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MULTIPARAMETER ELECTROMAGNETIC SENSORS FOR INFORMATION SYSTEMS OF CONTROL AND MANAGEMENT

Abstract. *Method for simultaneous determination of the electromagnetic and geometric parameters of products based on the measurement of the amplitude and phase of one or more spatial harmonics of the resulting magnetic field is developed. The feasibility of using electromagnetic sensors to obtain information about the state of metal objects control is shown.*

Keywords: *electromagnetic control, transformer converter, spatially periodic field, spatial harmonic, electromagnetic parameters*

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МНОГОПАРАМЕТРОВЫЕ ЭЛЕКТРОМАГНИТНЫЕ ДАТЧИКИ ДЛЯ ИНФОРМАЦИОННЫХ СИСТЕМ КОНТРОЛЯ И УПРАВЛЕНИЯ

Аннотация. *Разработан метод одновременного определения электромагнитных и геометрических параметров изделий на основе измерения амплитуды и фазы одной или нескольких пространственных гармоник результирующего магнитного поля. Показана целесообразность использования электромагнитных датчиков для получения информации о состоянии металлических объектов контроля.*

Ключевые слова: *электромагнитный контроль, трансформаторный преобразователь, пространственно-периодическое поле, пространственная гармоника, электромагнитные параметры*

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БАГАТОПАРАМЕТРОВІ ЕЛЕКТРОМАГНІТНІ ДАТЧИКИ ДЛЯ ІНФОРМАЦІЙНИХ СИСТЕМ КОНТРОЛЮ ТА УПРАВЛІННЯ

Анотація. *Розроблено метод одночасного визначення електромагнітних і геометричних параметрів виробів на основі вимірювання амплітуди і фази однієї або декількох просторових гармонік результуючого магнітного поля. Показано доцільність використання електромагнітних датчиків для отримання інформації про стан металевих об'єктів контролю.*

Ключові слова: *електромагнітний контроль, трансформаторний перетворювач, просторово-періодичне поле, просторова гармоніка, електромагнітні параметри*

Introduction. Currently a special practical interest represents the development of multiparameter measurement methods, which allow to receive the most complete information about the object and to determine the physical and technical parameters of multilayer structures [1 – 2]. In this regard electromagnetic methods and devices, the output signals of which are dependent on many parameters of the object of control (OC) and characteristics of the sensor have undeniable advantages. The output signals of the sensor give information about the magnetic, electrical and geometric parameters OC [3 – 4].

Objective of the work. Development of the method and device for non-contact joint determination of magnetic permeability, electrical conductivity and radius of products for sensors with spatially periodic magnetic fields, which arise because of heterogeneity of a field.

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Basic part. On a Fig. 1 the sensor with probing magnetic field with transmitting symmetry is presented. In cylindrical system of coordinates of r, φ and z with a longitudinal axis z such symmetry is characterized by that the magnetic field depends only on coordinates of r and φ [5].

A typical example of transmitting symmetry is the field of the long conductor with current. It should be noted that individual, particular cases of the field of the conductor with current located near a conductive cylindrical product were considered in works [6 – 8].

Ratios for distribution of values of the intensity of components of a magnetic field are given in work [9]. Thus, at known values of magnetic permeability μ_r, electric conductivity σ, radius of product a, distances from the centre of ferromagnetic product to the conductor with current d, current I and the radius of product r it is possible to calculate functions $f_n(r, \varphi, t)$ and $g_n(r, \varphi, t)$ for any spatial harmonics, and on these functions to make a picture of distribution of a field in any interesting area.

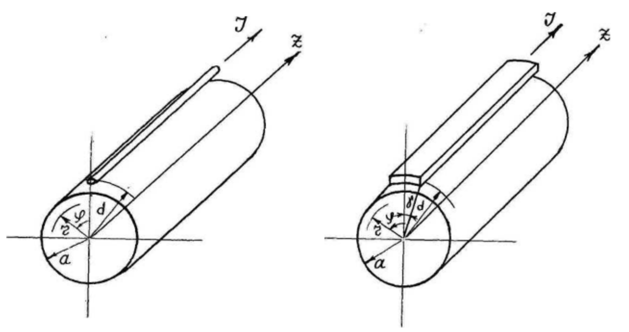

Fig.1. The electromagnetic sensor

To exclude from the picture of the spatial distribution of the field even or odd harmonics it is possible to use the system of conductors with the same or alternating directions of currents in them. And besides to save of a certain symmetry these conductors it is convenient to shift from each other on an azimuth on angle $\varphi = 2\pi/m$, where m – number of conductors.

When creating a device with spatially periodic fields appropriate to use transformer sensors which measuring windings are placed on radiuses $r = a_s$, smaller, than radiuses of exciting poles a_m. It allows select some first prevailing harmonics as the others are damped as $(a_s/a_m)^{n-1}$.

The windings can penetrate H_r or H_φ components of intensity of a magnetic field. In the first case the plane of the measuring winding must be perpendicular to the coordinate r, and in the second case – coordinate φ.

For the purpose of carrying out multiparameter measurements it is convenient to use normalized introduced r-th component of the magnetic flux (or introduced component EMF) n-th spatial harmonics.

Authors received expressions for the module and a phase for the flux components:

$$E_{in}^{(n)} = \left| \frac{E_{r0}^{(n)} - E_r^{(n)}}{E_{r0}^{(n)}} \right| = \left(\frac{a}{a_s} \right)^{2n} \sqrt{\left(Re\, h_r^{(n)}\right)^2 + \left(Im\, h_r^{(n)}\right)^2} , \quad (1)$$

where $E_{r0}^{(n)}$ и $E_r^{(n)}$ – r-th component EMF sensor without the product and with the product, respectively; $h_r^{(n)}$ – complex parameter which characterizes the reaction products on the exciting field (n-th harmonic).

$$tg\, \varphi_{in}^{(n)} = Im\, h_r^{(n)} \Big/ Re\, h_r^{(n)} . \quad (2)$$

The same component of the n-th harmonic of the normalized EMF is expressed in terms of modified Bessel's functions in the form:

$$E_{in}^{(n)} = \left(\frac{a}{a_s} \right)^{2n} \left[\frac{(\mu_r - 1) I_{n-1}\left(x\sqrt{i}\right) - (\mu_r + 1) I_{n+1}\left(x\sqrt{i}\right)}{(\mu_r + 1) I_{n-1}\left(x\sqrt{i}\right) - (\mu_r - 1) I_{n+1}\left(x\sqrt{i}\right)} \right] . \quad (3)$$

From (1) – (3) follows that for determination of three parameters of the product (a, μ_r and σ) it is necessary to use two any spatial harmonics of the field. From the point of view of achievement of high sensitivity and accuracy of measurements in the magnetizing system with one exciting pole (Fig. 1) it is better to allocate the 1st and 2nd harmonics [10].

Then for simplification of multiparameter measurements, as follows from (1) – (3), it is necessary to introduce the dimensionless parameters $N_{in}^{(1)} = \left(\frac{a_s}{a} \right)^2 E_{in}^{(1)}$ and $A_{21} = E_{in}^{(2)} \Big/ \left[E_{in}^{(1)} \right]^2$, which enable to construct the universal dependences connecting the sensor signals and characteristics of the product, which allows to solve the inverse problem of definition of a, μ_r and σ in the measured parameters (amplitude and phase) of the sensor.

Conclusions. The method consisting in carrying out a certain sequence of measuring and calculation operations for obtaining the informative parameters of OC is considered. Thus a simultaneous determination of μ_r, σ and a of the product based on the measurement of the amplitude and phase of one or several spatial harmonics of the resulting magnetic field is made. The last allows estimating the distribution of the electromagnetic parameters of over the section of product. The magnetic fields of all spatial harmonics change in time with the same frequency of the magnetizing current. Thus, multiparameter monitoring of the electromagnetic method provides its application in information and measuring systems.

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