MAGNETIC ANISOTROPY METER

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It is known that the texture quality of a large range of ferromagnetic strip materials [1, 2] can be evaluated from the curves representing magnetic anisotropy.

If the specimen has one definite type of texture, its quantitative characteristic will consist of the ratio of amplitudes on the curves of its mechanical moment, or of the normal component of the intensity of magnetization vector of a tested polycrystalline specimen or a monocrystal with a corresponding orientation (Fig. 1).

The most commonly encountered texture in practice consists of the dispersion of grains around several simple primary orientations. The quantitative characteristic of such textures can be provided by using the method of specific volumes developed by N. S. Akulov and N. L. Bryukhatov [2]. For this purpose a harmonic analysis is made of the curves representing the relationship of the mechanical moment or of the intensity of magnetization vector's normal component to the specimen's angle of rotation in a magnetic field. The quantity of definite texture components can be calculated by means of special formulas from the analyzed values of the even harmonic amplitudes \( A \) and the known anisotropic constants \( K \) [3, 4]. Moreover, it has been shown in [5] that for a more precise evaluation of the texture it is required to take into consideration three anisotropic constants \( K_1, K_2, \) and \( K_3 \). For this purpose it is necessary in the harmonic analysis to obtain higher amplitudes up to that of the eighth harmonic.

For the evaluation of the intensity \( W \) of Goss textures \( \{110\} <100> \), with the three Druzhinin anisotropic constants taken into consideration, we obtained formula

\[
W = - \frac{A_2}{\frac{1}{4} K_1 + \frac{1}{64} K_2 + \frac{11}{128} K_3}
\]  

(1)

for calculating by means of the second order harmonic \( A_2 \), and formula

\[
W = - \frac{A_4}{\frac{3}{8} K_1 + \frac{1}{16} K_2 + \frac{17}{128} K_3}
\]  

(2)

for calculating by means of the fourth harmonic amplitude \( A_4 \).

It is noted in [6, 7] that the presence of the second harmonic in the torque is not only related to the crystallographic texture, but also depends on the internal stresses and the precision of the disc manufacture. Therefore, in computing \( W \) it is preferable to use (2). For evaluating the texture intensity of cold-rolled electrical steel, it is recommended in [5] to take the mean \( W \) obtained for the values of \( A_2 \) and \( A_4 \).

The quantitative determination of texture from the above formulas is possible if a part of the crystallites' volume has a strictly determined orientation and the remaining part has a random orientation. Therefore, quantitative determination of texture from (1) and (2) is to a certain extent conditional.

It is suggested in [8] to determine the texture quantitatively by the degree of its dispersion. It is shown that there exists for a ripple texture a direct relationship between the torque harmonic amplitudes \( A_n \) and the variance of angles \( \alpha \)

\[
A_n = n b_n \cos n \alpha,
\]  

(3)

where \( b_n \) is a coefficient determined experimentally, \( A_n \) is the \( n \)-th harmonic amplitude.

It will be seen that in this method of evaluating texture it is also necessary to obtain harmonic curve amplitudes of the mechanical moment or of the normal component.

Thus, the evaluation of texture by means of magnetic methods requires in the majority of cases an additional analysis of the magnetic anisotropy curves with the selection of the 2nd, 4th, 6th, and 8th harmonics. The practical harmonic analysis which is normally carried out by means of the graphoanalytical method [9] is very labor-consuming and contributes considerable additional errors to the harmonic amplitude evaluations. It is of considerable interest to develop techniques which simplify this operation.

Below we provide a description of a magnetic anisotropy meter (developed by the Institute of Metal Physics of the Academy of Sciences of the USSR) which differs from existing designs [1] by the fact that it provides not only rapid plotting of anisotropy curves, but also the values of their harmonic amplitudes $A_2$, $A_4$, $A_6$, and $A_8$.

The anisotropic meter consists of synchronous motor 1 (Fig. 2), which rotates circular mounting 2, located between the poles of dc electromagnet 3. The mounting carries a specimen in the shape of a 30 mm diameter disc. The specimen is placed inside measuring winding 4, whose turns are strictly parallel to the lines of force in the field. The emf induced in the measuring winding by the rotation of the specimen is proportional to the derivative with respect to the rotation angle of the magnetization vector's normal component $dN/d\phi$.

The signal is fed from the measuring winding to integrating amplifier 5, which consists of a cascode dc amplifier with transistors 6N2P and a large negative feedback. The signal, which is proportional to the variations of the specimen's normal component with the rotation angle $N_\phi$, is transmitted from the output of the integrating amplifier to the input of the resonant measuring amplifier tuned to the frequencies of the second, fourth, sixth, and eighth harmonics of the tested signal.

The amplifier is tuned to the resonance frequencies by means of four twin-T bridges connected to the feedback circuit of the amplifier's cascode part. The bandwidth of each bridge does not exceed 3 Hz. For measuring the required harmonics the amplifier is connected to a bridge which is tuned to the appropriate frequency. The harmonic amplitude is read off the scale of recording instrument 7 which is connected to the amplifier output. The twin-T bridges are shown in Fig. 2 as analyzing unit 6.

The schematic of the integrating amplifier and analyzing unit are shown in Fig. 3. Cathode-ray oscillograph 8 (see Fig. 2) is connected in parallel with the integrating and resonant amplifiers. The oscillograph serves to observe and photograph the intensity of the magnetization vector's normal component (Fig. 4a) and its derivative with respect to the rotation angle (Fig. 4b). Typical oscillograms of these curves are shown for specimens with a texture of (110)[001].

For evaluating texture intensity the tested specimen is placed in a mounting, the electromagnet and motor are switched on, and the harmonic amplitude is evaluated from the meter readings.

The anisotropy meter has to be calibrated in order to express its readings in absolute units. Discs 30 mm in diameter with a monocristalline structure were cut out with a special die from cold-rolled transformer steel (2.9% Si) with large grains (100-150 mm wide). Moreover, the specimen's surface was made to coincide with plane (110) within the range of 1.5°. The texture intensity $W$ of the discs was assumed to equal 100%.

Having measured the discs on the anisotropy meter for known anisotropy constants of steel with 2.9% of Si the harmonic amplitudes were calculated from (1) and (2) in absolute units (J/m²).

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