DEVICE FOR MEASURING HYSTERESIS LOOP COEFFICIENTS

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In testing ferromagnetic materials by their hysteresis loop with its characteristic quantities $B_m$, $H_m$, $B_r$, and $H_c$ (Fig. 1a), it is often also necessary to know the quadrature factor $B_r/B_m$ for $H = \frac{1}{2} H_m$, the rectangularity factor $B_r/B_m$, and the factor $H_c/H_m$. These factors are calculated following the measurements of $B_m$, $H_m$, $B_r$, $H_c$, and $B_{rs}$ for $H = \frac{1}{2} H_m$ [1], or they are measured as the ratio of the distances between the corresponding points on oscillograms [2], which requires measurements of long duration and is not sufficiently precise.

For a direct measurement of the above factors with the possibility of reading them off scales, a special device is used which is based on the ferrograph principle. Measurements are then made by the "reflected loop" method [3].

"Reflected loop" method. The cathode-ray oscilloscope plates are fed with voltages (Fig. 1a) which are proportional to induction $I$ (Y axis) and to field strength $H$ (X axis), thus producing on the oscilloscope screen the hysteresis-loop image of the tested ferrite core.

If the voltage proportional to field strength $H$ (let us call it voltage $H$, Fig. 1b) is rectified, the voltage proportional to induction $B$ (voltage $B$) will be scanned on the screen only to the right of axis $B$ (the image seen on the screen is shown in the right-hand part of Fig. 1b). The hysteresis loop part which was previously to the left of axis $B$ (the right-hand part of Fig. 1a) will now be superposed on the right-hand part of the hysteresis loop. The image on the CRO screen (Fig. 1b) can be considered as consisting of a part of the hysteresis loop over which the other ("reflected") part is superposed, thus originating the name of "reflected loop" given to this method.

By adjusting voltage $H$ as shown in Fig. 1c, it is possible to convert the reflected part of the loop into a vertical line. Segment $O_m B$ will then correspond to maximum induction $B_m$, and segment $O_r$ to residual induction $B_r$ (right-hand side of Fig. 1c). By adjusting voltage $B$ as shown in Fig. 1c, it is possible to make points $m_b$ and $r$ coincide. The coincidence of the points means that the ratio of the amplitude of voltage $B$ at the instant when $H$ equals zero to its amplitude corresponding to the positive half-period of $H$, is equal to the ratio of segments $O_r/O_m B$, which in turn is equal to the rectangularity factor $B_r/B_m$.

By adjusting voltage $I$ as shown in Fig. 1d, it is possible, in a similar manner, to convert the reflected part of the loop into a horizontal line. Segment $O_m H$ will then correspond to the maximum field strength $H_m$, and segment $O_C$ to the coercive force $H_c$ (right-hand side of Fig. 1d). By adjusting voltage $H$ (see Fig. 1d), it is possible to make points $m_h$ and $C$ coincide. The coincidence of the points means that the ratio of the amplitude of voltage $H$ at the instant when voltage $B$ equals zero to its maximum amplitude is equivalent to the ratio of segments $O_C/O_m H$, which in turn is equal to factor $H_c/H_m$.

Fig. 1.
When the quadrature factor \( B_{rs}/B_m \) is measured for \( H = 1/2 H_m \), this condition is set by voltage \( H \) on a coupled potentiometer (Fig. 1e). The reflected part of the loop in this case is scanned to the right only up to the value of \( H \) which is equal to \( 1/2 H_m \). Segment \( O'm' \) then corresponds to induction \( B_m \), and segment \( O's \) to induction \( B_{rs} \) for \( H = 1/2 H_m \). By adjusting voltage \( B \) as shown in Fig. 1e, it becomes possible to make points \( m' \) and \( s \) coincide. The coincidence of points means that the ratio of the amplitude of voltage \( B \) at the instant when \( H = 1/2 H_m \) to its maximum amplitude is equivalent to the ratio of segments \( O's/O'm' \), which in turn is equal to the quadrature factor \( B_{rs}/B_m \) for \( H = 1/2 H_m \).

In all three cases the comparison and adjustment of voltages can be made by precision potentiometers whose scales are calibrated respectively in units of factors \( B_r/B_m \), \( H_c/H_m \), and of the quadrature factor.

Measurements by the "reflected loop" method are made by means of a normal ferrograph whose cathode-ray tube plates are preceded by a ratio-measuring unit (Fig. 2).

Channel \( y \) is connected to electronic commutator switch \( S \) (Fig. 3) in the ratio-measuring unit (Fig. 2), and channel \( x \) to the rectifying and control circuit \( B \), which consists of four diodes and a twin variable resistor \( R_2 \) (Fig. 4). Voltage \( H \) (see Figs. 1b, 1c, and 1d) is rectified by means of a rectifying and control circuit in such a manner that its input resistance remains constant for any position of the potentiometer sliders, thus keeping the total resistance consisting of \( R \) and the potentiometer resistance (Fig. 2) at a constant value. The circuit is suitable for adjusting the rectified half-period of the sinusoidal voltage from zero to its maximum value.

Voltage \( B \) (see Figs. 1c, 1d, and 1e) is adjusted by means of (see Fig. 2) potentiometer \( P_1 \) and electronic switch \( S \). The electronic switch is synchronized with the sinusoidal magnetizing voltage. The inputs of the electronic switch are changed over at the instant when the sinusoidal voltage passes through its zero value. This is arranged by means of the phase-shift circuit PSC connected to the electronic switch. The electronic switch connects either the full voltage \( B \) or a part of it through potentiometer \( P_1 \), thus serving to provide any of the values of \( B \) shown in Figs. 1c, 1d, and 1e.

The sinusoidal voltage, having passed through the phase shifter, synchronizes multivibrator MV, tube \( T_1 \). Trigger \( T \), tube \( T_2 \), is switched at the instants corresponding to the leading and trailing edges of the multivibrator pulses. The trigger energizes in turn tubes \( T_3 \), \( T_4 \), \( T_5 \), and \( T_6 \), thus serving to connect to the output the signals from input I or input II.

In measuring the rectangularity factors \( B_{rs}/B_m \), the sliders of potentiometers \( P_2 \) (see Fig. 4) are set to their extreme right-hand position and voltage \( H \) is rectified (see Fig. 1c). Voltage \( B \) is set by potentiometer \( P_1 \) so as to make points \( m_1 \) and \( r \) coincide (Fig. 1c). The ratio of the potentiometer resistance between its slider and ground to its total resistance is then equal to rectangularity factor \( B_r/B_m \).

In order to measure factor \( H_c/H_m \), the slider of potentiometer \( P_1 \) is set to its extreme bottom position, with voltage \( B \) having the shape shown in Fig. 1d. Points \( T_1 \) and \( c \) (Fig. 1d) are brought to coincidence by potentiometer \( P_2 \). Factor \( H_c/H_m \) is then equal to the ratio of the resistance of potentiometer \( P_2 \) between its slider and ground to its full resistance.