Khmelnik S.I.

The Second Structure of Constant Current

Annotation

Here we explore the structure of DC and the flow of electromagnetic energy in a wire. We show that the flow of electromagnetic energy is spreading inside the wire along a spiral. For a constant current value the density of spiral trajectory decreases with decreasing remaining load resistivity.

Contents

1. Introduction

In [1-3] was shown that DC in the wire has a complex structure, and the flow of electromagnetic energy is spreading inside the wire. Also the electromagnetic flow

- directed along the wire axis,
- spreads along the wire axis,
- spreads inside the wire,
- compensates the heat losses of the axis component of the current.

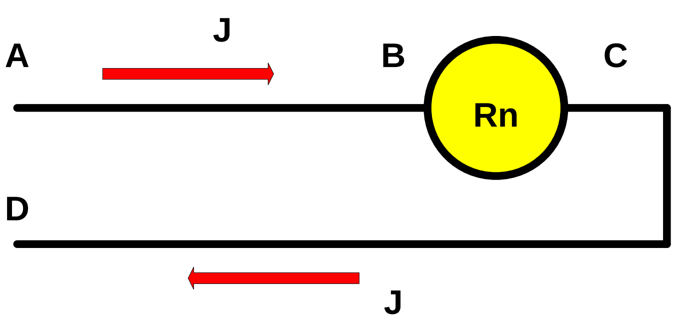

Fig. 1.

In [1-3] a mathematical model of the current and the flow has been. The model was built exclusively on base of Maxwell equations. Only one question remained unclear. The electric current **J** ток and the flow of electromagnetic energy **S** are spreading inside the wire **ABCD** and it is passing through the load **Rn**. In this load a certain amount of strength P is spent. Therefore the energy flow on the segment **AB** should be larger than the energy flow on the segment **CD**. More accurate, **Sab=Scd+P.** But the current strength after passing the load did not change. сила тока после прохождения нагрузки не изменилась. <u>How must the current structure change so that ehe electromagnetic energy decreased correspondingly?</u>

Below we shall consider a mathematical model more general than the model (compared to [1-3]) and allowing to clear also this question. This mathematical model is also built solely on the base of Maxwell equations.

2. Mathematical Model

In building this model we shall be using the cylindrical coordinates $r,\ \varphi,\ z$ considering

- the main current J_o,
- the additional currents $J_r,\ J_\varphi,\ J_z$,
- magnetic intensities $H_r,\ H_\varphi,\ H_z$,
- electrical intensities E,
- electrical resistivity ρ.

The current in the wire is usually considered as average electrons flow. The mechanical interactions of electrons with the atoms are considered equivalent to electrical resistivity. Evidently,

$$E=\rho\cdot J\,. \qquad (1)$$

The main current of density J_o creates additional currents with densities $J_r,\ J_\varphi,\ J_z$ and magnetic fields with intensities $H_r,\ H_\varphi,\ H_z$. They must satisfy the Maxwell equations. These equations for magnetic intensities and currents in a stationary magnetic field are as follows;

$$\mathrm{div}(H)=0, \qquad (2)$$

$$\mathrm{rot}(\mathrm{H})=J, \qquad (3)$$

Besides that, the currents must satisfy the continuity condition

$$\mathrm{div}(J)=0. \qquad (4)$$

The equations (2-4) for cylindrical coordinates have the following form:

$$\frac{H_r}{r} + \frac{\partial H_r}{\partial r} + \frac{1}{r} \cdot \frac{\partial H_\varphi}{\partial \varphi} + \frac{\partial H_z}{\partial z} = 0, \quad (5)$$

$$\frac{1}{r} \cdot \frac{\partial H_z}{\partial \varphi} - \frac{\partial H_\varphi}{\partial z} = J_r, \quad (6)$$

$$\frac{\partial H_r}{\partial z} - \frac{\partial H_z}{\partial r} = J_\varphi, \quad (7)$$

$$\frac{H_\varphi}{r} + \frac{\partial H_\varphi}{\partial r} - \frac{1}{r} \cdot \frac{\partial H_r}{\partial \varphi} = J_z + J_o, \quad (8)$$

$$\frac{J_r}{r} + \frac{\partial J_r}{\partial r} + \frac{1}{r} \cdot \frac{\partial J_\varphi}{\partial \varphi} + \frac{\partial J_z}{\partial z} = 0. \quad (9)$$

For the sake of brevity further we shall use the following notations:

$$co = \cos(\alpha\varphi + \chi z), \quad (10)$$

$$si = \sin(\alpha\varphi + \chi z), \quad (11)$$

where α, χ – are certain constants. In the Appendix 1 it is shown that there exists a solution of the following form:

$$J_r. = j_r(r) co, \quad (12)$$

$$J_\varphi. = j_\varphi(r) si, \quad (13)$$

$$J_z. = j_z(r) si, \quad (14)$$

$$H_r. = h_r(r) co, \quad (15)$$

$$H_\varphi. = h_\varphi(r) si + J_o r/2, \quad (16)$$

$$H_z. = h_z(r) si, \quad (17)$$

where $j(r)$, $h(r)$ - certain function of the coordinate r.

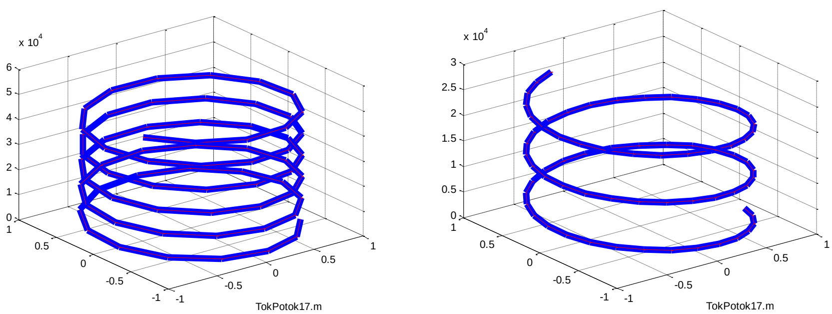

Fig. 2.

Figure 2 shows two spiral lines described by functions (10, 11) of the current, for $\alpha = -0.014$, but for different values of $\chi = 720$ and $\chi = 720/2$ - from right and left respectively.

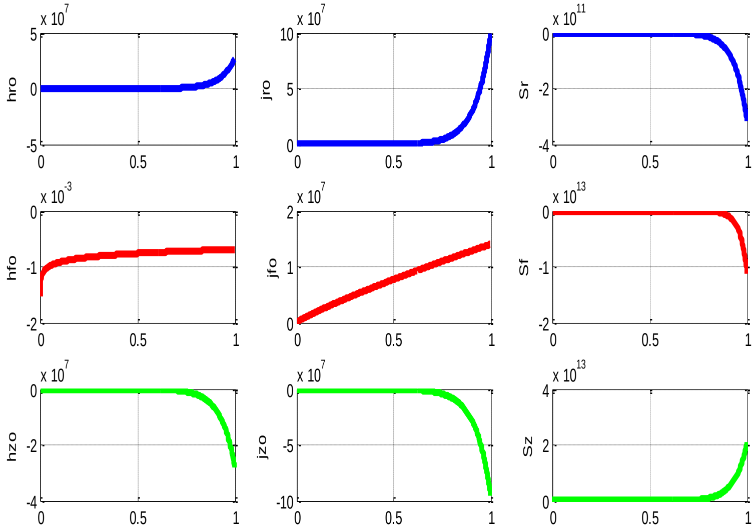

Fig. 3.

Example 1.

Fig. 3 shows graphs of the functions $j_r(r),\ j_\varphi(r),\ j_z(r),\ h_r(r),\ h_\varphi(r),\ h_z(r)$. These functions are calculated iteratively for the given $\alpha = -0.0018,\ \chi = 460$, the wire's radius $R = 0.001$ and initial (for $r = 0$) zero values of the named functions and their derivatives. The exception is the function $h_\varphi(r)$, determined for $r = 0$. More accurate, $h_\varphi(0) = h_{\varphi o} = 0$ and $h'_\varphi(0) = h'_{\varphi o} = 0.000001$. The functions shown in the third column will be treated further. Here and further all numerical data is presented in SI system.

3. Energy Flows

The density of electromagnetic flow is Pointing vector

$$S = E \times H. \tag{1}$$

The currents are being corresponded by eponymous electrical intensities, i.e.

$$E = \rho \cdot J, \tag{2}$$

where ρ is electrical resistivity. Combining (1, 2), we get:

$$S = \rho J \times H. \tag{3}$$

This vector product in cylindrical coordinates looks as follows:

$$S=\rho(J\times H)=\rho\begin{bmatrix} J_\varphi H_z - J_z H_\varphi \\ J_z H_r - J_r H_z \\ J_r H_\varphi - J_\varphi H_r \end{bmatrix}. \tag{4}$$

The energy flow **<u>along the axis</u>** of the wire for a given radius is

$$S_z=\rho(J_r H_\varphi - J_\varphi H_r). \tag{5}$$

The energy flow **<u>along the axis</u>** at a predetermined radius r

$$S_{zr}(r)=4\pi^2\rho\int_r S_z(r)\cdot r\cdot dr. \tag{6}$$

In particular, the density of energy flows along the wire $S_{rr}(r)$ and on the circle $S_{fr}(r)$ are determined in the same way. These functions are shown on Fig. 3.

The full energy flow **<u>along the axis</u>**

$$\overline{S_z}=\int_r S_{zr}(r)\cdot dr. \tag{7}$$

is equal to the strength P, i.e.

$$\overline{S_z}=P, \tag{8}$$

where

$$P=R_H\int_r\left(\int_\varphi J_o^2 d\varphi\right)dr=4\pi R^2 R_H J_o^2, \tag{9}$$

where R_H is the load resistivity.

Example 2.

For the conditions of Example 1 and special resistivity of copper wire $\rho=0.0175\cdot 10^{-6}$ further we find the value of energy for $\overline{S_z}\approx 1000$. The strength equal to this value is consumed in the resistivity $R_H=100$ for main current density $J_o=10^6$. It is important to note that the energy flow along the wire significantly exceeds the energy flows by the radius and by the circle. In our example

$$\overline{S_z}=1000,\ \overline{S_r}=-300,\ \overline{S_\varphi}=-15.$$

Example 3.

At the conditions of Example 2 we now shall change only the value χ, choosing it in such way that the condition (8) would be fulfilled. Fig. 4 shows the function d $P(\chi)$.

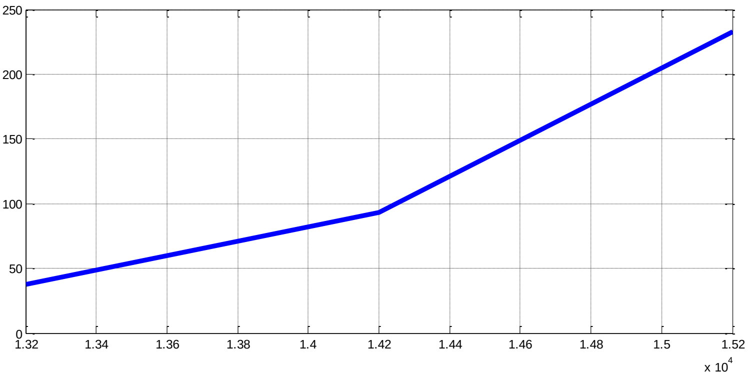

Fig. 4.

4. Discussion

From Fig. 4 it can be seen that

> **for <u>unaltered</u> current density in the wire the strength transmitted through it increases with the increase of the value χ .**

Here we can again consider Fig. 2. We can see that with increase of χ the density of the coils of the current's spiral path. Thus, the increase of transmitted strength

> **for <u>unaltered</u> current density in the wire the strength transmitted through it increases due to the increase of the coil density of the current's spiral path.**

Let us again look at the Fig 1. On segment **AB** the wire transmits the load energy **P.** It is corresponded by a certain value of χ and the density of coils of the current's spiral path. On the segment **CD** the wire transmits only small amount of energy. It corresponds to small value of χ and small density of the coils of current's spiral path.

Naturally, the resistivity of the wire itself is also a load. Thus,

> **as the current flows within the wire, the spiral of the current's path straightens.**

Thus, it is shown that there exists such a solution of Maxwell equations for a wire with DC which corresponds to the idea of

- spiral path of DC in the wire,
- energy transmission along and inside the wire,
- the dependence of spiral path density on the transmitted strength.

Appendix 1

Let us consider the solution of equations (2.5-2.9) in the form of (2.12-2.17). further the derivatives of r will be designated by strokes.

From (2.5) we find:

$$\frac{j_r(r)}{r}co + j_r'(r)co + \frac{j_\varphi(r)}{r}\alpha \cdot co + j_z(r)\chi \cdot co = 0 \tag{1}$$

or

$$\frac{j_r(r)}{r} + j_r'(r) + \frac{j_\varphi(r)}{r}\alpha + j_z(r)\chi = 0. \tag{2}$$

From (2.6, 2.7, 2.8) we find:

$$\frac{h_r(r)}{r} + h_r'(r) + \frac{h_\varphi(r)}{r}\alpha + \chi \cdot h_z(r) = 0, \tag{3}$$

$$\frac{1}{r} \cdot h_z(r)\alpha - h_\varphi(r)\chi = j_r(r), \tag{4}$$

$$-h_r(r)\chi - h_z'(r) = j_\varphi(r), \tag{5}$$

From (2.9) we find:

$$\frac{h_\varphi(r)}{r} + \frac{J_o}{2} + h_\varphi'(r) + \frac{J_o}{2} + \frac{1}{r} \cdot h_r(r)\alpha = j_z(r) + J_o, \tag{6}$$

So, we have got 5 equations (2-6) with 6 unknown functions $f(r),\ \phi(r)$. Therefore, one of the functions can be determined arbitrarily. We define the function $h_\varphi = k_h \ln(r)$. The algorithm for solving these equations is the following:

1. For $r = 0$ set zero values of all the functions $j(0),\ h(0)$, with the exclusion of function $h_\varphi = k_h \ln(r)$.
2. From (3) we find:

$$h_r' = -\frac{h_r}{r} - \frac{h_\varphi}{r}\alpha - h_z\chi, \tag{7}$$

$$h_r = h_{rold} + h_r' \cdot dr. \tag{8}$$

3. From (6) we find:

$$j_z(r) = h_\varphi'(r) + \frac{h_\varphi(r)}{r} + \frac{1}{r} \cdot h_r(r)\alpha \tag{9}$$

4. From (2) we find:

$$j_r'(r) = -\frac{j_r(r)}{r} - \frac{j_\varphi(r)}{r}\alpha - j_z(r)\chi = 0. \tag{10}$$

$$j_r = j_{rold} + j_r' \cdot dr. \tag{11}$$

5. From (4) we find:

$$h_z(r) = \left(j_r(r) + h_\varphi(r) \cdot \chi\right) r / \alpha . \qquad (12)$$

$$h'_z = \left(h_z - h_{zold}\right)/dr . \qquad (13)$$

6. From (5) we find:

$$j_\varphi(r) = -h_r(r)\chi - h'_z(r) . \qquad (14)$$

7. Proceed to p. 2 with a new value of r.

References

Comment: **Vixr**a - viXra Funding, http://vixra.org/funding;
DNA – "The papers of independent authors",
ISSN 2225-6717, http://izdatelstwo.com/

1. Khmelnik S.I. Electromagnetic Energy Flux in a Conductor with a Constant Current, DNA-32, ID16319679, 2015, in Russian; ViXra, http://vixra.org/abs/1503.0048, 2015, in Russian.
2. Khmelnik S.I. Structure of Constant Current, ViXra, http://vixra.org/abs/1503.0241, 2015; DNA-33, ID16537771, 2015, in Russian.
1. Khmelnik S.I. The Flow Structure of the Electromagnetic Energy in the Wire with Constant Current, DNA-33, ID16537771, 2015, in Russian; ViXra, http://vixra.org/abs/1504.0061, 2015, in Russian.