.795 for eqs. (1) and (2) respectively. Figure 3 displays the measured magnetic properties as a function of the calculated values according to these equations.

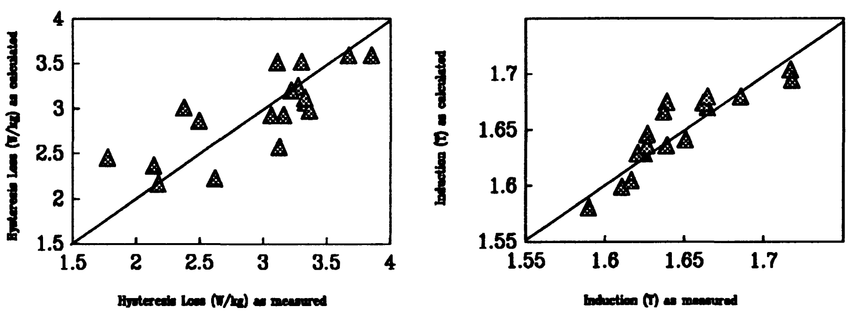

Figure 3: The measured magnetic properties as a function of the calculated values on the basis of the regression equations.

As appears from equation (1) there is no correlation between the induction and the grain size data. Consequently, according to the proper correlation coefficient, more than 90% of the variation of the induction can be explaned only by taking the texture parameter into account. For the hysteresis losses the fit is far less good. Grain size and texture only account for about 80% of the correlation. The remaining spread may have different causes. The rough approximation of the mathematical weighed thickness averaged A parameter by an arithmetic average of the A parameters on 15% and 50% depth may introduce a good part of the spread. Moreover, other parameters such as for example the residual carbon content influence the hysteresis losses.

CONCLUSIONS

The A parameter as defined in this paper is useful for magnetic applications, describing the anisotropy of the sheet.

The hot rolling texture can have a determining influence on texture evolution during the further production process.

Oriented growth can be the texture governing mechanism during primary and secundary recrystallization of steel sheet.

Regression equations have been found that represent the texture and grain size influence on magnetic properties.

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