



Calculation Of Magnetic Circuits With A Moving Screen Using The Superimposition Method

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ABSTRACT

The article considers the sequence of calculations using the method of superimposing magnetic circuits with a movable electromagnetic screen and when the parameters of the magnetic circuit are determined using different methods, the difference between the results is 1÷3%, and the difference between the theoretical and experimental results is found to be no more than 4÷7%.

Keywords:

movable screen, magnetic circuit, compensating device, superposition method, magnetic flux, magnetic voltage, magnetic capacitance.

It is known that devices with movable electromagnetic screen (MES) are used for non-contact measurement of direct and alternating currents. On the example of the magnetic system of the device developed by the authors [1], we will consider the sequence of determining the sizes of the magnetic circuit using the superimposition method. To do this, we will formulate separate equations for cases where MES is not present in the magnetic circuit and MES is considered as a source.

In the absence of MES, the switching scheme of the magnetic circuit has the form of the switching scheme presented in Fig. 1. Since the distribution of the magnetic flux in this mode is the same for the left and right sides, it is sufficient to derive expressions for the left side itself. Therefore, we create the following equation for the magnetic flux and magnetic voltage in the left part based on the equations created for the elementary section dx_2 along the coordinate x_2 .

$$U_{\mu x_2} = A_1 e^{\gamma x_2} + A_2 e^{-\gamma x_2}, \quad (1)$$

$$Q_{\mu_1 x_2}^l = \frac{Q_{\mu m}^l}{2} - \frac{\gamma}{2Z_{\mu p}} A_1 e^{\gamma x_2} + \frac{\gamma}{2Z_{\mu p}} A_2 e^{-\gamma x_2}, \quad (2)$$

$$Q_{\mu_2 x_2}^l = \frac{Q_{\mu m}^l}{2} + \frac{\gamma}{2Z_{\mu p}} A_1 e^{\gamma x_2} - \frac{\gamma}{2Z_{\mu p}} A_2 e^{-\gamma x_2}, \quad (3)$$

A_1, A_2 – the boundary conditions introduced to determine the integration constants are as follows.

$$Q_{\mu_1 x_2=0}^l = Q_{\mu m f}^l \quad (4)$$

$$Q_{\mu_1 x_2=x_M}^l = 0 \quad (5)$$

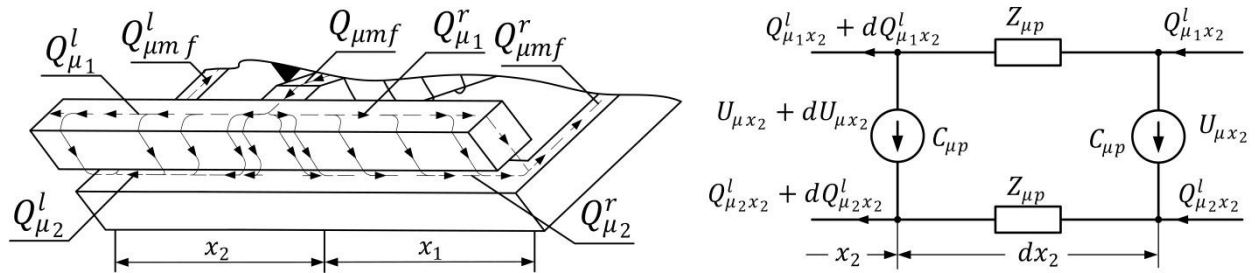


Figure 1. Distribution of magnetic fluxes and dx_2 elemental field exchange scheme for the case without MES

Based on these boundary conditions, we determine the integration constants A_1, A_2 :

$$A_1 = \frac{Q_{\mu mf}^l Z_{\mu p}}{2\gamma sh\gamma X_M} (e^{-\gamma X_M} + 1), \tag{6}$$

$$A_2 = \frac{Q_{\mu mf}^l Z_{\mu p}}{2\gamma sh\gamma X_M} (e^{\gamma X_M} + 1), \tag{7}$$

Putting the determined expressions of integration constants A_1, A_2 into equations (1), (2) and (3), we form the following expressions:

$$U_{\mu x_2} = \frac{Q_{\mu mf}^l Z_{\mu p}}{\gamma sh\gamma X_M} (ch\gamma x_2 + ch\gamma(X_M - x_2)), \tag{8}$$

$$Q_{\mu_1 x_2}^l = \frac{Q_{\mu mf}^l}{2} - \frac{Q_{\mu mf}^l (sh\gamma x_2 - sh\gamma(X_M - x_2))}{2sh\gamma X_M}, \tag{9}$$

$$Q_{\mu_2 x_2}^l = \frac{Q_{\mu mf}^l}{2} + \frac{Q_{\mu mf}^l (sh\gamma x_2 - sh\gamma(X_M - x_2))}{2sh\gamma X_M}, \tag{10}$$

To determine the maximum magnetic flux generated by the field winding (FW) in expressions (8)-(10), we write down the equation for the left side of the magnetic circuit in question according to Kirchhoff's second law, and based on this equation, we determine the expression for the maximum magnetic flux on the left side generated by FW:

$$F_f = Q_{\mu mf}^l Z_{\mu 0} + Z_{\mu p} \int_0^{X_M} Q_{\mu_1 x_2}^l dx_2 + U_{\mu x_2 = X_M} \tag{11}$$

By putting the appropriate quantities based on the boundary conditions of this equation, the maximum magnetic flux is determined as follows.

$$Q_{\mu mf}^l = \frac{2F_f sh\gamma X_M}{\Delta_5}, \tag{12}$$

here $\Delta_5 = \frac{4Z_{\mu p}}{\gamma} ch\left(\frac{\gamma X_M}{2}\right)^2 + (2Z_{\mu 0} + Z_{\mu p} X_M) sh\gamma X_M$.

Taking equality (12) into account, expressions (8)-(10) look like this:

$$U_{\mu x_2} = \frac{2F_f Z_{\mu p}}{\gamma \Delta_5} (ch\gamma x_2 + ch\gamma(X_M - x_2)), \tag{13}$$

$$Q_{\mu_1 x_2}^l = \frac{F_f}{\Delta_5} (sh\gamma X_M - sh\gamma x_2 + sh\gamma(X_M - x_2)), \tag{14}$$

$$Q_{\mu_2 x_2}^l = \frac{F_f}{\Delta_5} (sh\gamma X_M + sh\gamma x_2 - sh\gamma(X_M - x_2)). \tag{15}$$

Now, for the case where FW is not present in the magnetic circuit under consideration and MES is the source, we will draw up the scheme of replacement of the corresponding elementary sections, taking into account the distribution of the magnetic flux along the magnetic circuit.

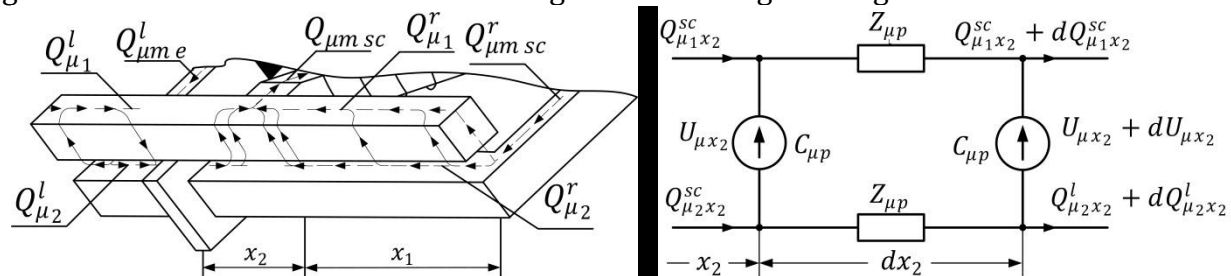


Figure 2. Distribution of magnetic fluxes and dx_2 elementary field exchange scheme for the case where MES is the source

Similar to the sequence of calculations given above, we draw up equations based on Kirchhoff's laws on the basis of the switching scheme shown in Fig. 2 and we form the second-order differential equation of the magnetic voltage. Through the solution of this second-order differential equation, we derive the magnetic flux expressions:

$$U_{\mu x_2} = A_1 e^{\gamma x_2} + A_2 e^{-\gamma x_2}, \tag{16}$$

$$Q_{\mu_1 x_2}^l = \frac{Q_{\mu msc}^l}{2} + \frac{\gamma}{2Z_{\mu p}} A_1 e^{\gamma x_2} - \frac{\gamma}{2Z_{\mu p}} A_2 e^{-\gamma x_2}, \tag{17}$$

$$Q_{\mu_2 x_2}^l = \frac{Q_{\mu msc}^l}{2} - \frac{\gamma}{2Z_{\mu p}} A_1 e^{\gamma x_2} + \frac{\gamma}{2Z_{\mu p}} A_2 e^{-\gamma x_2}, \tag{18}$$

We determine the integration constants A_1, A_2 based on the following boundary conditions:

$$Q_{\mu_2 x_2=0}^l = Q_{\mu msc}^l \tag{19}$$

$$Q_{\mu_2 x_2=x}^l = 0 \tag{20}$$

$$A_1 = \frac{Q_{\mu msc}^l Z_{\mu p}}{2\gamma sh\gamma x} (e^{-\gamma X_M} + 1), \tag{21}$$

$$A_2 = \frac{Q_{\mu msc}^l Z_{\mu p}}{2\gamma sh\gamma x} (e^{\gamma X_M} + 1), \tag{22}$$

A_1, A_2 – by inserting the expressions of the integration constants into the expressions (16)-(18), the expressions of the magnetic voltage and the magnetic current become as follows:

$$U_{\mu x_2} = \frac{Q_{\mu msc}^l Z_{\mu p}}{\gamma sh\gamma x} (ch\gamma x_2 + ch\gamma(x - x_2)), \tag{23}$$

$$Q_{\mu_1 x_2}^l = \frac{Q_{\mu msc}^l}{2} + \frac{Q_{\mu msc}^l (sh\gamma x_2 + sh\gamma(x_2 - x))}{2sh\gamma x}, \tag{24}$$

$$Q_{\mu_2 x_2}^l = \frac{Q_{\mu msc}^l}{2} - \frac{Q_{\mu msc}^l (sh\gamma x_2 + sh\gamma(x_2 - x))}{2sh\gamma x}, \tag{25}$$

To determine the maximum magnetic flux generated by the MES in expressions (23)-(24), we write down the equation for the left side of the magnetic circuit under investigation according to Kirchhoff's second law and we determine the expression for the maximum magnetic flux on the left side generated by the MES:

$$F_{sc} = Q_{\mu msc}^l Z_{\mu 0} + Q_{\mu msc}^l Z_{\mu p} (X_M - x) + Z_{\mu p} \int_0^x Q_{\mu_2 x_2}^l dx_2 + U_{\mu x_2=x}, \tag{26}$$

$$Q_{\mu msc}^l = \frac{2F_{sc} sh\gamma x}{\Delta_6}, \tag{27}$$

here $\Delta_6 = \frac{4Z_{\mu p}}{\gamma} ch\left(\frac{\gamma x}{2}\right)^2 + (2Z_{\mu 0} + Z_{\mu p}(2X_M - x))sh\gamma x$.

By inserting the expression (27) into the expressions (23)-(25), we form the following equations:

$$U_{\mu x_2} = \frac{2F_{sc} Z_{\mu p}}{\gamma \Delta_6} (ch\gamma x_2 + ch\gamma(x - x_2)), \tag{28}$$

$$Q_{\mu_1 x_2}^l = \frac{F_{sc}}{\Delta_6} (sh\gamma x + sh\gamma x_2 - sh\gamma(x - x_2)), \tag{29}$$

$$Q_{\mu_2 x_2}^l = \frac{F_{sc}}{\Delta_6} (sh\gamma x - sh\gamma x_2 + sh\gamma(x - x_2)) \tag{30}$$

(28)÷(30) and (13)÷(15) the curves formed when the magnetic current and magnetic voltages given in the expression are added using the superimposition method are consistent with the curves constructed based on the experimental results (Fig. 3). This, in turn, indicates the correctness of the results, as well as the possibility of using the superposition method in the calculation of magnetic circuits

with MES. It is possible to calculate magnetic circuits in other methods, but the process of calculating the magnetic circuit in the considered method is more complicated than in other methods. Therefore, it is appropriate to calculate magnetic circuits with separate results in the case where MES is absent and MES is a source.

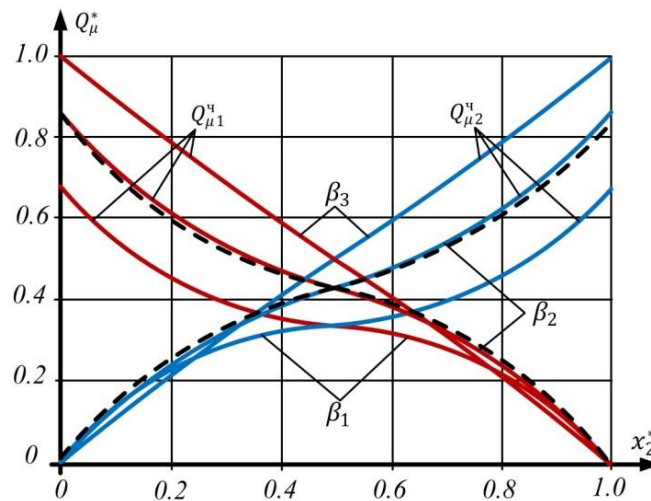


Figure 3. Curves of dependence of magnetic currents on the screen displacement at different values of the extinction coefficient $\beta_1 > \beta_2 > \beta_3$

When the parameters of the magnetic circuit were determined using different methods, the difference between the results was 1÷3%, and the difference between the theoretical and experimental results was found to be no more than 4÷7%. By analyzing the magnetic flux curves in the magnetic circuit of the investigated device, the nonlinear variation of the magnetic flux along the magnetic circuit and as a result of changing its sign at the magnetic neutral point and decreasing the value of the extinction coefficient, its linearity is determined.

References

1. Патент РУз (UZ) № IAP 06464. Компенсирующее устройство/Амиров С.Ф., Болтаев О.Т., Бедрицкий И.М., Файзуллаев Ж.С., Жураева К.К.// 2021 г. Официальный бюллетень – №4. 30.04.2021 г.
2. Sulston A., Otabek B., Firusa A. New created mathematical models of movable screens and a scatter parameters converters /Scopus/Journal of Advanced Research in Dynamical and Control Systems. – 2020. – Vol. 12. – № S2. – P. 122-126.
3. Amirov S.F., Boltayev O.T. Mathematical models of differential magnetic circuits of converters with movable screens and distributed parameters //Journal of Tashkent Institute of Railway Engineers. – 2019. – Т. 15. – №. 3. – С. 75-81.
4. Boltayev O., Akhmedova F., Kurbanov I. Consideration of the nonlinearity of the magnetization curve in the calculation of magnetic chains with a moving electromagnetic screen //Universum: технические науки. – 2022. – №. 2-7 (95). – С. 68-71.
5. Amirov S.F., Sharapov S.A., Sulliev A.K., Boltaev O.T. Biparametric resonant transformer sensor of large linear movements //AIP Conference Proceedings. – AIP Publishing, 2023. – Т. 2624. – №. 1.
6. Boltaev O., Ahmedova F., Nurxonov B.R. Classification of magnetic chains with moving electromagnetic screens//Internauka. 2021. № 27-2 (203). P. 55-57.
7. Amirov S. F., Boltayev O. T., Akhmedova F. A. Calculation of Magnetic Chains with Mobile Screens //International Journal of Advanced Research in Science Engineering and Technology. India. – 2019. – Т. 6. – С. 9243-9245.