The average nonuniform quasistatic and dynamic electric and magnetic fields in a coil-extended ferromagnetic rod system are investigated experimentally in the 20 Hz-50 kHz frequency band. Hodographs of the fields in the complex plane are constructed which enable the mechanisms by which they interact to be interpreted clearly.

Theoretical relations, obtained in [1], establish the relation between the average nonuniform quasistatic and dynamic electric and magnetic fields in a system consisting of a cylindrical coil of arbitrary relative length and an extended ferromagnetic rod, and are the basis for setting up experiments to determine the behavior of these characteristics experimentally.

Formulas for the experimental determination of the average internal dynamic magnetic and electric field strengths in the part of the extended ferromagnetic rod placed in a coil of arbitrary length, have the form

\[ \tilde{H}_i = \frac{i_2}{L_1} \tilde{H}_a = \left( \frac{L_{e1} - jL_{e2}}{L_1} \right) \tilde{H}_a; \]

\[ \tilde{E}_i = \frac{i_2}{L_1} \tilde{E}_a = \left( \frac{L_{e1} - jL_{e2}}{L_1} \right) \tilde{E}_a; \]

where \( \tilde{H}_i \) and \( \tilde{H}_a \) are the average internal magnetic field strength in the part of the rod and the average nonuniform magnetic field strength in the coil, A/m; \( \tilde{E}_i \) and \( \tilde{E}_a \) are the average internal electric field strength in the part of the rod and the average nonuniform field strength in the coil, V/m; \( L_e = (L_{e1} - jL_{e2}) \) and \( L_1 \) are the complex equivalent inductance of the coil of arbitrary length with the part of the extended rod and the quasistatic inductance of the same coil when the part of the rod is uniformly magnetized, H.

The interaction between the magnetic and electric fields is given by the relation

\[ \tilde{E}_a = j\omega L_1 \beta \tilde{H}_a, \]

where \( \omega \) is the angular frequency, sec\(^{-1}\),

\[ \beta = \frac{l_k}{w^2 q \pi d_k}; \]

\( l_k \) and \( d_k \) are the length and average diameter of the coil, m; \( w \) is the number of turns in the coil; and \( q \) is the uniformity coefficient of the coil magnetic field.

*The averaging symbol – a bar above the letter denoting the characteristic – is omitted to simplify the notation.*

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The average nonuniform magnetic field strength of the coil and its uniformity coefficient are defined by the formulas

\[ H_n = \frac{i L_w}{I_k} \]  
\[ q = \frac{w_0 L_0}{w L_0} \]

where \( i \) is the current in coil, A; \( L_0 \) and \( w_0 \) are the inductance and number of turns of the coil for a relative length \( \lambda_k = l_k/d_k = 100 \); and \( L_01 \) and \( w \) are the inductance and number of turns in the coil of arbitrary relative length.

Formulas (1) and (2) give the resultant fields and take into account all the fields acting in the rod–coil system. In order to represent these fields in more detail, we will write an extended expression for the complex inductance:

\[ L_e = L_4 \left( 1 - k^2 \right) - L_2in = L_4 - L_2in - L_2in = L_e - L_2in. \]

where \( k \) is the quasistatic magnetic coupling coefficient; \( L_2in = k^2 L_4 \) is the quasistatic insertion inductance of the magnetic-polarization loop, H; \( L_2in = (L_{2in1} + jL_{2in2}) \) is the insertion inductance of the eddy-current loop, H; and \( L_e \) is the equivalent quasistatic inductance of the coil with the part of the rod, H.

Substituting (7) into (1) and (2), we obtain the following expressions for the internal magnetic and electric field strengths:

\[ \ddot{H}_i = \ddot{H}_n - \ddot{H}_\infty - \ddot{H}_2 = \ddot{H}_n - \left( 1 - \frac{L_e}{L_4} \right) \ddot{H}_n - \left( \frac{L_{2in1}}{L_4} + j \frac{L_{2in2}}{L_4} \right) \ddot{H}_n; \]
\[ \ddot{E}_i = \ddot{E}_n - \ddot{E}_\infty - \ddot{E}_2in = \ddot{E}_n - \left( 1 - \frac{L_e}{L_4} \right) \ddot{E}_n - \left( \frac{L_{2in1}}{L_4} + j \frac{L_{2in2}}{L_4} \right) \ddot{E}_n, \]

where

\[ \ddot{H}_\infty = \frac{L_{2in1}}{L_4} \ddot{H}_n = \left( 1 - \frac{L_e}{L_4} \right) \ddot{H}_n, \]
\[ \ddot{E}_\infty = \frac{L_{2in1}}{L_4} \ddot{E}_n = \left( 1 - \frac{L_e}{L_4} \right) \ddot{E}_n, \]

are the secondary magnetic and electric polarization field strengths, and

\[ \ddot{H}_2 = \frac{L_{2in1}}{L_4} \ddot{H}_n = \left( \frac{L_{2in1}}{L_4} + j \frac{L_{2in2}}{L_4} \right) \ddot{H}_n, \]
\[ \ddot{E}_2in = \frac{L_{2in1}}{L_4} \ddot{E}_n = \left( \frac{L_{2in1}}{L_4} + j \frac{L_{2in2}}{L_4} \right) \ddot{E}_n \]

are the eddy-current magnetic and electric field strengths.