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Investigation of vibration impact on metrological characteristics of measuring devices in conditions of pump station №5 channel named after Satpayeva

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Abstract. The article presents the results of the investigation of the effect of vibration on the metrological characteristics of measuring instruments, measurement methods and measurement techniques in real operating conditions. The topicality of the work is to ensure the reliability of the measurement results of the pump unit operation parameters in order to achieve the uninterrupted operation of the pump station objects. The investigation was carried out using the method 102-1, a vibration test was performed under the influence of sinusoidal vibration. The tests were carried out by smoothly changing the frequency in the specified range from lowest to highest. The conducted vibration studies made it possible to establish when the "normal" vibration becomes a "problem" or exceeds the permissible levels, the results obtained helped to determine the source and cause of the vibration, thereby ensuring effective prevention and eliminating the malfunctions of pumping units. In addition, it is established that when vibration occurs at several frequencies, it separates one frequency from the other so that it is possible to obtain each individual vibration characteristic. It is suggested at the pumping station to check the measuring instruments for vibration resistance, which allows to determine whether there are any additional errors of the instrument under the influence of vibrations during measurement, for example, as a result of tearing off the measuring tips of the CMM touch sensor from the measured surface. In the course of the study, we found that the use of vibration damping with the use of liquids for manometric equipment is quite effective in the conditions of operation of the pumping station. It is established that the most effective method is vibrodempfirovanie, which consists in reducing vibration by strengthening the design of friction processes that dissipate vibrational energy. This can be achieved by immersing the pressure gauge in the liquid, reducing the vibration amplitudes even in the resonance zone will depend on the damping ratio of the oscillations n..

1. Introduction

Regional State Enterprise "Kanysh Satpayev Canal" is intended for water supply of industrial regions and agriculture of Central Kazakhstan. The head water intake hub of the canal is located on the left-bank channel of the Irtysh River. White, above the city of Aksu. It ends at the pumping station No. 1 of the city of Karaganda, at 458 kilometers of the route. 272 kilometers of the channel pass through the territory of Pavlodar and 186 kilometers in the Karaganda region. Since 2001, water from the canal has been fed through the water pipeline to the Yesil river, then to the Vyacheslav reservoir for water supply to the capital of the republic - Astana. The idea of watering the arid Central-Kazakhstan region at the expense of the Irtysh River was expressed by many scientists long ago - back in 1930-1940.

The scheme of water supply of the city is divided into two zones because of the remoteness of the districts. The length of water supply networks in the city of Karaganda is - 1006 km. The design capacity of the water treatment facilities is 650 tons. The annual intake of water from the canal is 74 million cubic meters per year. The water from the channel to the scheme: channel - Pumping station № 1 - conduit - channel - Pumping station № 2 - penstock is fed to the water treatment plants, where the entire complex purification according to the standard. From wastewater treatment plants, drinking water is transported through 4 main water conduits to consumers. Such pumping stations – 6 pcs; booster pumping stations – 86 pcs.

2. Experimental

The main part of the pumping station is a pump unit [1, 2]. On. The pump unit consists of a centrifugal pump driven by an electric motor. The working member of the centrifugal pump - the impeller is installed in a ring-shaped chamber of variable cross-section [3, 4]. On the shaft of the impeller planted curved blades which during rotation of the pump entrain liquid fills the pump body, and the centrifugal force throws it by gradually expanding spiral chamber of the pump casing to the discharge nozzle. If in the case one wheel set, it is called a single-stage pump when multiple impellers placed in a common housing, the pump may be respectively two, three-stage, etc [5]. Due to the constant discharge of liquid in the rotating flow from the center of the pump wheel, a vacuum may be created in this zone, which is continuously replenished from the process pipeline by an external pressure at the pump intake [6, 7]

The technical operation of pumping units is the process of using them to fulfil the state plan for pumping volumes of water in order to guarantee the satisfaction of the needs of the economy while maintaining the technical parameters characterizing the technological process at the back level, ensuring maximum economy of operation, high efficiency, minimum cavitation damages of the flowing part and ensure the reliable operation of the channel as a whole. The technical characteristics of the OP pumps and the VDS electric motors of the Irtysh-Karaganda canal are given in Tables 1 and 2.

Table 1. Technical characteristics of the pump.

№	Name of parameters	Unit. amend.	Amount	
			OP10-185	OP11-185
1	Optimal pressure	m	21	17–18
2	Productivity	m^3/s	14–19	14–19
3	Rotational speed (slave)	rev / min	333	333
4	Direction of rotation	-	left	left
5	Blade turn range	-	0–9	0–8
6	Number of blades	pc.	6	4
7	Minimal penetration from the impeller	m	3.5	2.0
8	Coefficient of efficiency (max)	%	86	88
9	Angular rotation speed	rev / min	520	520
10	Diameter of pressure pipeline	m	2.6	2.6

Table 2. Technical characteristics of the electric motor – VDS 325/44-18.

№	Name of parameters	Unit. amend.	Amount
			OP10-185
1	Power	kW kVA	5000 5900
2	Voltage	V	6000
3	Stator current	A	566
4	Excitation voltage	V	to 150
5	Excitation current (rotor)	A	340
6	Power factor	-	0,9
7	Rotational speed	rev / min	333
8	Coefficient of efficiency	%	94.6
9	Causative agent	BBC 74/24-6	1
10	Exciter power	kW	76/5
11	Voltage	V	180/40
12	Weight VDS 325/44-18	H	50100

Instrumentation and automation facilities for the hydraulic engineering structures of the Irtish-Karaganda Canal, serviced by the KIP and A laboratories include:

1. Instruments for measuring water flow.
2. Devices for measuring the water level in the pool.
3. Instruments for measuring oil levels in engine oil sprouts VDS -325.
4. Devices for automatic monitoring and measurement of temperatures of electric motors, transformers;
5. Instruments for measuring pressure.
6. Vibration measuring instruments.

Oscillations (vibrations) in pumping units are considered primarily from the position of their influence on the durability of the operation of the elements of the design of any unit, the effect on the foundations or concrete overlaps where they are installed, and also on human effects [8–10]. The sources of vibration in pump units of water supply and discharge systems include: - pipelines; - pumps; - electric cars. Vibrations in pipelines are caused by wave processes occurring in the pumped liquid [11, 12]. During operation, the service life of radio electronic devices and systems installed at pumping stations is drastically reduced due to their operation under conditions of high random vibration. The increase in the periods of their working capacity and functioning is associated with carrying out highly effective vibration tests [13, 14].

Vibration has a different effect on the operation of devices and auxiliary devices. It increases the mechanical fatigue of parts and their wear, changes the frictional force in the rotating parts, increases the looseness of the movable joints, causes spontaneous unscrewing of bolts, screws and nuts. The most dangerous are the resonance and associated destruction of the individual elements and the whole structure, as well as the errors in the readings of the measuring instruments.

Low-frequency mechanical vibrations (2…10 Hz) can cause vibration of the whole device. The device should be isolated from the effects of these vibrations, otherwise high resolution can not be achieved. All these effects can be eliminated by careful design of the device, and therefore they are not very important when considering the limiting resolution. However, they are significant in the practical operation of the device [15 – 17].

3. Results and considerations

The study of vibration allows us to establish when the "normal" vibration becomes a "problem" or exceeds the permissible levels. These results can also help determine the source and cause of vibration, thereby providing effective prevention and troubleshooting. The vibration analyzer measures the amplitude, frequency and phase of vibration. In addition, when the vibration occurs at several frequencies, it separates one frequency from the other so that it is possible to obtain each individual vibration characteristic.

Instruments are tested in two ways for vibration and vibration resistance. Vibration test allows to identify drawbacks of assembly, soldering and other manufacturing defects. Therefore, it is advisable to check for vibration vibration all the devices at the factory. The vibration test allows you to determine whether there are any additional errors in the instrument due to vibrations during measurement, for example, as a result of tearing off the measuring tips of the CMM touch sensor from the measured surface.

Table 3. Comparative characteristics of measuring devices of pump station no 5.

№	Devices	Type		Class / non-pred.	Range / Limit.	Vibration resistance	Possible. Amplitude and frequency of vibrations.
1	Amperemetre	M325	Shielded	1.5	0…500	-	5.5
2	Voltmeter	M325	Shielded	1.5	0…250	-	5.5
3	Varmeter	C42303	Shielded	1.5	0…6	acceleration 15 m/s^2, frequency of 30 Hz.	5.5
4	Measuring t / n	VTOM-10	Stationary	0.5	57–6000	-	5.5
5	Current transformer	CTPCI-10	Stationary	0.5	2000/5	-	5.5
6	Manometer	STM4	Stationary	1.5	0…2.5	-	5.5
7	Flowmeter “Vzlyot MR”	UFM-510d	Shielded	-	-	-	5.5
8	Electricity meter	SA3U-E720	Stationary	1	-	-	5,5

It is advisable to check the instruments for vibration resistance only when developing and releasing new models. Electrodynamic vibration sets with a frequency range of 5-5000 Hz, a maximum displacement of 10 mm are suitable for testing instruments for vibration resistance and vibration resistance.

Verification of the vibration resistance of the device and evaluation of the quality of the installation of electrical equipment is carried out using a vibration shaker that generates vibrations at a frequency of 50 Hz and with an amplitude of vibration displacement (half the span) to 0.2 mm. All components of the device are fixed in the working position on the platform of the shaker. Within 10 minutes, tests are carried out on the modes specified in Technical Specifications [18–20]. The device is considered to have withstood the test, if, after the vibration load has ceased, the external inspection will not reveal any mechanical damage, weakening of the fastenings, a violation of the quality of the installation of electrical equipment. At the same time, the standardized characteristics of devices must meet the requirements of standards and technical conditions.

With the toughening of working conditions, the intensity and frequency of vibrations of aggregates, installations, etc. are increasing, just as pressure pulsations lead to an increased error in measuring pressure, wear of mechanical devices and, as a consequence, lead to a breakdown in the technological process, and therefore sharply increase requirements for vibration protection of sensitive devices for measuring pressure. As a protection against vibration, the following methods are used [14, 21]:

Vibration isolation: Reduction of vibration consists in reducing the transfer of vibrations from the oscillating device to the manometer, with the help of elastic pads, springs placed between them, etc. An example of vibroinsulation with Getzner gaskets is shown in Figure 1

Figure 1. Vibration isolation Getzner.

Vibration damping: is to increase the mass of the system and it is carried out by installing aggregates on a massive foundation [22, 23]. This method is effectively used when reducing the vibration of block equipment. In Figure 2 shows the vibration damping of a gas piston power plant.

Figure 2. Vibration damping.

Vibration damping: This method consists in reducing vibration by strengthening the design of friction processes that dissipate vibrational energy [24]. This can be achieved by immersing the pressure gauge in the liquid (Figure 3), reducing the vibration amplitudes even in the resonance zone will depend on the damping coefficient of the oscillations *n*.

Figure 3. Glycerin filled manometer.

4. Conclusions

Protection from vibration and shock is achieved through the convenient placement of devices, reducing the vibration of the source of vibration and the use of anti-vibration devices. Of course, it is best to install instruments in special rooms, away from sources of vibration and shocks. If this is not possible, it is desirable to mix the analyzers on massive shock-absorbing stands or independent foundations, or finally, near supporting structures (walls, columns), where the vibration is felt less. The balancing of moving parts and the multiplication of the oscillation frequency of a source above 10-20 Hz (devices are easier to protect from the effect of a higher frequency of oscillations) make it possible to reduce the influence of vibration of oscillation sources.

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