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METHOD FOR BASIC MEASUREMENT ADJUSTMENT OF COMMUTATOR PROFILES

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The possibility of error minimization as a result of noncontact measurement of the distance between eddy-current converter and commutator has been shown. The problem was solved by means of adjustment in transfer constant of the device measuring channel in the process of measuring distance to arbitrary taken commutator bar according to the method proposed.

Introduction

It is shown in the series of papers that embedding devices of diagnostic and forecasting performance quality of electric machine (EM) sliding contact (SC) allows increasing significantly their service reliability, decreasing costs for maintenance and repair, actually excluding losses from emergency and unplanned downtimes, increasing service life [1–4]. The most widespread EM SC complexes in the systems of dynamic diagnostic are those constructed on the basis of noncontact measuring converters (MC) of eddy-current type [5–7]. The main sources of output errors of diagnostic complex analog parts appearing when using converters of such nature are unlike specific electric resistances of separate commutator bars (CB) (especially their surface layer, properties of which may depend on process technology), temperature difference of plates heating, linear velocity of controlled surface movement relative to MC as well as inaccuracy of MC orientation relative to controlled surface in calibration process and when measuring on real object [8–10].

The problem of clearing the mentioned errors influence is urgent and may be solved by means of changing calibrating characteristic parameter (coefficient of transmitting the device measuring circuit) in the process of measuring the distance to arbitrary CB according to the method of base adjustment of measuring results suggested at the chair of electric drive and electrical equipment of Tomsk Polytechnic University [11].

Main part

Using noncontact measuring device (Fig. 1) the dependence of output parameter y_i on measured gap size x between MC and controlled area is written as

$$y_i = a_{1i} + a_{2i}x, \qquad (1)$$

where i is the serial number of measurement; a_{1i}, a_{2i} are the parameters of calibrating characteristic.

At proper installation of MC and adjustment of measuring device a_{1i}= 0 may be taken. Then (1) is rearranged in the form:

$$y_i = a_{2i}x.$$

This implies that output parameter of measuring device is proportional not only to the measured gap x but to the coefficient of calibrating characteristic a_{2i} which depends on many factors including external influences on object of measuring and elements of measuring device.

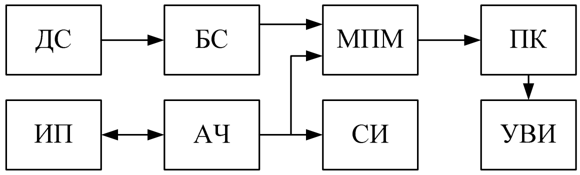

Fig. 1. *Flowchart of noncontact profilometer with eddy-current measuring converter: ИП (MC) is the measuring converter of eddy-current type; ПС (SC) is the signal converter; МПМ (MPM) is the microprocessor module; СИ (PI) is the pointer indicator; ПК (PC) is the personal computer; УВИ (DIO) is the device of information output; ДС (SS) is the synchronization sensor; БС (CU) is the clock unit*

Therefore, it is appropriate to correct parameter a_{2i} in the process of measuring that allows increasing accuracy of measurement [12]. It may be carried out by reference and additional measuring at the gap increased by a reference value. We obtain a system of two equations with equal coefficients a_{21}=a_{22} as the measurements are carried out on one object at identical perturbation actions

$$y_1 = a_{21}x;$$
$$y_2 = a_{21}(x+\delta_0), \qquad (2)$$

where δ_0 is the reference value of gap changing.

The solution of the system (2) is of the following form:

$$a_{2i} = \frac{y_2 - y_1}{\delta_0}, \quad x = \frac{y_1\delta_0}{y_2 - y_1}. \qquad (3)$$

It follows from the expression (3) that gap design value does not depend on the mentioned above instability of parameter a_{2i} that results in increasing accuracy of measurements. When gap decreasing by reference value the system of initial equations is written similarly to the system (2)

$$y_1 = a_{21}x;$$
$$y_2 = a_{21}(x-\delta_0).$$

The solution of this system is of the form:

$$a_{2i} = \frac{y_1 - y_2}{\delta_0}, \quad x = \frac{y_1\delta_0}{y_1 - y_2}. \qquad (4)$$

Thus, expressions (3, 4) ensure the adjustment of parameter a_{2i} of linear correcting characteristic in measuring device at any direction of gap changing that allows decreasing significantly negative influence of a number of factors on the results of measurement and increasing its accuracy.

As the gap changes by reference value with a certain error (which may be stipulated by inaccuracy of measurement of the given movement by this or that reason) then this influences the accuracy of defining the parameter of calibrating characteristic a_{2i} and correspondingly the measured gap. The error of gap measuring of inaccuracy of MC movement by a reference value should not exceed, as a rule, 1 %. For this purpose it is necessary to change the gap until the following conditions are fulfilled:

- at gap increasing $y_2 \geq y_1\left(1+\dfrac{\Delta}{\Delta x}\right)$;
- at gap decreasing $y_2 \leq y_1\left(1-\dfrac{\Delta}{\Delta x}\right)$,

where Δ is the maximal error of gap changing by a reference value; Δx is the permissible error of gap measuring stipulated by inaccuracy of gap changing by a reference value.

The value of reference gap change δ_0 achieved in this case is measured by auxiliary measuring system and used for determining the parameter a_{2i} and correcting the results of measurement according to the expressions (3, 4).

MC relative to the commutator of electrical machine may be installed for example by the device with a micrometer screw, Fig. 2.

The matter of the technique may be illustrated by the following example, Fig. 3

Let the parameter of calibrating characteristic be determined at measuring the gap between MC and CB № 1. Then calibrating characteristic of the device $y=f(x)$ represents the line passing through the naught on-the-miter of 45° to the abscissa axis (characteristic 1, Fig. 3). In this case the output values of the device conform to the real distance from MC to the controlled surface of CB № 1 and line 1 is the standard calibrating characteristic (output characteristic of profilometer). If the distance between MC and CB № 1 equals to the base one (the recommended initial distance from MC to the measured commutator profile) then the value y_a corresponding to point a on its calibrating characteristic ($y_a=x_{base}$) is fixed at the device output.

If CB № 2 with the same level of profile that CB № 1 has another electric resistance then the device calibrating characteristic at CB № 2 controlling passes on another miter to the abscissa axe (line 2 in Fig. 3). Then the profile level of CB № 2 (y_c) is interpreted as the distance x_2 corresponding to point cc' at calibrating characteristic 1. The measured value x_2 here difers from the real value x_{base}.

By analogy of measured value y_b at CB № 3 (characteristic 3) stay-put at value x_{03} relative to bars № 1, 2, the false value x_3 corresponding to the point b' at reference characteristic 1 is bound. For projecting bar № 4 (by value x_{04} relative to bars 1, 2) the false measured value equals to x_4, corresponding to the point d' at characteristic 1 etc.

To eliminate disagreements between measured values and real gap sizes it is necessary to reduce the slopes of characteristics 2, 3, 4 to the reference value which is the slope of characteristic 1. Slope angles of characteristics 2, 3, 4 in the general case are unknown and they should be determined somehow.

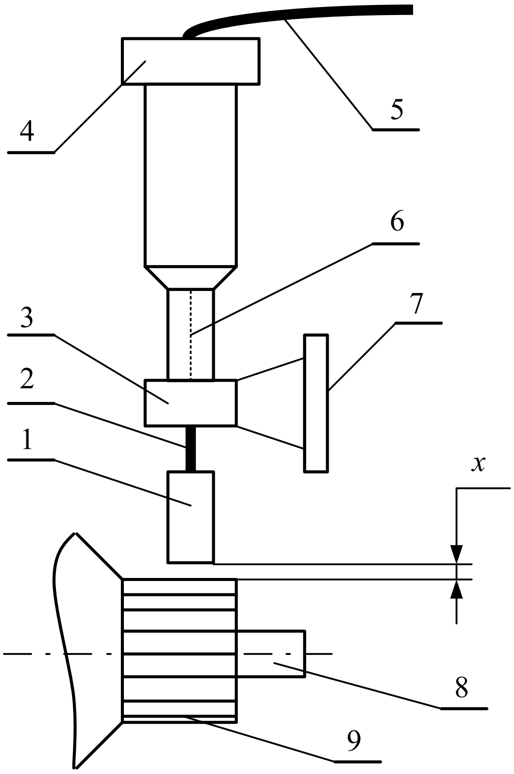

Fig. 2. *The example of installing the measuring converter relative to the object of measurement: 1) the MC; 2) the moving (in the direction perpendicular to commutator cylindrical surface) element, at which MC is fixed; 3) the body; 4) the rotating element; 5) the electric cable; 6) the vernier reference scale; 7) the frame; 8) the shaft; 9) the commutator; x is the measured gap*

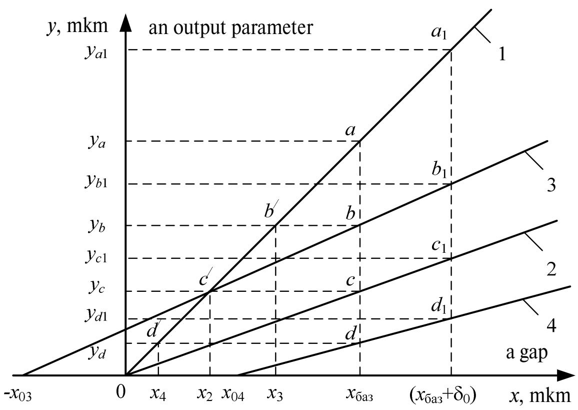

Fig. 3. *Calibrating characteristic of profilometer*

For this purpose the reference movement (δ_0) of MC relative to measured object to the side of gap increasing may be carried out in the process of measuring. It is fixed by means of reference scale of micrometer screw (or measuring head etc.). In this case actual magnitude of the gap between MC and CB № 1, 2 equals to ($x_{base}+\delta_0$).

Instrument readings for point a_1 of characteristic 1 equal to y_{a1} ($y_{a1}=x_{base}+\delta_0$). Instrument readings for bars 2, 3, 4 equal y_{c1}, y_{b1}, y_{d1} in this case.

As a result, slope ratios of characteristics 2, 3, 4, ..., i are solved by the expression

$$\mathrm{tg}\alpha_i = \frac{\Delta y_i}{\delta_0},$$

where α_i is the slope of i^{th} characteristic; Δy_i is the increment of instrument readings at i^{th} characteristic at converter moving by value δ_0.

It allows defining the parameters of corrected calibrating characteristics 2, 3, 4, ..., i:

$$a_i = \mathrm{tg}\alpha_i = \frac{\Delta y_i}{\delta_0}.$$

Naturally the corrected instrument readings at i^{th} characteristic equal:

$$y_{i0} = y_i / a_i.$$

The calibrating characteristics of the device for bars 2, 3, 4 corrected according to the suggested technique look like it is shown in Fig. 4.

The corrected calibrating characteristic for bar № 2 coincides here with the reference line 1. Instrument readings for bars 1, 2 in base point equal respectively $y_{a,c0}$, that corresponds to the real values of gaps between MC and bars № 1, 2 ($y_{a,c0}=x_{base}$). Instrument readings at characteristic 3 in this case equals to y_{b0} that corresponds to the ordinate of point b_0' on line 1 and gap x_3 ($x_3=x_{base}+x_{03}$). Similarly the instrument reading at characteristic 4 equals y_{d0} that corresponds to the coordinate of point d_0' on reference line 1 and gap x_4 ($x_4=x_{base}-x_{04}$).

Therefore, the corrected readings of the instrument correspond to the actual values of the gaps between the measuring converter and controlled collector bars.

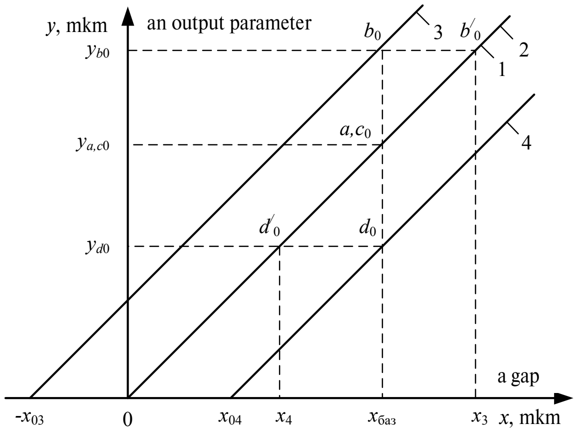

Fig. 4. *Calibrating characteristics of profilometer corrected by calculated way*

The adjustment of calibrating characteristic parameter may be carried out by analogy in the case of gap decreasing by the reference value δ_0.

Another example of applying the technique of base adjustment may be the use of measuring device for recording linear microdisplacements of some object, for example, EM brush in a brush-holder well in operating process. For this purpose copper foil relative to which eddy current MC is based may be glued on external face surface of a brush. After that at inactive EM the operations of reference and additional measuring similar to the stated above ones are carried out. It allows determining the calibrating characteristic parameter:

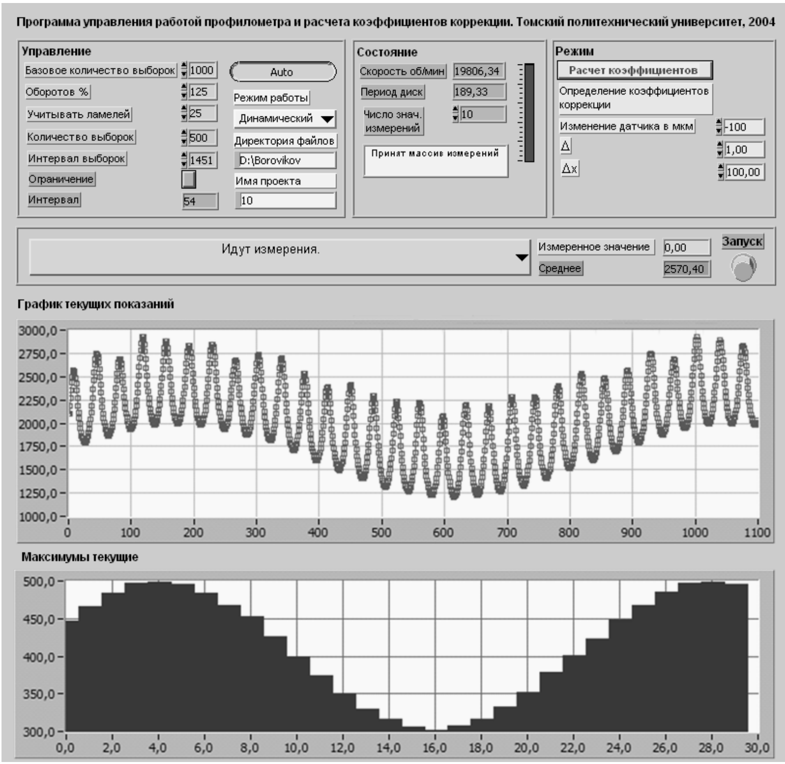

Fig. 5. *The example of output of commutator profile measuring results*

$$a_{2i} = \frac{y_д - y_0}{\pm\delta_0},$$

where y_{ad} and y_0 are the values of additional and reference measuring. Signs (+/–) corresponds to increase/decrease of a gap by δ_0.

The suggested technique is realized in graphic programming environment LabVIEW 5.0. The example of output to the monitor the commutator profile measuring results is shown in Fig. 5.

The carried out experiments showed that when applying the technique of bar base adjustment in dynamic operating conditions the correcting of profile level upon the average 25 % occurs [13, 14].

Conclusions

1. The developed and approved technique of measuring the electrical machine commutator profile allows increasing the control accuracy at varying heating temperature of commutator bars, change of specific resistances of bars surface layer, linear velocity of commutator moving relative to measuring converter and inaccuracy of its orientation relative to the controlled surface.
2. Testing high-speed electric machines of low power in dynamic conditions showed that adjustment of commutator profile level achieves 25 %. It allows developing constructions and technologies of commutator manufacturing at all stages of production process.

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