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DIAGNOSING THE MECHANICAL STATE OF THE COLLECTOR-BRUSH UNIT OF THE HIGH-SPEED ELECTRIC MACHINE AT RESOURCE TESTS

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The questions on defining the mechanical state of collector-brush units in dynamic modes applying the techniques of result processing obtained with use of contactless profilometer developed in TPU have been considered. The results of experimental researches of the collector-brush unit mechanical state of the electric motor with alternating current during the process of resource operating time are introduced. The experimental data are analyzed. Recommendations on improvement of current collection conditions in sliding contact and increasing of brush resource are developed.

The increase of communication reliability and resource of modern high-speed commutator machines is determined to a large extent by mechanical stability of electric sliding contact (SC). However, SC behavior in dynamics is not studied enough theoretically and experimentally owing to the process complexity as well as the absence of special measuring systems and techniques of processing measured information [1–4].

The aim of the carried out researches was to test the techniques developed in Tomsk Polytechnic University (TPU). They allow extracting the information interesting for the designers of commutator electric machines about a change of collector profile at maintenance, about the value and character of armature chatter as well as about the other mechanical parameters from the whole array of the results of measuring carried out with application of contactless profilometer. On the basis of the carried out experimental investigations and further data processing with application of the developed techniques the separation of the initial array of source information into components characterizing the collector surface levels without armature chatter and changes of these levels owing to armature chatter was carried out. As a result, the quantitative information about the state of collector profile of high-speed electric machine, size and character of bearing armature chatter, as well as the degree of their influence on mechanical state of collector-brush unit (CBU) at resource operating was obtained. The data obtained during investigations should become a base for modeling dynamic processes in SC and working out references concerning the increase of CBU working resource.

The test subject: electric motor of vacuum-cleaner unit of LG Electronics company, VCE280E02 model, 35000 rev/min, 1800 W, electric brushes of HG25 type.

During the tests the electric motor operated with ventilator load. Endurance test duration amounted to 709 hours. Brush wear was measured by a micrometer with interval of 35...45 h. Collector profile of electric machine was measured as well in dynamics at rated revolutions with the use of contactless hardware-software measuring system developed in TPU [5]. All the graphic materials introduced in this article are constructed on the basis of experimental data and their mathematical processing by special techniques.

The experimental data obtained during resource tests show that at brush limiting wear of 28,8 mm (1900 mm^3) the collector sliding path wear amounted to 0,74 mm (532 mm^3). It indicates the triple collector resource stock in comparison with brush set resource (on the basis of the constructive included stock for lamel wear amounting about 2...3 mm [6]). Therefore, the increase of CBU resource in similar machines is possible by decreasing the intensity of electric brush wear which depends on the factors of friction, electrocorrosion (current) and electroerosion nature. The electroerosion component of SC element wear is the most significant and determined by the commutation character which is conditioned to a large extent by collector profile state and armature chatter.

Distances form measuring transducer (eddy current type) stationary relative to the studied electric motor body to collector working surface in rated duty were me-

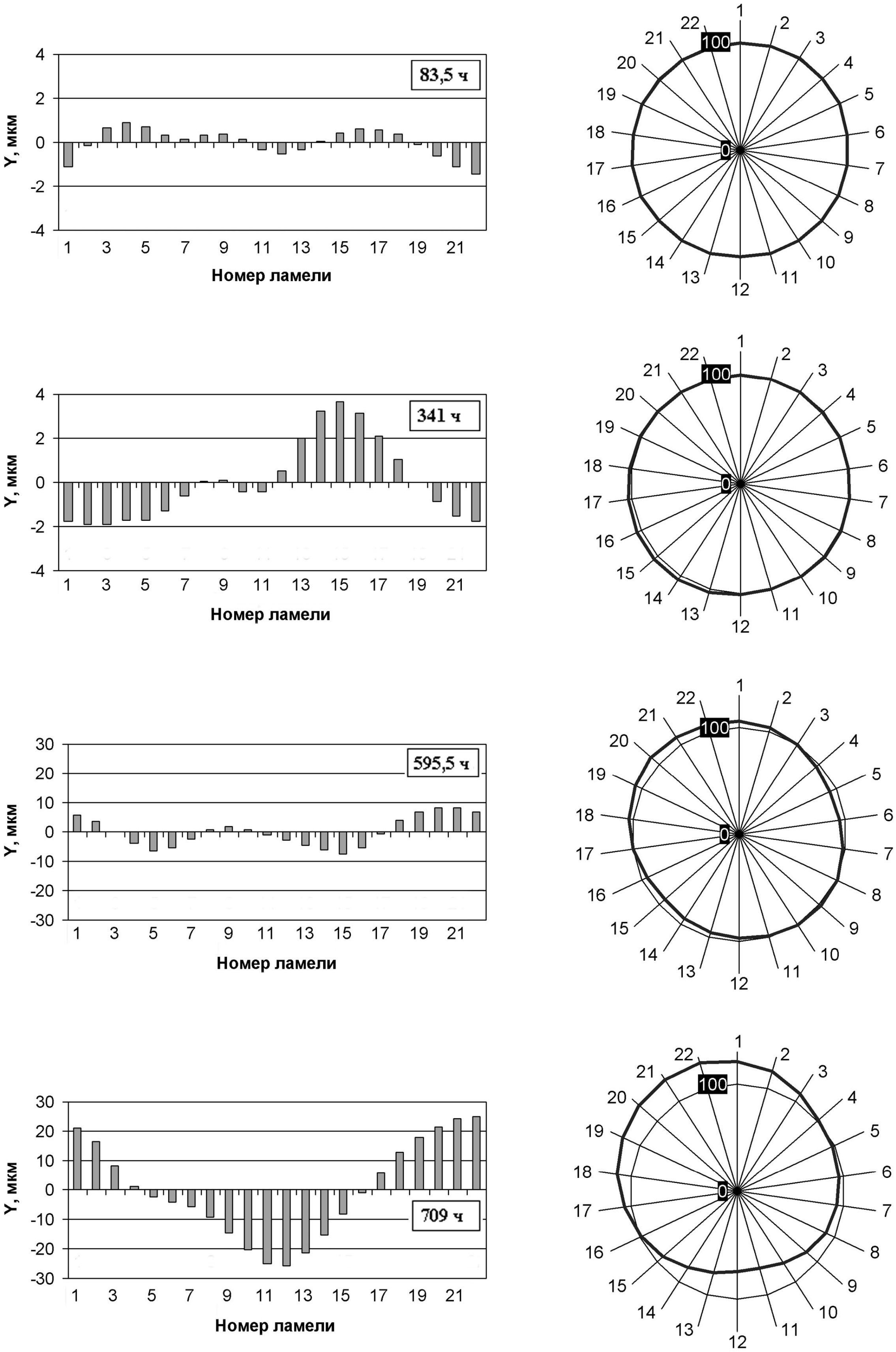

Fig. 1. *Collector profile change during resource operation*

Номер ламели – Lamel number

asured with the use of contactless diagnostic system [5]. It allowed determining the change of collector profile at maintenance, the magnitude and character of armature chatter using the techniques developed in TPU. It allowed as well determining other parameters characterizing CBU mechanical state on specified time interval of resource operating.

The changes of collector profile of the studied high-speed electric machine during endurance test are illustrated in Fig. 1. In the left part of the Figure the collector profile sweepings relative to mean lines of proper profiles at resource operating are given. In order to improve the perception of the collector cross-section geometry the collector profiles at resource tests relative to ideal circles (mean lines) reduced to the level of 100 ?m are introduced in the right part of Fig. 1. As it is seen from the given diagrams, the collector geometry changes greatly during the electric motor service life. In particular, the profile intensive changes occur after 350 h of operation i.e. after electric motor yield about a half of brush resource.

The dynamics of changing the values of drops between the collector adjacent lamels in the process of resource operating is introduced in Fig. 2. It follows from the given data that the peak values of drops between the lamels during the resource tests increased in 7,8 times and an average value of drops along the collector circle increased in 13,5 times.

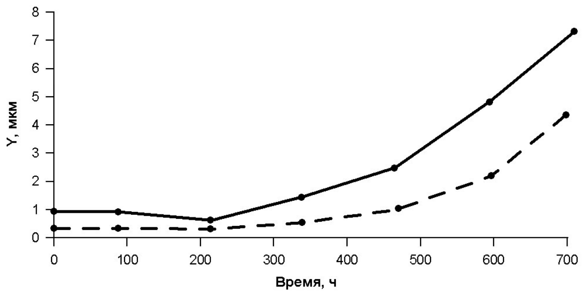

Fig. 2. *Dynamics of changes of peak (——) and average (– – –) values of drops between the collector lamels along the collector circle during the resource tests*

It is seen from Fig. 2 that during the first 220 h of electric machine operation the peak values of drops between lamels decrease by a third, average value of drops along the collector circle decreases as well but insignificantly (83,5 h – 0,34 μm, 215,5 h – 0,32 μm). This indicates that collector runs-in at this stage. Then the collector geometry impairs step-by-step during operation.

It is known [7, 8] that at vibration signal decomposition from body of revolution into Fourier series the first harmonic characterizes eccentricity, the second one – ellipticity and the third harmonic characterizes triangle feature. The obtained data indicate the fact that during the first 220 h of electric motor operation the amplitudes of the specified harmonics decrease or increase slightly (eccentricity) – the collector surface runs-in, then the harmonic amplitudes increase. Eccentricity during the electric motor operation grew in 21,2 times, ellipticity in 5,6 times and triangle feature in 7,7 times. The introduced data show one more time the collector profile degradation in the process of resource operation.

According to the technique developed at the department of electric drive and electric equipment (EDEE) of TPU the brush accelerations conditioned by the action from the side of collector working surface were determined. The dynamics of changing an average acceleration of brush during the electric machine service life is shown in Fig. 3.

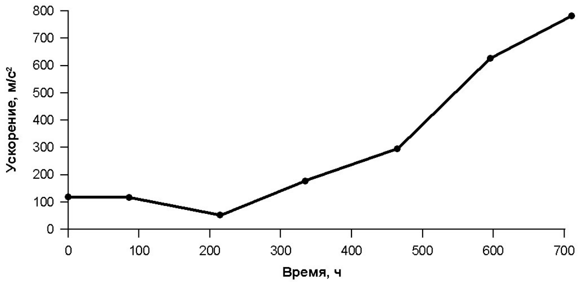

Fig. 3. *Dynamics of changing brush average acceleration conditioned by the action from the side of the collector working surface during resource testes of the electric machine*

Ускорение, м/с² – Acceleration, m/s²; Время, ч – Time, h

An area of collector run-in is seen as well from the data introduced in Fig. 3. After it the acceleration amplitude grows at increase of electric motor operating hours. This indicates degradation of the collector working surface geometry owing to unequal wear and, probably, integrity deterioration because of stress reduction due to mechanical and thermal actions on collector. Average values of accelerations influencing the brush from the side of the collector surface during the electric motor resource tests increased in 6,5 times.

Using the original techniques developed in TPU the information on armature chatter parameters which are mainly conditioned by bearing vibrations (radial motions of inner race relative to exterior ring surface owing to inaccuracy of bearing element manufacturing and their wear) was obtained. The dynamics of changing the armature chatter maximums conditioned by bearing beating at electric motor operation is introduced in Fig. 4. As it is seen from the given diagram, maximum swing of armature chatter increased in 5,9 times during the resource tests.

Using the data on the armature chatter of electric machine its vibration velocity and vibration acceleration may be determined. The dynamics of changing an average value of vibration acceleration of electric motor armature at electric machine service is introduced in Fig. 4. It is seen from the diagram that the average value of vibration acceleration of electric motor armature increases at resource operation and exceeds the initial value in 6,6 times at final stage.

It should be noted that during the resource tests the vibration action of the electric motor armature on brushes were about 1,6 times higher in comparison with similar actions of the collector profile that is, probably, typical for the high-speed machines.

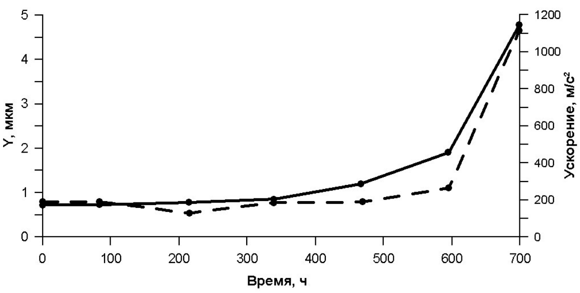

Fig. 4. *Dynamics of changing the armature chatter maximums (—) and average value of armature vibration acceleration of the electric motor (– – –) during the process of resource operation*

Ускорение, м/с² – Acceleration, m/s²; Время, ч – Time, h

Possessing the data on average values of brush acceleration caused by the action from the side of the collector surface $a_{щ.кол}$, as well as the data on average vibration accelerations of the electric machine armature $a_{щ.якоря}$, influencing the brush owing to vibrations in bearing units the summary average vibration acceleration (maximum average vibration acceleration) of the brush at electric motor operation: $a_{щ.сум}=a_{щ.кол}+a_{щ.якоря}$ may be determined. Change of the average summary vibration acceleration in the process of resource tests of electric motor is reflected in Fig. 5.

Using the data on the brush wear as well as its density the dynamics of changing the brush weight $m_щ$ may be determined. And using the value of pressure spring stiffness coefficient of (this case k=48 N/m) the maximum brush acceleration provided by the pressure spring at any time moment at electric motor maintenance may be determined, Fig. 5.

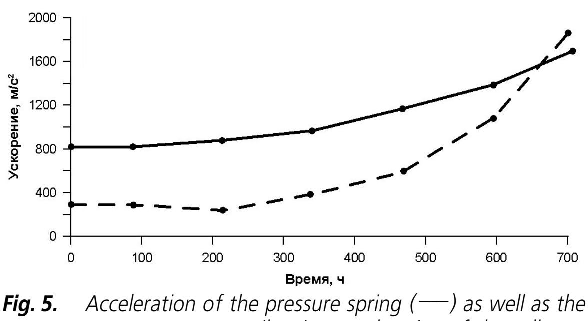

Fig. 5. *Acceleration of the pressure spring (—) as well as the summary average vibration acceleration of the collector and bearing units of the electric motor (– – –) during the process of resource operation*

Ускорение, м/с² – Acceleration, m/s²; Время, ч – Time, h

As it is seen from the introduced data the summary average vibration acceleration (of collector and armature) increased in 6,5 times and achieved the limit value for normal operation of collector-brush unit during the electric motor operation. This indicates the fact that at some moments of time the failure of mechanical contacting in sliding pair brush-collector (brush hanging, commutation failure and as a result, the increased wear of SC elements) is possible.

Analyzing Fig. 5 the conclusion may be drawn that the reliable contacting in sliding contact brush-collector should be provided at final stage of electric motor maintenance for further increase of electric motor service life. It may be achieved either by adjustment of the pressure spring acceleration (it is necessary that the acceleration curve increases more steeply at final stage) or by adjustment of the curve of summary average vibration acceleration of collector and armature of the electric motor (it is necessary for the curve to be flatter and for acceleration value to decrease at final stage). In other words it is necessary to achieve the parallelism of the pressure spring acceleration curve and the curve of summary average vibration acceleration of collector and bearing units.

The curve of the pressure spring acceleration may be adjusted by the change of spring type, screwdown arrangement type and brush type.

The curve of summary average vibration acceleration of electric motor collector and armature may be in their turn adjusted by improvement of collector strength properties, decrease of sparking degree and, respectively, wear of collector working surface (for example, by optimization of electromagnetic condition of commutation process), application of more qualitative and wear-resistant bearing.

Thus, from the obtained experimental data the trend to collector profile degradation with its wear is clearly observed. The increase of vibrations and vibration accelerations conditioned by the action from the side of electric machine armature is also observed that indicates the wear and incipient defects in bearing units.

It should be noted that during the resource tests the vibration influence of electric motor armature on brushes was in 1,6 times higher in comparison with the similar actions of the collector profile.

Therefore, one of the ways of prolongation of electric motor resource is to set up more qualitative, wear-resistant bearings or application of improved lubricants in them for extension of their resource. These measures are required for decreasing bearing vibrations and vibration accelerations that improves commutation processes and increases the resource of collector-brush unit. However, these measures need significant volume of additional experimental investigations and economic justification.

The efficient direction of increasing brush resource is application of new constructive solutions decreasing commutation sparking and erosive component of wear [9, 10]. In this case the collector profile stability increases in time that allows reducing additionally the commutation sparking due to improve of mechanical state of collector-brush unit at electric machine maintenance and decreasing SC element wear.

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ROLLING CURRENT COLLECTOR IN DIRECT CURRENT MACHINES

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The new method of rolling current collector has been developed. Its theoretical research was carried out. The operating model sample of the current collecting device using the rolling contact was made.

Considerable difficulties at adjusting switching of the direct current machines (DCM) are connected with known disadvantages of rolling contact of brush-collector and its limiting switching capacity.

Absence of influence of mechanical factors as well as discharged atmosphere or mordant environment on rolling current collector makes it rather perspective for using in reduced conditions.

The analysis of the existing current collecting devices (CCD) for the direct current machines using the rolling contact shows that all similar devices do not possess switching capacity the same as the rolling contact possesses.

In this connection a new method of rolling current collector was proposed [1]. The matter is in using additional link – rolling rollers (circles) providing electric contact between rotating collector and stationary «brushes» (Fig. 1).

In order to provide the switching capacity of such device its «brushes» should be compound with increasing resistances of their elements to the leaving edge [2, 3].

In Fig. 2 the typical examples of dependences of «brushes» resistances on the place of contact with them for reversible (solid line) and irreversible machines (dotted line) are introduced. R_{min} and R_{max} note minimal and maximal resistances of «brush» components (C), $b_щ$ is the «brush» width.

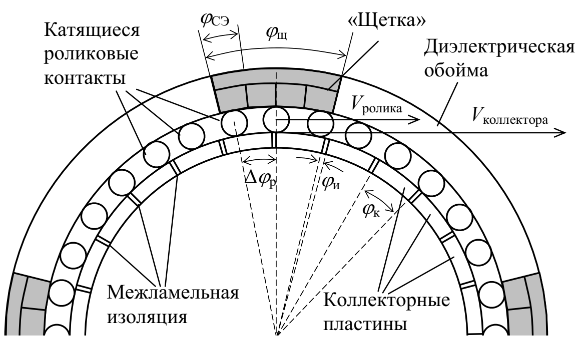

Fig. 1. *Current collecting device for DCM*

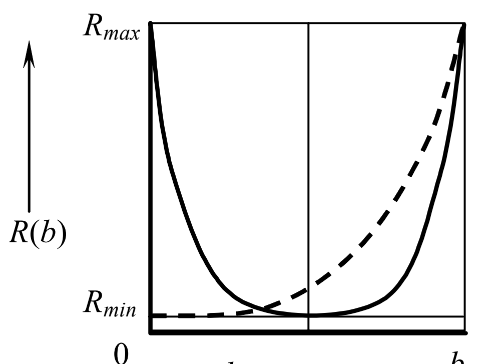

Fig. 2. *«Brush» resistance from the place of contact with roller*