Nexus : Journal of Innovative Studies of Engineering Science (JISES)
Volume: 01 Issue: 03 | 2022 ISSN: 2751-7578
http://innosci.org/

The Influence of the Nonlinearity of the Magnetization Curve at Resonance in Biparametric Sensors

Sulliev Absaid Xurramovich, Boltayev Otabek Tashmuxammatovich, Akhmedova Firuza Anvarovna
Toshkent state transport university, Tashkent, Uzbekistan, 100167

Annotation: In article influence nonlinearity of the basic curve magnetization of steel on a resonant mode in biparametrical resonant gauges of parameters movement is investigated.

Key words: biparametric resonant sensors, magnetic circuit, coefficient approximation, non-linearity of the main magnetization curve, movable screen.

In biparametric resonant sensors (BPRS) motion parameters because of the desire to ensure the resonance current in the windings and hence, the induction in the magnetic circuit varies within wide limits and the working point moves beyond the linear plots of the magnetization curve $B = f(H)$. In this case, the specific magnetic resistance depends on induction and change of its output equations inductance of the resonant circuit and static characteristics BPRS cannot be neglected.

Evaluate the impact of nonlinearity $B = f(H)$ on the resonant mode for the most common magnetic circuit BPRS with a movable coil, a core and screen (Fig.1). Thus we assume that the reactive component of the specific magnetic resistance of the magnetic material (steel) is much less active and can be neglected. Note that the case of strong saturation were almost at the considered BPRS not found.

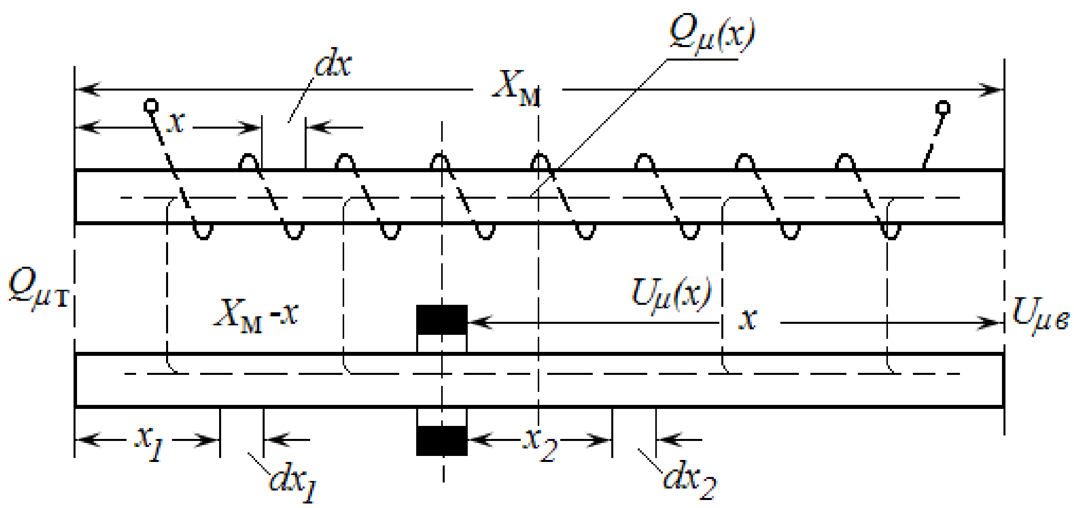

Fig.1 Magnetic circuit BPRS

In this case, the dependence of the specific magnetic resistance steel induction, i.e. $\rho_\mu = f(B)$ with a sufficient degree of accuracy within a given range of variation of induction can be approximated by the dependence:

$$\rho_\mu = \frac{K_B}{B}, \qquad (1)$$

Nexus : Journal of Innovative Studies of Engineering Science (JISES)
Volume: 01 Issue: 03 | 2022 ISSN: 2751-7578
http://innosci.org/

where - K_B coefficient approximation.

1. The magnetic circuit with a movable coil. Changes of magnetic flux $Q_\mu(x)$ and the magnetic voltage $U_\mu(x)$ at the elementary segment of dx is [1]:

$$dQ_\mu(x) = U_\mu(x)\, C_{\mu p} dx \qquad (2);$$

$$dU_\mu(x) = 2Q_\mu(x)\, Z_{\mu p} dx, \qquad (3)$$

where Z - respectively linear values of the total magnetic resistance of the long rods and magnetic capacitance between them, attributable to the unit of length *x*.

After simple transformations we obtain:

$$\frac{d^2Q_\mu(x)}{dx^2} = 2Z_{\mu p} C_{\mu p} Q_\mu(x) \qquad (4)$$

The differential equation (4) after substituting (1) in (4) has the following form:

$$\frac{d^2Q_\mu(x)}{dx^2} = 2\rho_\mu \frac{1}{S_\mu} C_{\mu p} Q_\mu(x) = 2\frac{K_B}{BS_\mu} C_{\mu p} Q_\mu(x) = 2K_B C_{\mu p}. \qquad (5)$$

The General solution of the linear homogeneous differential equation (4) has the form:

$$Q_\mu(x) = K_B C_{\mu p} x^2 + A_1 x + A_2 \ . \qquad (6)$$

The solution for the magnetic voltage in accordance with (2) has the form:

$$U_\mu(x) = 2K_B x + \frac{A_1}{C_{\mu p}}. \qquad (7)$$

Continuous integration and Dene the following boundary conditions:

$$Q_\mu(x)\big|_{x=0} = 0,\ U_\mu(x)\big|_{x=X_M} = U_{\mu в} \ . \qquad (8)$$

Substituting (8) into (6) and 7 and solving them together is:

$$A_1 = U_{\mu b}\, C_{\mu p} - 2K_B X_M C_{\mu p},\ A_2 = 0\ . \qquad (9)$$

After substituting (9) into (6) we obtain the law of change of magnetic flux in the cross section of the rods along the magnetic circuit:

$$Q_\mu(x) = U_{\mu b} C_{\mu p} x \left[1 - K_U\left(2 - \frac{x}{X_M}\right)\right], \qquad (10)$$

where, $K_U = \dfrac{K_B X_M}{U_{\mu b}}$.

In adifferential circuits electromagnetic sensors with distributed parameters of the law of change of $Q_\mu(x)$ is almost identical to the law of change of inductance of the output winding.

The degree of nonlinearity changes the inductance of the resonant circuit BPRS determined by the method described in:

$$\varepsilon_0^H = \frac{\left[f(x_{\kappa 1}) - \frac{f(X_M)}{X_M}x_{k1}\right] + \left[\frac{f(X_M)}{X_M}x_{k2} - f(x_{k2})\right]}{2\,f(X_M)} \cdot 100\% = \frac{0{,}125K_U}{1-K_U}100\%, \quad (12)$$

where $f(x) = L(x) = w_p^2 C_{\mu p} x\left[1 - K_U(2 - \frac{x}{X_M})\right]$, $x_{\kappa 1}$, $x_{\kappa 2}$ - he roots of the equation

$$f'(x) = \frac{f(X_M)}{X_M}$$

t should be noted that the expression (12) allows to determine the degree of nonlinearity changes the inductance of the resonant circuit, taking into account the distribution of the parameters of the magnetic circuit and the nonlinearity of the magnetization curve $B = f(H)$. If you want to determine the degree of nonlinearity only from the influence of non-linear dependence of $B = f(H)$, it is

$$\Delta\varepsilon_0^H = \varepsilon_0^p - \varepsilon_0^H , \quad (13)$$

where ε_0^p - is the degree of nonlinearity from the influence of the distributed nature of the parameters of the magnetic circuit of the sensor. At $\rho_\mu = const$ we have: $\varepsilon_0^p = \varepsilon_0^H$ and $\Delta\varepsilon_0^H = 0$.

The relative detuning frequency circuit BPRS with moving coil relative to the resonant frequency is equal to:

$$\Delta_0^H = \frac{\omega(x) - \omega_0}{\omega_0} \cdot 100\% = \frac{\sqrt{LC} - \sqrt{L(x)C(x)}}{\sqrt{L(x)C(x)}} \cdot 100\% = \quad (14)$$

$$= \sqrt{\frac{1}{\left[1 - \frac{\varepsilon_0^H}{(12{,}5 + \varepsilon_0^H)}(2 - \frac{x}{X_M})\right]}} - 1 \cdot 100\%$$

where $L = w_p^2 C_{\mu p} x$, $L(x)$ - the inductance of the circuit, respectively without and with regard to $Z_{\mu p}$; $C = C(x) = \varepsilon\varepsilon_o \frac{S_e}{x}$ - capacity circuit.

2. The magnetic circuit with a movable screen. Accounting for the differential equation to the screen and thereafter in accordance with and solving them will get the expression of the magnetic flux and the voltage on these sites:

$$Q_\mu(x_1) = K_B C_{\mu p} x_1^2 + A_1 x + A_2, \; U_\mu(x_1) = 2K_B x_1 + \frac{A_1}{C_{\mu p}} , \quad (15)$$

$$Q_\mu(x_2) = K_B C_{\mu p} x_2^2 + A_3 x_2 + A_4, \; U_\mu(x_2) = 2K_B x_2 + \frac{A_3}{C_{\mu p}} . \quad (16)$$

The constant of integration $A_1 \div A_4$ are determined from the following boundary conditions:

$$Q_\mu(x_1)\big|_{x_1=0} = 0, \qquad U_\mu(x_1)\big|_{x_1 = X_M - x} = U_\mu(x_2)\big|_{x_2=0},$$

$$Q_\mu(x_1)\Big|_{x_1=X_M-x}=Q_\mu(x_2)\Big|_{x_2=0}-U_\mu(x_2)\Big|_{x_2=0}C_{\mu\delta}\ ,\ U_\mu(x_2)\Big|_{x_2=x}=U_{\mu b}\ . \tag{17}$$

For magnetic flux in the respective sections of the magnetic circuit finally have:

$$Q_\mu(x_1)=K_BC_{\mu p}x_1^2+U_{\mu b}C_{\mu p}(1-K_U)x_1\ , (18)$$

$$Q_\mu(x_2)=K_BC_{\mu p}x_2^2+U_{\mu v b}C_{\mu p}(1-K_U\frac{x}{X_M})x_2+K_BC_{\mu p}(X_M-x)^2+$$
$$+U_{\mu b}C_{\mu p}(1-2K_U)(X_M-x)+U_{\mu b}C_{\mu\delta}(1-2K_U\frac{x}{X_M}). \tag{19}$$

EMF inductively these flows uniformly distributed on one of the parallel rods of the magnetic circuit of the coils of the winding (3.1. shown by the dotted line) is defined as:

$$\dot{E}_{ex}=-j\omega w_{pu}\dot{U}_{\mu b}C_{\mu p}\left[\frac{X_M}{2}(1-\frac{4}{3}K_U)+\frac{C_{\mu\delta}x}{C_{\mu p}}(1-2K_U\frac{x}{X_M})\right] \tag{20}$$

The degree of nonlinearity changes the inductance of the resonant circuit is determined according to (12) as:

$$\varepsilon_c^H=\frac{x_k(1-2K_U\frac{x_\kappa}{X_M})}{2X_M(1-2K_U)}-\frac{x_k}{2X_M}=\frac{0{,}125K_U}{0{,}5-K_U}\cdot 100\%\ , \tag{21}$$

where the root of x_κ is found from the condition

$$\frac{dE_{ex}}{dx}=\frac{E_{ex}(X_M)-E_{ex}(0)}{X_M}\quad \text{as}\quad x_k=0{,}5X_M\ .$$

The relative detuning frequency circuit BPRS a movable screen is equal to:

$$\Delta_c^H=\frac{\omega(x)-\omega_0}{\omega_0}\cdot 100\%=\sqrt{\frac{\left(\frac{X_M^2}{2x}+\frac{C_{\mu\delta}}{C_{\mu p}}\right)}{\frac{X_M^2}{2x}\left[1-\frac{2\varepsilon_c^H}{3(12{,}5+\varepsilon_c^H}\right]+\frac{C_{\mu\delta}}{C_{\mu p}}\left[1-\frac{\varepsilon_c^H}{(12{,}5+\varepsilon_c^н)}\cdot\frac{x}{X_M}\right]}}-1\cdot 100\%\ \ . \tag{22}$$

3. The magnetic circuit with a movable screen. Determining the constant of integration on the basis of the boundary conditions

$$Q_\mu(x_1)=0\,,\ U_\mu(x_1)\Big|_{x_1=X_M-x}=U_\mu(x_2)\Big|_{x_2=0}-Q_\mu(x_2)\Big|_{x_2=0}R_{\mu e} \tag{23}$$

And $Q_\mu(x_1)\Big|_{x_1=X_M-x}=Q_\mu(x_2)\Big|_{x_2=0}\ ,\quad U_\mu(x_2)\Big|_{x_2=x}=U_{\mu b}$

get the expression for the magnetic flux $Q_\mu(x_2)$

$$Q_\mu(x_2)=K_BC_{\mu p}x_2^2+U_{\mu b}C_{\mu p}(1-2K_U\frac{x}{X_M})x_2+U_{\mu b}C_{\mu p}(X_M-x)\times$$
$$\times\frac{1-K_U\frac{x}{X_M}-K_U}{1+C_{\mu p}K_{\mu e}(X_M-x)}. \tag{24}$$

he EMF of self-induction, inductive excitation winding, placed on the section of magnetic circuit with coordinate $x = 0$ assuming $R_{\mu э} C_{\mu т} X_M >> 1$ to be determined from

$$E_{ex} = -j\omega w_b U_{\mu b} C_{\mu p} \left[x - K_U \frac{x^2}{X_M} + \frac{1 - K_U \dfrac{x}{X_M} - K_U}{R_{\mu e} C_{\mu p}} \right]. \quad (25)$$

The degree of nonlinearity of the change of inductance of a circuit is defined as:

$$\varepsilon_e^H = \frac{x_k - K_U \dfrac{x_k^2}{X_M} + K_U \dfrac{x_k}{R_{\mu e} C_{\mu p} X_M}}{2(X_M - K_U X_M - \dfrac{K_U}{R_{\mu e}})} - \frac{x_k}{2X_M} = \frac{0{,}125 K_U}{1 - K_U} \cdot 100\%, \quad (26)$$

The relative detuning frequency circuit BPRD with a movable screen is as

$$\Delta_e^H == \sqrt{\frac{1}{\left[1 - \dfrac{\varepsilon_e^H}{(12{,}5 + \varepsilon_e^H)} \cdot \dfrac{x}{X_M}\right] + \dfrac{1 - \left(\dfrac{x}{X_M} - 1\right)\left(\dfrac{\varepsilon_e^H}{12{,}5 + \varepsilon_e^H}\right)}{R_{\mu e} C_{\mu p} x}}} - 1 \cdot 100\% \quad . \quad (27)$$

The analysis of expressions (12), (24) and(14), (22), (26), as well as the corresponding curves shows that for the same value of K_U, the degree of non-linearity of inductance changes and disorders of the frequency of the resonant circuit at BPRS a movable screen is much larger than that BPRS with moving coil or screen, BPRS with a movable screen ε_e^H and Δ_e^H depends on the compositions $R_{\mu e} C_{\mu p} X_M$ and high $R_{\mu e}, C_{\mu p}$, and X_M is the terms $\varepsilon_o^H = \varepsilon_e^H$ and $\Delta_o^H \approx \Delta_e^H$.

Conclusion

Thus the article is theoretically investigated the effect of nonlinearity basic magnetization curve began at the resonant mode in BPRS motion parameters. It is established that under the same conditions disorders frequency of the resonant circuit BPRS a movable screen is much larger than that BPRS winding or screen, and in the case of ideal screen disorders frequency of the resonant circuit at BPRS with movable winding and the screen has the same value.

References

1. 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. - №6, Issue 5, May 2019 - pp. 9243-9245.
2. A. Sulton, B. Otabek, A. Firuza New created mathematical models of movable screens and a scatter parameter converters //(Scopus) Jour of Adv Research in Dynamical & Control Systems, Vol. 12, Special Issue-02, 2020. pp. 122-126.
3. Амиров С.Ф., Болтаев О.Т. и др. Исследование магнитных цепей новых преобразователей усилий. Автоматизация. Современные технологии. 2020. Т. 74. № 1. С. 24-26.
4. Boltaev O., Ahmedova F., Nurxonov B.R. Classification of magnetic chains with moving electromagnetic screens//Internauka. 2021. № 27-2 (203). P. 55-57.

5. 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. – T. 15. – №. 3. – C. 75-81.
6. Болтаев О.Т., Мирасадов М.Ж., Нурхонов Б.Ш. Исследование статического режима магнитных цепей с подвижными электромагнитными экранами и с распределенными параметрами //Universum: технические науки. – 2021. – №. 5-5 (86). – С. 90-94.
7. Otabek, Boltayev, Akhmedova Firuza, and Kurbanov Islombek. "Consideration Of The Nonlinearity Of The Magnetization Curve In The Calculation Of Magnetic Chains With A Moving Electromagnetic Screen." Universum: технические науки 2-7 (95) (2022): 68-71.
8. Boltaev Otabek Tashmuhammatovich, Akhmedova Firuza Anvarovna, & Nafasov Nabijon Otabek ugli. (2021). Analysis Of Moving Electromagnetic Screen Devices. Texas Journal of Multidisciplinary Studies, 3, 188–192. Retrieved from https://zienjournals.com/index.php/tjm/article/view/464