MECHANICAL MEASUREMENTS

FERRODYNAMIC TRANSDUCERS FOR AUTOMATIC MONITORING
AND CONTROLLING DEVICES

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The compensation method is the most rational for transmitting readings of primary instruments in systems of automatic monitoring and control. Telemetering ac compensation systems are now being widely used. These systems include the one using rheostat transducers. Although relatively simple the above system has certain essential defects, the most important of which consists of unreliable contacts.

The present tendency in Soviet and foreign instruments and regulators is to discard rheostat transducers and change over to contactless converters, which provide highly reliable automatic devices.

The most widely used telemetering system employs differentially wound transformer transducers and provides reliable operation as a transmission link between the instruments and the regulators. The considerable nonlinearity of differential transformer transducers prevents, however, their use in computing circuits, thus limiting the sphere of their applications. The differential transformer transducers have also other less important defects, such as the effect of the plunger's position on the output voltage phase, and the difficulty in providing a linear kinematic connection between the transducer plunger, with its reciprocating movement, and the rotating components of the instrument.

The Kharkov KIP (Control and Measuring Instruments) plant has developed a contactless ferrodynamic transducer which converts the angle of rotation into an appropriate voltage. On the basis of this transducer a new improved telemetering system has been designed and several computing circuits developed.

The principle of operation of the ferrodynamic transducer consists of the following. Coil 6 (Fig. 1), whose ends are connected to terminals 3 and 4 of terminal strip 7, can rotate about its axis in a radial magnetic field formed between the concentric surfaces of components 4 and 5 of the magnetic circuit. The magnetic flux is provided by an alternating current flowing through excitation winding 10 of coil 8, fitted over components 2 and 3 of the magnetic circuit. The ends of the excitation winding are connected to terminals 1 and 2 of terminal strip 7.

When the coil is in a neutral position (horizontal line through center 5), the emf induced in it is equal to zero, since the total number of the lines of force crossing the plane of the coil is equal to zero.

When the coil is rotated away from the neutral position through angle \( \alpha \) the emf \( E_p \) induced in it is equal to[1]

\[
E_p = \frac{\omega}{V^2} \psi = \frac{\omega}{V^2} B_m l R_m \sin \alpha,
\]

where \( \omega \) is ac angular frequency, \( \psi \) is the number of inter-linkages in the coil, \( B_m \) is the amplitude of the mean magnetic induction in the air gap, \( R_m \) is the mean radius of the coil, \( l = 2b w_p \) is the length of the coil conductor cut by the magnetic field, \( b \) is the width of the core, \( w_p \) is the number of turns in the coil.

The induction in the air gap may be represented as

\[
B_m = \frac{V^2}{\sigma R \Theta b} \omega w G,
\]

where \( I \) is the excitation current, \( w_1 \) is the number of turns in the excitation winding, \( G \) is the permeance, \( \sigma \) is the leakage coefficient, \( \Theta \) is the angle of the concentric part of the core.

Inserting the value of \( B_m \) from (2) into (1) we obtain

\[
E_p = 2 \frac{\omega w \omega_1}{\sigma \Theta} G l \alpha,
\]
or taking into account that for an actual transducer the values of \( w_p, w_1, \sigma \) and \( \Theta \) are constant, we have

\[
E_p = k_1 G I \alpha,
\]

where

\[
k_1 = 2 \frac{o w_p w_1}{\sigma \Theta}.
\]

In ferrodynamic transducers the relation of \( E_p \) to all the three quantities \( \alpha, I \) and \( G \) is used.

Let us examine the relation of \( E_p \) to \( \alpha \), considering \( I \) and \( G \) to be constant:

\[
E_p = k_2 \alpha,
\]

where \( k_2 = k_1 I G \).

Figure 2A provides a graphic representation (curve 1) of this relationship, from which it follows that \( E_p \) varies between \(-E_{p\text{max}} \) for \( \alpha = -20^\circ \) to \(+E_{p\text{max}} \) for \( \alpha = +20^\circ \). For \( \alpha = 0 \), \( E_p = 0 \).

The signs "*" and "-" denote conventionally emfs \( E_p \) whose phases differ by 180° and whose angles \( \alpha \) are calculated respectively clockwise and counterclockwise from the neutral position (see Fig. 1).

If the external circuit conductors connected to terminals 3 and 4 are interchanged, the graph shown in Fig. 2B is obtained.

The output emf \( E \) is measured in terms of the value of emf \( E_{p\text{max}} \) obtained when the coil is rotated through 20° (the effective angle of rotation of the coil amounts to \( \pm 20^\circ \) from the neutral position). This method of expressing \( E \) provides a graph of \( E = f(\alpha) \) independent over a wide range of the absolute values of \( I \) and \( G \).

In several practical instances (mainly when carrying out computing operations) it is necessary to make the zero value of the emf correspond to one of the extreme positions of the coil instead of the middle position. This is attained by connecting in series with the moving coil a biasing coil 9—see Fig. 1 (wound over the excitation winding)—whose emf \( E_b \), which is made to equal \( E_{p\text{max}} \), does not depend on the rotation angle of the moving coil (see curve 2, Fig. 2A). At the same time \( E_b \) is related to \( I \) and \( G \) in the same manner as \( E_p \). Thus, for any given value of \( \alpha \), variations of \( G \) and \( I \) within certain limits do not produce changes in the ratio of \( E_p/E_b \). The ends of winding 9 (see Fig. 1) are connected to terminals 5 and 6 of terminal strip 7.

Curve 3 (Fig. 2A) of the total emf \( E = E_p + E_b \) equal to the geometric sum of curves 1 and 2 will be obtained if \( E \) is taken from terminals 3 and 6 (see Fig. 1) and terminals 4 and 5 are short-circuited. If the conductors of the external circuit connected to terminals 3 and 6 are interchanged, curve 4 is obtained (Fig. 2A).