STATIC CHARACTERISTICS NEW TRANSFORMER CONVERTERS OF ANGULAR DISPLACEMENT

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Abstract: The article shows that the static characteristics of new transformer angular displacement converters retain linearity at any values of relative magnetic permeability of ferromagnetic materials, and the sensitivity remains unchanged. The static load-bearing characteristics of these transducers remain linear at higher load resistance than the induction resistance of the transducers, and their commensurate values exhibit nonlinear static characteristics.

Key words: Angular displacement, transformer converter, static characteristic, sensitivity, load-bearing static characteristic.

Introduction. In automatic monitoring and control systems used in technological processes and industrial production, various mandatory elements and devices operate together to ensure proper system performance. Among these components, measurement transducers (MTS) that provide information about the linear and angular displacements of the monitored object or its elements are widely applied [1–5].

This paper investigates the static characteristics and sensitivity parameters of newly developed measurement transducers.

For the first newly proposed transducer [6], whose measuring windings are connected in a mutually differential configuration, the modulus of the resulting output electromotive force (EMF) can be expressed as follows:

$$E_{out.1} = \omega w_{\text{out.}} \frac{F_{\text{к}}}{2} \left\{ \frac{sh[\beta_{\text{wor.}}(1+\alpha^*)]}{\Delta_{11}^*} - \frac{sh[\beta_{\text{wor.}}(1-\alpha^*)]}{\Delta_{12}^*} \right\}, \qquad (1)$$

бу ерда $F_{\text{ex.}}$ – the magnetomotive force generated by the current flowing through the excitation windings, $[A]$; ω – the angular frequency of the sinusoidal source voltage, $[s^{-1}]$; $w_{out.}$ – number of turns in the measuring coil, $[-]$; $\Delta_{11}^* = [Z_{\mu 0} + Z_{\mu}(1-\alpha^*)] sh[\beta_{wor.}(1+\alpha^*)] + \frac{\beta_{wor.}}{C_{\mu wor.}} ch[\beta_{wor}(1+\alpha^*)], [H^{-1}]$; $\Delta_{12}^* = [Z_{\mu 0} + Z_{\mu}(1+\alpha^*)] sh[\beta_{wor.}(1-\alpha^*)] + \frac{\beta_{wor.}}{C_{\mu wor.}} ch[\beta_{wor.}(1-\alpha^*)]$, $[H^{-1}]$; $\beta_{wor.} = \gamma_{wor.} \frac{a}{\pi} \alpha_{м} = \gamma_{wor.} X_{м}$, $[m^{-1}]$ – magnetic field attenuation coefficient along the magnetic circuit; $Z_{\mu}= Z_{\mu п}X_{м}, [H^{-1}]$, $= Z_{\mu п}$ – magnetic reluctance of long ferromagnetic rods and its specific (per-unit-length) value; $C_{\mu wor.} = C_{\mu wor..п}X_{м}, [H]$, $C_{\mu wor..п}$ - permeance of the working air gap between long ferromagnetic rods and its specific (per-unit-length) value; α^{*} - relative angular displacement of the movable part of the MTS, $[-]$.

(1) expression represents the analytical equation of the static characteristic of the first new MTS. In order to express this characteristic in relative (per-unit) values, we determine the maximum value of the output EMF $E_{\text{out}.1}$ at given values of the supply voltage applied to the excitation winding of the new MTS and its geometric dimensions [8]. This maximum is achieved when the relative magnetic permeability of the ferromagnetic core material of the MTs tends to infinity, i.e., $\mu \to \infty$ and it is equal to the following:

$$E_{out.1(max)} = 2\omega w_{\text{чик.}} F_{\text{қ}} C_{\mu \text{wor.п}} a, \tag{2}$$

where a – denotes the pitch of the helical magnetic conductor (core), $[m]$.

The transformation function (1) of the MTS, expressed in relative (per-unit) units, is given as follows

$$E^{*}_{\text{out.1}} = \frac{E_{\text{out.1}}}{E_{\text{out.1}(max)}} = \frac{1}{4C_{\mu\text{wor.п}}a}\left\{\frac{sh[\beta_{\text{wor}}(1+\alpha^{*})]}{\Delta^{*}_{11}} - \frac{sh[\beta_{\text{wor}}(1-\alpha^{*})]}{\Delta^{*}_{12}}\right\}. \tag{3}$$

The magnitude of the resultant EMF at the output of the measuring windings of the second new MTS [7,10], connected in a mutually series and inductively matched configuration, is expressed as follows

$$E_{out.2} = \frac{2\omega w_{\text{out.}} F_{\text{қ}}}{\left(2Z_{\mu 0} + \dfrac{X_{\text{м}}}{\mu\mu_0 b h_{\text{м}}} + \dfrac{1}{C_{\mu s\text{п}} X_{\text{м}}}\right)\alpha_{\text{м}}}\alpha, \tag{4}$$

where $Z_{\mu 0}$ – magnetic reluctance of the Z-shaped ferromagnetic coupling element in the MTS magnetic circuit, $[H^{-1}]$; $C_{\mu s\text{п}}$ – specific (per-unit-length) magnetic permeance of the air gap between two closed ring ferromagnetic cores, $[H \cdot m^{-1}]$; $b, h_{\text{м}}$ ва $X_{\text{м}}$ – the width, maximum thickness, and half-circumference of the closed ring magnetic core, $[m]$; α, $\alpha_{\text{м}}$ – angular position of the movable part of the MTS and its maximum value, $[degri]$.

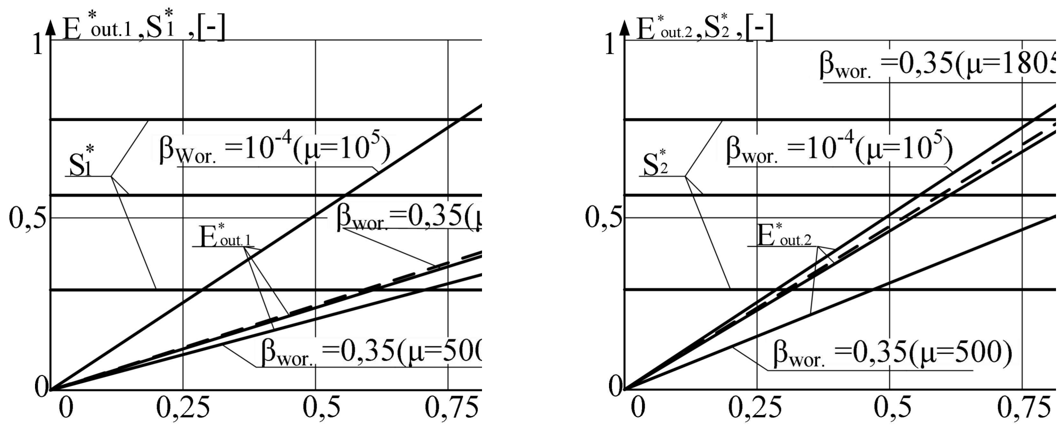
For this MTs, the maximum output EMF corresponding to the limiting case of infinite relative magnetic permeability of the ferromagnetic core material $\mu \to \infty$ is given by:

$$E_{out.2(max)} = 2\omega w_{\text{out.}} F_{\text{к}} C_{\mu s\text{п}} X_{\text{м}}. \qquad (5)$$

The transformation function (4) of the second new MTs, expressed in relative (per-unit) units, is given as follows

$$E^*_{\text{out.2}} = \frac{E_{\text{out.2}}}{E_{\text{out.2}(max)}} = \frac{\alpha^*}{C_{\mu s\text{п}} X_{\text{м}} \left(2Z_{\mu 0} + \frac{X_{\text{м}}}{\mu \mu_0 b h_{\text{м}}} + \frac{1}{C_{\mu s\text{п}} X_{\text{м}}} \right)}. \qquad (6)$$

In Fig. 1(a) and (b), the static characteristics of the two investigated new MTs are presented for their prototype samples, plotted at different values of μ with the following parameters: parameters of the first new MTs [9]: $b = 0{,}01\, m$; $h = 0{,}01\, m$; $\delta_s = 0{,}01\, m$; $\delta_{wor.} = 0{,}001\, m$; $a = 0{,}025\, m$; $X_{\text{м}} = 0{,}025\, m$; $\alpha_{\text{м}} = 175\, degri$; $w_{\text{e}} = 200$; $I_{\text{e}} = 1\, A$; $w_{\text{mes.}} = 100$; иккинчи янги ТЎЎ [7] нинг параметрлари: $b = 0{,}01\, m$; $h_{\text{м}} = 0{,}01\, m$; $\delta_s = 0{,}01\, m$; $X_{\text{м}} = 0{,}14\, m$; $\alpha_{\text{м}} = 175\, degri$; $w_{\text{e}} = 200$; $I_{\text{e}} = 1\, A$; $w_{\text{mes.}} = 100$.



а) б)

Figure 1. Plots of the static characteristics and sensitivities of the new MTS

Conclusion. The static characteristics of the new MTS remain linear for any values of the relative magnetic permeability of the ferromagnetic material, while their sensitivity values remain constant over the entire measurement range. The load static characteristics of the new MTS preserve linearity within the measurement range when the load resistance is much greater than the mutual inductive reactances of the transducers. However, when these resistances become comparable in magnitude, nonlinearity appears in the static characteristics.

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