JOURNAL OF CRITICAL REVIEWS

ISSN- 2394-5125VOL 7, ISSUE 15, 2020

TO THE PROBLEM OF THE CALCULATION CAPACITY OF THE NONLINEAR INDUCTANCE

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Received: 16 March 2020 Revised and Accepted: 17 June 2020

Abstract

The article describes the method of determining the equivalent capacitance of the nonlinear electromagnetic inductance.

Keywords: Nonlinear inductance, equivalent electromagnetic volume, resonance method, standard capacitor, dielectric permittivity and magnetic permeability.

1.Introduction

The problem of the calculation capacity of the multilayer toroidal coil with iron-core transformers and other configurations of nonlinear inductance presents practical interest. To this issue the works of M.A. Rosenblat, I.B. Negnevitskiy, S.I. Eleseev and others' [1,2] are devoted. High interest is given to the use of nonlinear inductance devices in secondary power sources (SPS) at increased frequency In well known works are shown what parameters can be influenced by equivalent capacity of the nonlinear inductance, particularly in highly sensitive operating devices. In these studies the capacities of toroidal coils performed on metal containers for tape cores were experimentally investigated. The capacities were measured by the resonance method according to the scheme shown in Fig. 1.

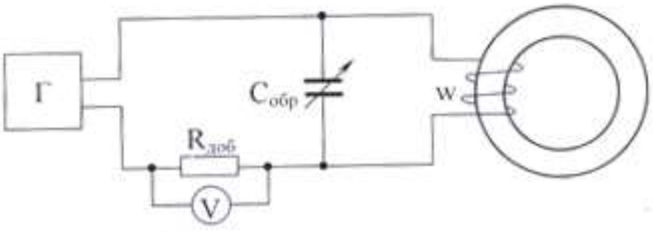

FIGURE 1.The scheme of the experimental determination of the equivalent capacitance of the nonlinear inductance

Here:

G -generator of harmonic oscillation (50-20 kHz);

$C_{обр}$ - Exemplary condenser of variable capacity (pF);

$R_{доб}$ - Additional resistance (ohms)

As well known [1], the main difference of the multilayer torpidly coil is determined by different length of the layer on the inner and outer side surfaces of the toroid. In this case, the gleam on the outer surface between coils is seen, and it gets higher as the ratio of the outer diameter to the inner core is rise. Therefore, part of the coils of the subsequent layers on the outside of the wind sinks between coils earlier. Hence there is capacity, not only between 1 and 2 layers, 2 and 3 layers, etc., but also between 1 and 3 layers, 1 and 4, 2 and 4, etc.

According to the authors [1,2] with the increasing the number of layers the equivalent capacitance of the wind increases at first, due to delay of the winds of the subsequent layers, and then decreases, cause of gradually emerging the series connection of inter-layer capacitances.

The number of layers, determining a maximum capacity, depends mainly on the ratio of the outer diameter to the inner of the container.

If we assume $D_к$ the capacitance between two adjacent layers, and each has a capacity $d_к$, taking the equivalent circuit of Fig. 2, in the case of k≥2 the following expression:

$$C_{э} = \frac{C_0 + C_1}{K + \frac{C_1}{C_0} + 0.5C_1}, \qquad (1)$$

Where: K is the number of layers of the wind.

(1) concludes that the equivalent capacitance depends on C_0, C_1 and K. In a real situation, as the authors affirm, the equivalent capacity depends on the type and thickness of the insulation of the wire, and the temperature of the environment, etc.

2.Methodology

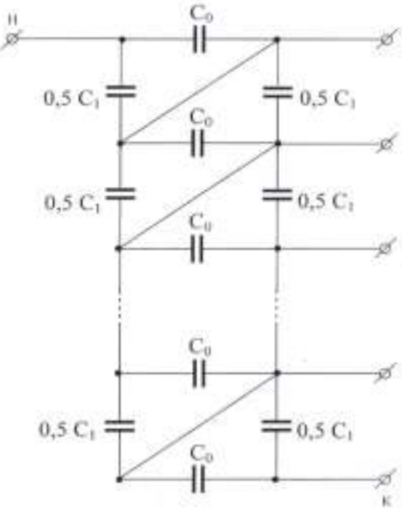

FIGURE 2. The equivalent circuit of the multilayer wind

As the following expression for the equivalent capacitance:

$$C_{э} = \frac{\pi\varepsilon_0\varepsilon_{э}\left(D_K + d_K\right)\cdot\left(D_K - d_K + 2h_K + 4Kd_{из}\right)}{4\sigma_{из}\left(K-1\right)}, \qquad (2)$$

Where: $D_{K,}d_{K,}h_K$ - the outer and inner diameters respectively and height of the container;

$\sigma_{из}$ -The thickness of the wire insulation;

$d_{из}$ - The diameter of the insulation of the wire;

ε_0 - Dielectric constant of the material of the wire;

$\varepsilon_{э}$ - Equivalent dielectric constant of the material of the wire;

Under appropriate assumptions, the relationship between the number of layers and the number of winds are:

$$K = \frac{d_K}{2d_{из}}\sqrt{\left(\frac{d_K}{2d_{из}}\right)^2 - \frac{w}{\pi\gamma}}, \qquad (3)$$

Where: γ coefficient accounting non densely inlay of the winds in the layer.

From (1), (2), (3) it is seen that when corresponding parameters are constant and geometry of the nonlinear inductance, the equivalent capacitance doesn’t depend on the electric and magnetic parameters of the nonlinear inductance [6].

However, our studies show that the equivalent capacity not only depends on the geometry and dielectric constants, but also on the frequency of the magnetization reversal of the nonlinear inductance, as well as the values of the magnetic and electrical quantities. Therefore, the equivalent capacitance of the nonlinear inductance we call electromagnetic equivalent capacity.
As known from our studies, under certain conditions electromagnetic volume received [3]:

$$C_э = \frac{a\psi_r + b\psi_r^3 - \frac{1}{R_э}\sqrt{U_m^2 - \psi_r^2\omega^2}}{\omega^2\psi_r} = \frac{a\psi_r + b\psi_r^3 - \frac{\omega}{R_э}\sqrt{\psi_m^2 - \psi_r^2}}{\omega^2\psi_r}, \tag{4}$$

if we consider that: $\psi_m = \frac{U_m}{\omega}; \quad \psi_r = wSB_r$

$$R_э = \frac{\omega^2 w^2 SB}{l\left(H_c + 0.125\omega\sigma^2 d^2 B_c\sqrt{2\varepsilon - 1}\right)};$$

After some transformations from (4), the following expression for the electromagnetic equivalent capacitance is:

$$C_э = \frac{a}{\omega^2} + \frac{b}{\omega^2}\psi_r^2 - \frac{1}{\omega\psi_r R_э}\sqrt{\psi_m^2 - \psi_r^2} \tag{5}$$

The analysis shows that the coefficient "a" is changed inversely proportional to a linear inductance, which is determined by the following formula:

$$a = \frac{1}{L_Л}, \tag{6}$$

$$L_Л = \frac{w^2 S}{l} \cdot \mu, \tag{7}$$

Where: μ the absolute magnetic permeability of the ferromagnetic material

$$\mu = \frac{B_m}{\sqrt{2}H};$$

With account (6) and (7) for the equivalent capacitance of the electromagnetic
expression (5), we finally obtain:

$$C_э = \frac{1}{L_Л\omega^2} + \omega K\psi_r^2 - \frac{\sqrt{U_m^2 - \psi_r^2\omega^2}}{\psi_r\omega^2 R_э}, \tag{8}$$

where: $K = \frac{b}{\omega^3}$.

3. Result

After some transformations for the electromagnetic equivalent capacity, we obtain

$$C_э = \frac{1}{L_Л \omega^2} + KW^2 S^2 B_r^2 \omega - \frac{\sqrt{U_m^2 - (WSB_r)^2 \omega^2}}{WSB_r R_э \cdot \omega^2}, \qquad (9)$$

Expression (9) makes possible to determine the capacity of the non-linear electromagnetic inductance in a wide range of the frequency changing and taking into account the influence of the individual parameters of the nonlinear inductance to the value of the container, in particular, frequency of the alternating current and the influence of the number of winds of the nonlinear inductance to the value $C_э$ shown in Fig. 3.

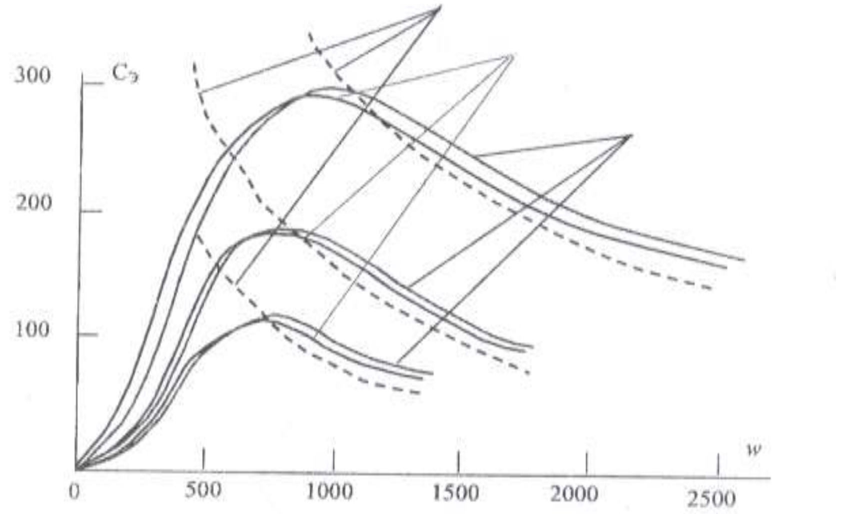

FIGURE 3. Dependence of the nonlinear inductance of the equivalent capacitance on the frequency of the alternating current

4. Conclusion

The experimental studies prove that (9) describes the equivalent capacitance of the nonlinear electromagnetic inductance with great accuracy.

It has been proved that the active resistance and the electromagnetic equivalent capacitance depend not only on the electrical and geometric parameters of the nonlinear inductance, but also they depend on its magnetic parameters.

A computational experiment and comparative analysis with well-known works show that the equivalent electromagnetic capacitance determined by the proposed method practically coincides with the experimental curves

5. References

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