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Measuring system for non-destructive control of metal bars.

The structural scheme, which will provide an increase in metrological characteristics of the vortex-stroke non-destructive control method, is developed.

The control of the parameters of metal products with the help of the eddy-current method of non-destructive control of electromagnetic induction based on the law has become widespread today. Due to the high sensitivity of a wide range of frequencies, it is possible to control the mechanical properties, uniformity of the material, both magnetic and non magnetic materials, contactlessness, high reliability, automation of the control process, etc.

The object of the study is the process of interaction of an external electromagnetic field with defects in the heterogeneity of the structure in a metal rod, which causes deformation of vortex currents and, accordingly, their influence on the inductance of the coil of the sensor. So, according to the law of electromagnetic induction, vortex currents induced by an external electromagnetic field will ask for their own field, which will counteract the external field, which will lead to a change in the inductance of the coil of the sensor. Therefore, the most informative parameter in this case will be a relative change in the sensor's inductance. Therefore, the most informative parameter in this case will be a relative change in the sensor's inductance.

In known developments, differential-transformer transducer type transducers are used, which differ in implementation difficulties, but have high sensitivity. In existing works insufficient attention is paid to increasing the metrological characteristics of measuring the output signal of sensors, such as sensitivity, noise protection, accuracy (insert names)

Modern means of eddy current flaw detectors in most cases are intended for scientific research, but little attention is paid to the means that can be used in technological processes, due to the complex implementation of the measuring process in existing means and the large amount of software with automatic processing of information.

To eliminate the above-mentioned shortcomings a structural scheme of the measuring system of non-destructive control was developed in Fig. 1

Parameters of the sensor - C_X, L_x, r_x, - parasitic capacitance (C_x), inductance (L_x), resistance (r_x), which characterizes the loss of energy in the core. The sample coil (2) is defectless, respectively , C_0, L_0, r_0. C_x, L_x, r_x - coil, which is under the influence of defective zones in a controlled rod. A defects are considered cracks, some inhomogeneities of the material, which through the mechanism of interaction of the magnetic field, eddy currents and interaction with the magnetizing field of the coil cause a change in equivalent parameters of the coil, with the most informative parameter will be the relative change in the coil inductance

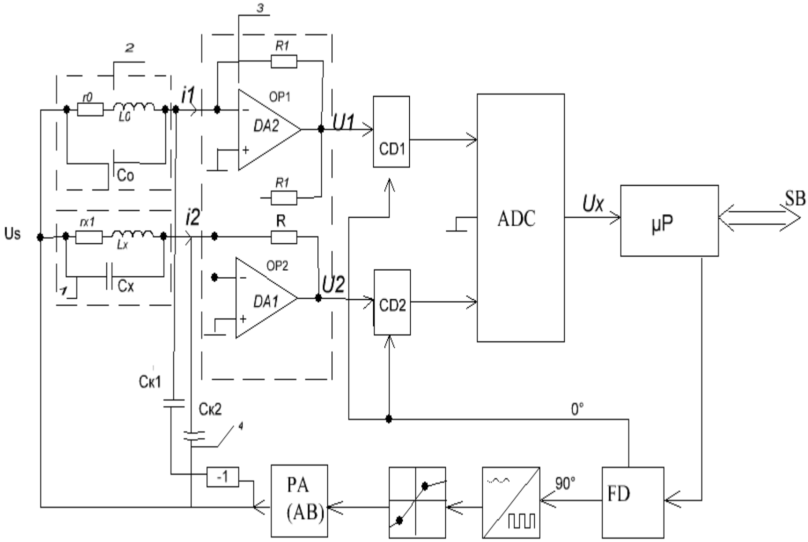


Fig.1 Functional scheme of the measuring channel.

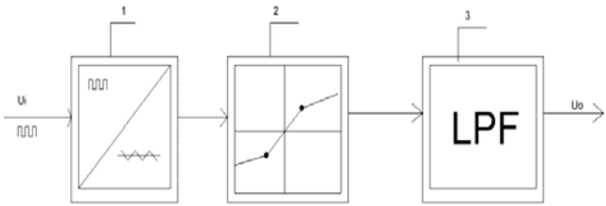
$$\delta = \frac{L_x - L_0}{L_0} \qquad (1)$$

These coils form adjacent shoulders of an unbalanced bridge circuit with a short-circuited measuring chart. In this case, as a current comparator, a measuring amplifier with differential currents inputs (3) is used. Its elements are operational amplifiers $DA1, DA2$ and supports R_1, R_2, R_3. Output voltages of this amplifier with the help of two synchronous detectors $CD1, CD2$, which form the wall voltage, which fall on the inputs of the ADC with a simultaneous sampling. The results of conversion to ADC entering the microprocessor μP in which the diagnostic criterion is calculated. The sensor initiation signal is formed from the so-called frequency of the microprocessor μP using the phase separator divider, the quadrature outputs of which are used for controlling the synchronous detectors $CD1, CD2$, and the second for forming the signal of the initiation of the sensor by means of successively connected rectangular voltage converters into a triangular (integrator) non-linear converter with coccoline approximation and low pass filter low pass filter/ The output of the FD is amplified by the power amplifier PA (AB).

A negative capacitance method is used to complete the parasitic capacitance of the coils C_0, C_x. With adjustable capacitors Ck_1, Ck_2 and a similar inverter (4).

In order to increase the sensitivity to cracks or scratches, which can be considered as air layers in the core. The magnetization coil is used flat in order to reduce the average length of the magnetic power line.

The work of the scheme. To reduce the phase error, which is due to the deviation of the ideal square bipolar axes from the real ones. The formation of signals, control, synchronous detectors and sensors initialization is realized with the help of the equadractor output signals of the phase separator divider, which are synchronized with the output signals of the programmed microprocessor timer timer. The initialization signal is formed by successive execution of a series of firstly converted vortex signals, the DFR is converted into a bipolar symmetric meander, which is then integrated into a real integrator, while the vortex integrator generates a silicon-like voltage symmetrically shifted in the phase by 90 ° relative to the input signal (whose phase we accept for 0)



1-Integrator, 2-piecewise linear approximation, 3-low pass filter
Fig. 2 The block diagram of the generator of initialization signals

The output signal of the integrator falls into the piecewise-linear scheme of the sinus approximation .. to reduce the coefficient of nonlinear distortions, the vortex signal of the piecewise linear approximator is less than 0.1%. The signal of the piecewise-linear approximator is formed by the LPF. As the LPF, a second-order filter is used with the Baterworta approximation, while its constant time rotates so that at the initialization signal frequency, the phase shift it creates is 90 ° ± 0.5 °, this allows you to represent the position of the measurement signals using the vector diagram.

Where there θ_1, θ_2 are corners of the inappropriate real and imaginary axes, respectively, A′ and B′, the active and real coordinates of the vector can be represented

$$A' = A \cdot \cos\theta_1 - B \cdot \sin\theta_2 \qquad (2)$$

$$B' = B \cdot \cos\theta_2 + A \cdot \sin\theta_1 \qquad (3)$$

$$C' = C \cdot \cos\theta_1 - D \cdot \sin\theta_2 \quad (4)$$

$$D' = D \cdot \cos\theta_2 + C \cdot \sin\theta_2 \quad (5)$$

if $\theta_1, \theta_2 \ll 1$, then

$$A' = A + B\theta_2 \quad (6)$$

$$B' = B + A\theta_1 \quad (7)$$

$$C' = C - D\theta_1 \quad (8)$$

$$D' = D + C\theta_2 \quad (9)$$

The measurement error of the imaginary frequency will be equal

$$\text{to } \gamma = \frac{A}{B} \cdot \theta_1, \quad (8)$$

or considering that $\frac{B}{A} = Q$

$$tg\delta = \frac{r_x}{\omega L_x} = D \quad (9)$$

$$\gamma = \frac{\theta_1}{Q} \quad (10)$$

From the equation it follows that, but it is 0.01 and $Q \geq 10$ at a frequency of 10 kHz. This means that the phase error will not exceed 0.1%. That is enough for the means of technical diagnostics of non-destructive testing

U_1 vector voltage is proportional to the current in the sample coil

$$\dot{U}_1 = U_S \cdot \left[\frac{r \cdot R_1}{r_0^2 + (\omega L_0)^2} - j \frac{\omega L_x \cdot R_1}{r_0^2 + (\omega L_0)^2} \right] = $$
$$= U_S \cdot R_1 \left[\frac{r_0}{r_0^2 + (\omega L_0)^2} - j \frac{\omega L_0}{r_0^2 + (\omega L_0)^2} \right] \quad (11)$$

C - the real part of the vector U_1 will be equal

$$C = \frac{r_0}{r_0^2 + (\omega L_0)^2} \quad (12)$$

and the variable part D will be

$$D = \frac{\omega L_0}{r_0^2 + (\omega L_0)^2} \quad (13)$$

$$\dot{U}_x = \left[\frac{U_s \cdot R_3}{r_x + j\omega L_0} \right] = U_s \cdot R_3 \left[\frac{r_x}{r_x^2 + (\omega L_x)^2} - j \frac{\omega L_x}{r_x^2 + (\omega L_x)^2} \right] \quad (14)$$

The reactive part of the difference vector is marked $U_2 = U_2 - U_2$. The difference voltage vector is directly proportional to the difference in currents i_1, i_2 in the structural diagram U_2, then the imaginary par tmulti-vector

$$I_m = \{U_x - U_1\} = B \cdot D = \frac{\omega L_x}{r_x^2 + (\omega L_x)^2} - \frac{\omega L_0}{r_0^2 + (\omega L_0)^2} \quad (15)$$

The informative parameter will be the ratio of the smaller component of the difference vector to the smaller component of the model vector U_0. Since the Q-factor of the coils is much larger than one, these components will be collinear with an imaginary axis.

$$\delta = \frac{I_m \{\dot{U}_x - \dot{U}_1\} / I_m \{\dot{U}_1\}}{1 - I_m \{\dot{U}_x - \dot{U}_1\} / I_m \{\dot{U}_1\}} \quad (24)$$

Conclusions

Thus, the proposed system will provide an increase in the metrological characteristics of the eddy current ND method. Due to minimization of phase errors and errors caused by parasitic parameters of sensors and communication lines, and also due to a more efficient way of implementing the AB mode of the output stages of the power amplifier, which will reduce the distortion of the "step" type initialization signal in a wide frequency range.