Determining of complex magnetic permeability of the ferromagnetic material by complex impedance of inductance coil with ferromagnetic core

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Abstract **In the work there has been presented the method of determining of complex magnetic permeability of ferromagnetic material by the results of measuring complex impedance of inductance coil with ferromagnetic core. The complex impedance of the inductance coil was measured with immitance measuring device "E7-25".**

Keywords **Inductance coil with ferromagnetic core, complex impedance, magnetic permeability.**

I. Physical processes which occurs in the ferromagnetic core of the coil

A laying-on parametric eddy current probe (inductance coil with ferromagnetic core) with U-type core is traditionally used in the process of eddy current defectoscopy for ferromagnetic material with anisotropy properties. This eddy current probe is a coil with ferromagnetic U-type core with winding of number turns *w* thereon. To determine active resistance and reactance introduced by the tested area of ferromagnetic material it is necessary to know complex magnetic permeability [1]–[2].

The objective of the research is development of methods for determining complex magnetic permeability of ferromagnetic material by the results of measuring of active resistance and reactance of inductance coil with toroidal core (shown in Fig.1).

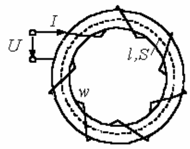

Fig. 1. Inductance coil with toroidal ferromagnetic core

The flux induced in the ferromagnetic core of inductance coil is determined by correlation:

$$U = 4{,}44 f w \Phi_m , \quad (1)$$

where U - effective voltage of the winding; f – working frequency; Φ_m - amplitude value of the working magnetic flux, w – number of winding turns.

Expressions for constituents of active resistance R and reactance X for coil:

$$R = \frac{\mu_r \mu_0 S \omega w^2 \sin\delta}{l}; \quad X = \frac{\mu_r \mu_0 S \omega w^2 \cos\delta}{l} \quad (2)$$

As is known, complex magnetic permeability of the ferromagnetic material:

$$\tilde{\mu}_r = \mu_1 - j\mu_2 = \mu_r e^{-j\delta} = \mu_r \cos\delta - j\mu_r \sin\delta \quad (3)$$

Components μ_1 and μ_2 of complex magnetic permeability we shall determine from equations (2):

$$\mu_1 = \mu_r \cos\delta = \frac{Xl}{\mu_0 S \omega w^2}; \quad \mu_2 = \mu_r \sin\delta = \frac{Rl}{\mu_0 S \omega w^2} \quad (4)$$

II. Experimental research

When carrying out experimental research we measured active resistance and reactance of eddy current probe by immitance measuring device "E7-25". Measurements were made on frequencies 100Hz, 200Hz, 500Hz, 1kHz, 2kHz, 5kHz, 10kHz, 20kHz, 50kHz, 100kHz, 200kHz.

By results of measurement there were determined components μ_1 and μ_2 of complex magnetic permeability, the values of which are shown in Table I.

Correctness of calculations can be checked by calculating tangent of angle of magnetic losses

$$\delta = arctg\frac{\mu_2}{\mu_1} \quad (5)$$

and by comparing the obtained result with

$$\delta_1 = (\pi/2 - \varphi), \quad (6)$$

where φ - angle determined by device data.

TABLE I
DEPENDENCY VALUES COMPONENTS μ_1 AND μ_2 OF COMPLEX MAGNETIC PERMEABILITY ON FREQUENCY

***f*, Hz**	100	200	500	10^3	$2\cdot10^3$	$5\cdot10^3$
μ_1	1482	1353	1224	954	718	445
μ_2	475	371	464	451	447	324
***f*, Hz**	10^4	$2\cdot10^4$	$5\cdot10^4$	10^5	$2\cdot10^5$	-
μ_1	282	207	141	112	98	-
μ_2	165	126	88	69	65	-

III. References

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