Metrological support of diagnostic complexes for assessment of technical conditions

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Abstract. This article is dedicated to main aspects of implementation of monitoring of vibration in power equipment. An example of planning of current repairs for the analysis based on diagnostic signs is illustrated. The probable frequency ranges and magnitude of the increase in vibration levels of mechanisms for various operational defects are demonstrated. The requirements for the system of metrological support of diagnostic complexes are noted. The normalized metrological characteristics of measuring channels for diagnostic complexes are listed. The interface of a promising diagnostic complex for assessing the technical condition of rotary equipment is presented. The conclusion about the economic efficiency of the use of diagnostic systems with standardized metrological characteristics of measuring channels for monitoring of technical condition of rotor equipment is made.

1. Introduction

To determine the technical state of power equipment, complexes and systems for monitoring, diagnosing, forecasting (or systems for monitoring of technical condition) based on processing vibration signals are developed and produced. They allow you to monitor the technical condition of virtually any rotary type components: rolling and sliding bearings, gears and mechanical transmissions, electromagnetic systems of DC and AC machines, impellers of compressors, turbines, pumps and fans, coupling connections, etc [1, 2].

For a complete and reliable assessment of the technical condition of power equipment, diagnostic complexes (DC) should include certified software for processing vibration signals received from measuring transducers from sub-control power equipment. Since the main purpose of metrological support is to obtain reliable measuring information on the values of quality indicators of power equipment, then to assess the technical condition of these diagnostic complexes should be entered in the State Register of measuring instruments [1, 2].

2. Determination of the technical condition

Using vibrodiagnostic methods for determining the technical condition, diagnostic complexes can detect a wide variety of defects in power equipment, such as imbalance, misalignment and unparalleled shafts, stiffness and weakening of bearings, breakage of anchor bolts, violation of the geometry of the shaft line, as well as various bearing defects, including lubrication problems [3].
It is possible to optimize planning of maintenance and overhaul (figure 1), increase the overhaul interval, reduce the cost of purchasing spare parts and consumables basing on obtained information.

![Figure 1](image1.png)

**Figure 1.** An example of planning of maintenance basing on analysis of diagnostic signs.

Vibrodiagnostic examination allows you to:

- comprehensively evaluate technical condition of rotor equipment;
- identify clearly expressed (imbalance, misalignment, insufficient rigidity of the supports) and incipient defects in the equipment (defects in bearings, gears, etc.) (figure 2);
- assess the condition of any bearings (rolling, sliding), gears (gear, belt and chain) and pumping equipment (pumps, compressors, fans);
- identify defects in the electromagnetic systems of electrical machines;
- plan the volume and terms of repair work, evaluate the quality of their implementation.
- increase the reliability of rotary equipment;
- identify and prevent failures and malfunctions;
- determine the condition of the equipment;
- optimize the planning of maintenance and overhaul;
- reduce the cost of purchasing spare parts and consumables [3-5].

![Figure 2](image2.png)

**Figure 2.** Frequency ranges and magnitude of increase in vibration levels of mechanisms for various operational defects.  
1 - imbalance of rotor; 2 - asymmetry of a rotating magnetic field; 3 - defects of pumps and fans, misalignment of shafts; 4 - undulation of the bearing tracks; 5 - destruction of bearings; 6 - violation of lubrication of bearings, cavitation.
Figure 2 shows the most likely frequency ranges and magnitude of the increase in vibration levels of mechanisms for various operational defects.

The basis of a promising DC for monitoring the technical state of energy equipment is the indication and measurement of diagnostic parameters that reflect the dynamics of destructive processes in power engineering.

The composition of a promising recreation center for assessing the technical condition of energy equipment includes:

- computing system;
- measuring system;
- communication system;
- power supply system.

The measuring system includes primary measuring transducers (vibration sensors, selsyns, impedance heads and others). Using primary measuring transducers, parameters of various physical nature (temperature, pressure, displacement, frequency, etc.) are transferred into a unified signal, convenient for subsequent processing. Normalizers, which are voltage (frequencies) dividers or amplifiers are used. In order to standardize the equipment and narrow the dynamic range of the analyzed signals, essentially, primary measuring transducers, normalizers, communication lines, and sometimes secondary measuring transducers that convert analog signals to digital, form the measuring channels of monitoring and control systems.

Promising DCs for monitoring the technical condition have special metrological requirements due to their resistance to external factors of natural and artificial origin (vibration resistance, high and low temperatures, impact resistance and others). Normal and operating conditions of use for power equipment, including transportation and storage conditions are established as well.

To satisfy the requirements above, DCs must have a set of properties evaluated using metrological, operational and other characteristics. The metrological properties of measuring equipment, determined by their metrological characteristics, affect the error of measurement result, and on their basis one can judge its suitability for use in certain conditions. The need to evaluate the error of the measurement result by the known properties of military measuring equipment has led to the fact that a set of standardized metrological characteristics was established for it, namely:

- nominal conversion characteristic (for measuring transducers), scale interval and its limits;
- output code, the number of bits of the code, the nominal value of the unit of the smallest bit of code (for digital measuring equipment);
- systematic component of the error;
- random component of the error;
- total error;
- output and input resistance;
- functions of influence.

In accordance with State Standard GOST R 8.596-2002 "Metrological support of measuring systems. Fundamentals" measuring system (MS) is a combination of measuring, connecting, computing components that form the measuring channels, and auxiliary devices (components of a measuring system), functioning as a whole, designed for:

- obtaining information about the state of an object using measuring transformations in the general case of lots of time-varying and distributed in space quantities characterizing this state;
- machine processing of measurement results;
- registration and display of measurement results and the results of their machining;
• converting this data into system output signals for various purposes.

MSs are kinds of measuring instruments and they are subjects to all the general requirements for measuring instruments.

Figure 3 shows the interface of a promising DC for monitoring the technical condition of rotary equipment with the ability to establish standardized metrological characteristics of measuring channels for estimating an error of measurement result of MS.

Figure 3. The interface of a promising diagnostic complex technical condition of rotor equipment evaluation

For MSs, which are part of more complex structures, one should take into account the requirements of a set of standards and regulatory documents for automated systems: State Standards GOST 34.201, GOST 34.601, GOST 34.602 and other documents of this complex, as well as regulatory documents and operational documentation for the areas of application of these structures.

Metrological support of MS includes the following activities:

• rationing, calculation of metrological characteristics of measuring channels of MS;
• metrological examination of technical documentation for MS;
• MS tests for type approval; type approval of MS and tests for conformity to the approved type;
• MS certification;
• verification and calibration of MS;
• metrological supervision of the production, installation, adjustment, condition and use of MS.

Rationing of metrological characteristics of MS is one of the main elements of the metrological support system at the design stage.

Metrological characteristics of a MS are standardized for each measuring channel of MS and, if necessary, for complex and measuring components of a MS.

For measuring MS channels (including for measuring channels of various types of MSs or more complex structures for which the type of such a measuring channel is approved without specifying the name of a specific MS), the manufacturer, as a rule, sets the standards for the metrological characteristics of the measuring channels as a whole in accordance with State Standard GOST 8.009-84 "Normalized metrological characteristics of measuring instruments" and taking into account MI 2439-97 "State system for ensuring uniformity of measurements. Metrological characteristics of measuring systems. Nomenclature. The principle of regulation, definition and control” Normalized metrological characteristics of measuring channels should ensure:

• calculation of characteristics of the error of measurements performed by the measuring channel in the operating conditions;
• control during testing and verification of the MS for compliance with the standardized metrological characteristics of the measuring channel of the MS.

Implementation of monitoring of diagnostic parameters with normalized metrological characteristics of measuring channels in relation to rotary power equipment allows determining its residual life and service life with a high degree of certainty and, either to recommend another campaign of power plants without any significant recovery operations or carry out necessary maintenance and repair.

3. Conclusion
In conclusion, it should be noted that presence of a metrological support system allows you to determine the metrological characteristics of the primary converters (vibration sensors, impedance heads, etc.) of DSs, designed for evaluation of technical condition, which certainly allows to solve the reliability of the results obtained with predicting failures of working machines and mechanisms qualitatively, basing on the analysis of mechanical energy, which is distributed from the working mechanism by the attached design pits of objects, as well as in environment.

From the point of view of economic efficiency, the use of diagnostic systems with normalized metrological characteristics of measuring channels for monitoring allowed to reduce the cost of repairing power equipment by about half, while increasing the overhaul period of the power equipment by about 35%.

References
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