

Vibrodiagnostic method of water pump control

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Abstract. The research aims to carry out comprehensive diagnostics and develop diagnostic systems for vertical pumping units. The article discusses the method of technical diagnostics of large vertical pumping units to ensure reliability during their operation. An assessment of the qualitative and quantitative changes in the parameters of their operating modes during wear is given, and a diagnostic system is proposed for monitoring these parameters.

1 Introduction

Improving the efficiency of irrigated agriculture largely depends on reducing the operating costs of irrigation. In Uzbekistan, up to 50% of the areas of irrigated agriculture are areas with machine water lifting. To ensure reliability during pumping stations (PS) operation, the authors consider methods of maintenance and technical diagnostics of pumping units (PU). The development of new energy-saving modes of operation of the PS-1 of the Karshi Main Canal (KMC) provides for the improvement of the operating mode of the PS, which gives significant saving due to the elimination of excessive consumption of electricity due to unfavorable operating modes of the PU [1].

The technical condition of irrigation pumping stations (PS) should reflect the continuity and effective coverage of the specified water supply schedule, cost of pumped water, as well as indicators of technical condition and reliability of units.

The main feature of assessing the technical state of the NS is to take into account the factors of physical and moral aging of its elements (hydraulic structure, canal, PS), into which this system is conventionally divided. When assessing this state, the element is considered as a whole. This allows you to determine the dynamic level of the technical state of the NS element, diagnose the technical condition of the NS, and decide on its further use or modernization.

The development of dynamic control methods with reliability tests is the most time-consuming since they determine the mean time between failures, usually 4000-8000 hours, and the time before overhaul (20-30 thousand hours).

The wear of the elements of the flow paths of the PU during operation due to cavitation and attrition by suspended sediments leads to a deterioration of the operating modes. Repair work to eliminate the consequences of wearing the flow path parts requires significant labor and material costs [3].

The pump diagnostics system allows increasing operational reliability by preventing the installation of defective parts, clarifying the scope of upcoming repairs to restore the units' operability.

The performers considered creating a system for vibration diagnostics and monitoring the technological process at the NS using a hardware and software complex [4].

The proposed system is based on an IBM-compatible computer and a "Robotron" -type vibration measuring kit or similar and assumes automatic control and recording on magnetic media of information about analog and discrete parameters (temperature, pressure, vibration, voltage, current, position of contactors, starters, etc.). etc.).

To enter analog information of an electrical, mechanical or thermal nature, standard converters such as MP (pressure sensors), E (converters of electrical quantities), specialized microcircuits LM20 (temperature sensors), etc. can be used with unified output signal parameters - 0-5 V or 0-5 mA.

Parameter values are recorded to preserve historical information accurate to seconds and are available for subsequent analysis and processing.

The main tasks of the dynamic control of the PS by assessing the technical condition are:

1. Establishment of factors that determine the risk of danger of violation of the technical condition of the PS.
2. Identification of deviations from design solutions, damage, structural defects of structures that can cause accidents, dangerous changes in processes in the structure-base system, affecting its strength, stability, and water resistance (filtration, displacement, precipitation, stress level)
3. Data analysis of field observations of technical condition.

To assess the dynamic control of the PS for the reliability of maintaining the technical condition of objects, the following is performed:

- analyze possible failure situations. In the absence of relevant data, the technical condition analysis is carried out using the information on the technical condition situations of similar objects;
- establish by calculation the average values according to the data of similar objects, the average deviations and correlation moments of the limiting and effective values of the quantitative indicators of the technical condition;
- establish quantitative indicators of the reliability of the technical condition of elements (objects).

2 Methods

When determining the vibration of operating in various modes and conditions, methods have been developed for creating computer calculation programs that reflect their technical condition by analyzing vibration spectrum and vibration acceleration spectrum diagrams on the chamber and pump motor of pumping units.

3 Results and Discussion

Within the framework of monitoring the state of the scientific equipment, vibration is measured on non-rotating parts as a normalized parameter of the general vibration level and the establishment of the root-mean-square value of vibration displacement in the operating frequency band of 2–1000 Hz during stationary operation of the pump.

From the point of view of vibration strength in units, oscillations of a periodic nature are the most dangerous, resulting from mechanical, electromagnetic, and hydraulic processes with pronounced discrete components. Such dangerous vibrations are mainly strong diagnostic signals (that is, they stand out well against the background of vibration noise) [5, 6].

In a pump, vibrations of a hydraulic nature are manifested at a blade frequency proportional to the number of impeller blades (IB). For a new 300 VO-37/26C pump, their 6-blade frequency is:

$$f_b = 6 \cdot f_o;$$

The OPV11-260 pump has four blades, and the vane frequency is:

$$f_b = 4 \cdot f_o;$$

The straightening device at the outlet from the IB excites oscillations with a frequency proportional to the number of its own blades:

$$f_b = 12 \cdot f_o;$$

The reasons for the vibrational activity of vertical PU are subdivided into mechanical, hydraulic, and electrical ones by their origin [7, 8].

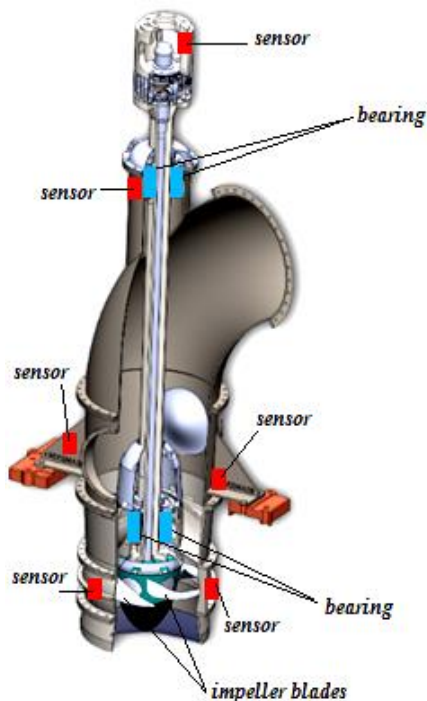


Fig. 1. Installation of vibration sensors on a vertical pump unit

The reason for the non-uniformity of the flow is the asymmetric flow around the rotating blades during the formation of vortex zones [9]. The heterogeneity of the flow leads to the appearance of the impeller chamber of vibration at the blade frequency flow and its higher harmonics. For worn spherical chambers in the absence of technological capabilities of turning, a combination of the above reasons prevails.

On vertical units in which the electromagnetic and hydrodynamic radial forces are ideally balanced, the clearances in the plain bearings increase when there are other defects, such as imbalance or misalignment of the shafts. These defects cause vibration, which should lead to shaft deformation around the circumference of the bearing. In front of, there is an external force that in certain phases of rotation will press the shaft against the bearing shell or unload the bearing at least for a fraction of the time, causing a violation of the "oil wedge". The wear rate of bearings depends on the size of the additional defect and increases in the presence of abrasive in the lubricant [10, 11].

Monitoring of such diagnostic parameters as the size of the clearance in the pump guide bearings, the overall vibration level, the insulation resistance of the windings, the transient resistance of the electrical contacts (especially the frontal connections), and the purity of the process water are not carried out, which often leads to accidents and failures. Currently, work is underway to create diagnostic systems for monitoring such diagnostic parameters.

In the practice of operating the OP10-260 pumps (which are the head samples of the largest pumps), there were no such precedents; therefore, the task of creating a diagnostic system was divided into the 1st and 2nd stages similarly [12].

The first stage involves monitoring a limited number of diagnostic parameters during operation, changes in which, according to statistics, caused the greatest number of failures. Other diagnostic parameters also affect the technical resource and the service life of the units. Their control is provided by the second stage of the diagnostic system.

The advantages of the device are to do remote monitoring system. With the installing remote sending apparatus, one can achieve the opportunity to get information in the distance. The scheme of this sending system is such (figure2).

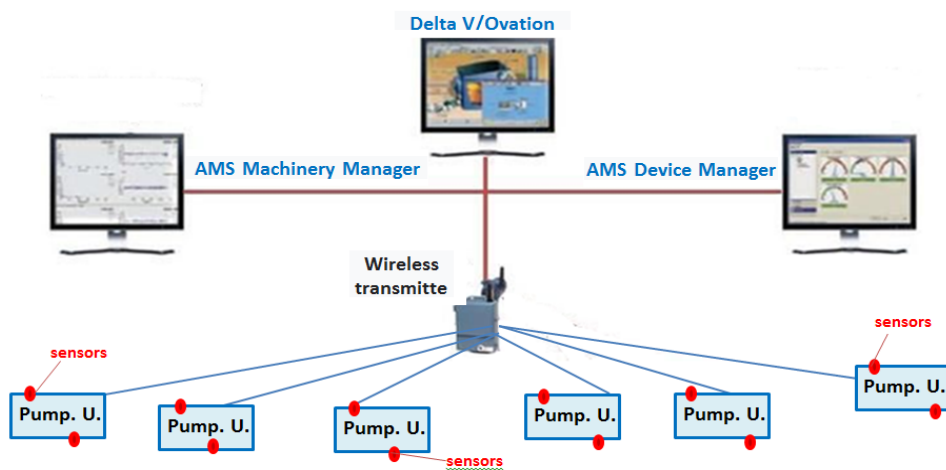


Fig. 2. Self-organizing wireless set

In addition, the second stage of the technical diagnostics system provides for automatic shutdown of the unit in case of unacceptable deviations of the diagnosed parameter. In contrast, the first stage of the system provides in the same cases only the issuance of a warning signal to the control panel.

To prevent accidents of units associated with excessive wear of the bearings, to ensure the operation of the bearings to the onset of the limit state, it is necessary to monitor the wear of the bearing shells [13].

The technical condition of the scientific equipment was usually determined by periodic or discrete control of the dimensions of its movable interfaces and the working body (diameters of rubbing pairs, sizes of blades, and their geometry).

The maximum vibration amplitude among the pumps of both types (17.9 m/s^2) at a frequency of 989,2 Hz in the vertical direction can be associated with increased mechanical vibration of the IB at low frequencies (figure 3).

A similar picture was observed during the inspection of the PS-1 in 2019 when on the PU No. 4, with a range of displacement at the revolving and blade frequencies of 32–42 microns, the value of the peak vibration acceleration was 22.1 m/s^2 .

On the pump chamber, the main source of increased vibration is the hydrodynamic imbalance and flow heterogeneity in the pump. The nature of these two defects is the same - an uneven gap between the blades and the chamber, differences in pitch and angle between the blades, length, and thickness, or their operational uneven wear, and the vibration manifestation is different [14].

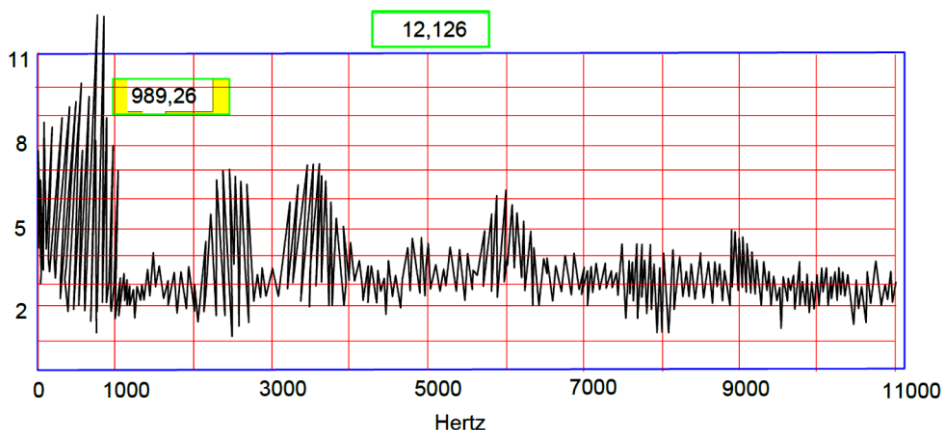
The growth of vibration at the blade frequency and its higher harmonics indicates the unevenness of the velocity and pressure field in the flow between the blades of the IB.

Hydrodynamic imbalance, as the asymmetry of the forces acting on the blades of the wheels, leads to an increase in vibration at the revolving frequency and the first three harmonics, depending on the form of symmetry breaking.

Since all the blades are already welded, it is not possible to correct the effect of some unevenness of the blade inclination angles on the hydrodynamic imbalance of the wheels and the flow in them.

Hydraulic imbalance is also present on two of the three new pumps 300VO-37/26C, where both the blades are new, and the chambers are cylindrical.

At PU No. 1, the maximum swing exceeds 32-41 microns, and in the same place, at PU No. 6, the swing rises to 42-53 microns, which indicates unfavorable modes of water supply to the extreme PU.



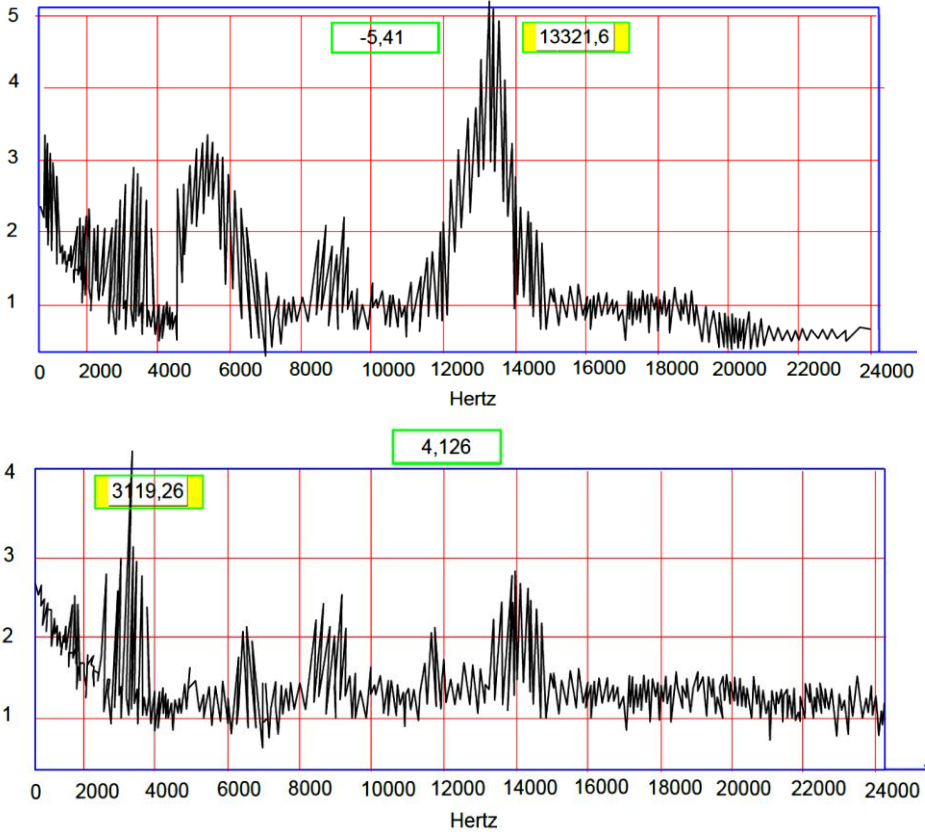


Fig. 3. Amplitude spectrum of vibration acceleration on the impeller chamber of the PS pumps.

4 Conclusions

- wear of individual elements of the main hydro-mechanical equipment of the PU leads to the deterioration in the operation of pumps, a decrease in their efficiency, and significant losses. Concerning pumps for irrigation PU, the reason for the increase in vibration may be the incorrect location of the unit about the water level of the downstream, associated with the peculiarities of their operation;
- a method is proposed for accounting for hydro abrasive wear of blades and elements of an axial-flow pump, taking into account the hydrodynamic parameters of the pump, the properties of the wear material, and the characteristics of the suspended flow;
- operating modes of pumps with a minimum wear rate of their parts are set. Rational from the point of view of reducing the hydro abrasive wear of the axial pump parts are modes with $Q \geq Q_{op}$;

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