

## Complex diagnostic system of ship electrical machines.

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In Riga Technical University and Latvian Maritime Academy (Latvia) complex system of diagnostics of large ship electrical machines is developed. The given system is based on simultaneous registration both joint processing of a number of mechanical and electrical diagnostic parameters and allows to diagnose damages of a mechanical and electrical part of ship electrical machines and also to determine a residual resource. The described system of diagnostics is two-channel - contains the channel of registration both transformation of mechanical diagnostic parameters and channel of registration and processing of electrical diagnostic parameters. In each channel the primary processing of the diagnostic information is made by the microprocessor. Further the information is transferred for final processing to the personal computer. To one personal computer it is possible to connect 8...16 diagnostic complete sets. Each complete set serves one electrical machine.

Mechanical diagnostic parameters are size vibroacceleration, measured two-plane - sensors directly in region both bearing units, angular speed, angular situation of rotor of a rather given point of zero situation, size and character of microdeformation of an external ring of the bearing. The signals from sensors act through convertor device on the microprocessor of the channel of processing of mechanical diagnostic parameters. In result of mathematical processing signals, proportional vibroacceleration, vibrospeed, vibrotransference for each plane each vibrosensor are allocated. Angular speed of a rotor and its angle of turn of a rather initial point of zero situation is determined also.

The channel of processing of electrical diagnostic parameters consists the microprocessor, convertor device and sensors of instantaneous magnitude three phase of currents and three phase of voltage. On instantaneous magnitude phase of currents and voltage instantaneous active and reactive power, harmonics structure of currents and voltage (control of amplitudes 3 ...7 harmonics), active resistance and temperature of a winding is de-termined and also appropriate working sizes [ 1 ].

The signals with both microprocessor channels act in the personal computer for final processing and accumulation in a database. The joint processing of electrical and mechanical diagnostic parameters allows to determine irregularity of angular speed and rotating moment for one revolution of a rotor. This irregularity can be caused as by defects of bearing units and irre-regularity

mechanisms. The analysis vibroinformation of bearing units allows to determine various defects - damage raseway of both rings and their skew, destruction of separator, deflection of the shaft. At presence of the sensor of a moment on the shaft of the electrical machine is possible to supervise balance of mechanical and electrical power at all modes of operations of electrical machines - that allows to carry out complete diagnostics of the machine. If necessary increases of depth of diagnosing the driving unit can as be equipped by the appropriate sensors. Comparing at any moment and for any interval of time the balance of consumed electrical power and made mechanical, is possible to carry out diagnosing of given depth not only electrical machine, but also process equipment connected with it. For example, the large pump, except vibroacceleration sensors on bearings can have sensors of pressure and temperature on input and output branch pipes. Under the indications of these sensors it is possible to determine productivity and pressure of the pump and, hence, consumed power. For anchor- mooring arrangement installation of sensors of a tension of a cable and its length and etc. is necessary. An effective diameter of a drum, the weight of a cable determined automatically. In it case the microprocessor device makes as continuous comparison of electrical and mechanical power, account arrangement efficiency and etc. Comparing at any moment and for any interval of time the balance of consumed electrical power and made mechanical, is possible to carry out diagnosing of given depth not only electrical machine, but also process equipment connected with it. Any deviation of mechanical and electrical parameters from reference is an attribute of damage. The specified deviations with the help of a logic matrix of damage are analyzed in personal computer are compared with similar by data, stored in a database for certain period of time and in a final kind are given out to the operator.

The condition of the bearing can be described by functional dependence:

$$F = \{A(a, b, c) + B(d, e) + C(g, h)\}, \quad (1)$$

Where

A - current condition of an external ring of the bearing;

B - current condition of an internal ring of the bearing;

C - information on the previous condition of the bearing.

The account of parameter C requires presence of a database, which can be realized only with application of

The classical method of diagnostics bearing units is based on measurement and registration vibroacoustics signals and subsequent their mathematical processing (spectrum analysis, revealing of correlation dependences and other necessary parameters) [ 2 ]. At all advantages of this method it concerns to indirect methods of measurement. Direct methods of measurement of design parameters of bearing units are applied much less often. It is connected first of all to a complex design of the appropriate sensors and difficulty of their accommodation. In a certain measure these difficulties are solved in offered system ( Fig.1 ).

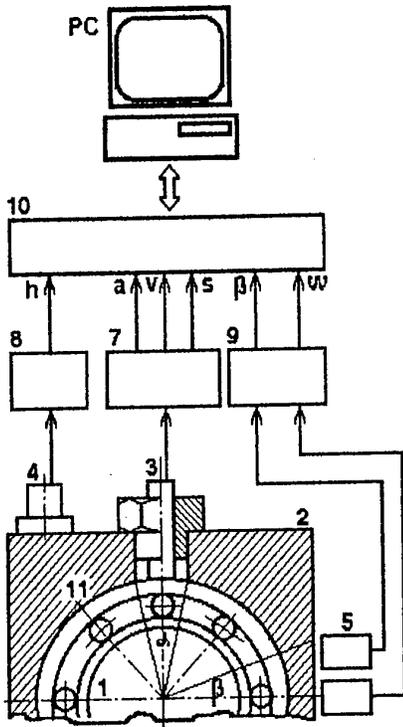


Fig.1. The scheme of system diagnostic with microdeformation sensor.

For increase of reliability and depth of diagnosing the offered system contains, except the sensor - piezoacceleration 4, sensors of angular speed 6 and angle of turn 5, also sensor 3 microdeformations of an external ring 11 bearing 1. In the block 8 signals piezoacceleration 4, proportional vibroacceleration  $\alpha$ , vibrospeed V, vibroway S will be transformed to the digital form and act in microprocessor - interface block 10. Through the converter 9 digital signals from sensors 5 and 6 angular speeds  $\omega$  and angle of turn  $\beta$  act there. In the block 7 the information from the sensor of microdeformations 3 will be transformed. Measurement of character and size of microdeformations h (share and unit micron) external ring 11 of bearing allows directly to estimate a condition raceway both rings of the bearing and his balls. Microprocessor - interface block 10 contains 16 bits computer and 16 K bytes memory. For

further processing of the information under the given program the personal computer serves.

For very large and responsible electrical machines for increase of accuracy and the depth of diagnosing bearing units is possible to recommend modulation way of diagnostics. At direct measurement of low-frequency sites spectrum of noise of the bearing (share both unit Hz) and signals with small amplitude their registration is a difficult problem. For example, at registration with the help measuring magnet device at record such signals are modulated by high-frequency fluctuations from the special generator. In the given work a way of modulation of noise of the bearing high-frequency making of ultrasonic fluctuations directly in the bearing is offered by imposing them against each other and mutual displacement. High-frequency fluctuations pass through a zone of contact ball-ring-separator and mix up with noise of the bearing, generated in a zone of the specified contact. In result the high-frequency signal appear modulated on amplitude, phase and frequency by noise of the bearing. Sum signal consists harmonics with various parameters:

$$U = \sum_{k=1}^N \{a_k \cos(k\omega + \varphi) + b_k \sin(k\omega + \varphi)\} \quad (2)$$

At further detecting of a high-frequency signal the necessary information is allocated. The typical picture of spectral density of the specified signal is given on Fig. 2.

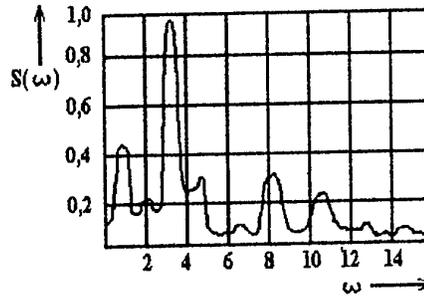


Fig. 2. The spectral density of ball track of the bearing - ring.

The specified way allows to register changes of diagnostic parameters there, where own generating ability of acoustic signals is small - for example, in slowly driving bearings.

Principle of work explains Fig. 3.

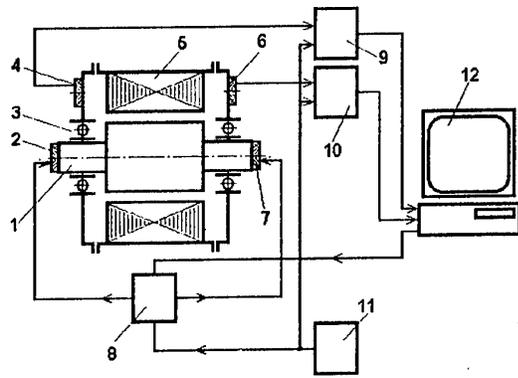


Fig. 3. The scheme of modulating way of diagnostics bearing units.

- 1 - shaft with a rotor of the electrical machine;
- 2, 7 - radiating high-frequency piezoelements;
- 3 - bearings;
- 4, 6 - piezoaccelerometers;
- 5 - stator;
- 8 - switchboard radiating high-frequency piezoelement;
- 9, 10 - synchronous detectors of amplitude, phase and frequency of modulated high frequency signals;
- 11 - high-frequency generator;
- 12 - personal computer.

The high-frequency ultrasonic signals from the generator 11 act on synchronous detectors 9 and 10 as basic and on the switchboard 8. The work of the switchboard 8 is operated by the personal computer 12. From an output of the switchboard 8 high-frequency signals alternately or according to the given program act on piezoceramic high-frequency radiators 2 and 7, placed in region internal rings of bearings 3. Further the high-frequency fluctuations through a zone of contacts an internal ring - ball - external ring act in bearing boards of the electrical machine, where are registered piezoaccelerometers 4 and 6. In a zone of contact ball - ring - ball the bearing generates own acoustic signals, which there modulate a high-frequency signal. In synchronous detectors 9 and 10 there is the processing high-frequency of a signal on allocation of changes of amplitude, frequency and phase of a modulating signal. From an output of synchronous detectors 9 and 10 transformation the received information for processing acts in the personal computer 12 for complete processing under the given program.

The given method allows to register diagnostic parameters in cases, when the own acoustic generation of bearings is small or is away at all - low rotation bearings or stopped mechanisms.

Economically expediently to apply complex system of diagnostics to electrical ship machines by capacity more than 50 kW.

[1] Y. Greivulis, A. Gasparian, A. Terebkov, Integrated parametrics of quality of electrical energy and technical diagnostics of ship electrical machines. Energetics economy, electricity quality, electromagnetic compatibility on railway transport. Russia, Moscow, MIT, RAPS, 1997.

[2] R. Collacott, Mechanical fault diagnosis and condition monitoring, Chapman and Hall, London. 1977.