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OPERATIONAL CAPABILITY OF AN ELECTRIC PUMP UNIT WITH NEW AND WORN ROTOR WHEELS

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This article is devoted to experimental studies of the operational capability of an electric pump unit in operation with new and worn out rotor wheels. Results of measurements are presented for the operating parameters of the electric pump unit, vibration monitoring, and thermal imaging, and the calculation of static durability of a shaft, based on which the main conclusions are formulated.

Keywords: pump; wear; rotor wheel; operational capability; working parameters; vibration; temperature; static strength.

In many mines and shafts, water removal units based on centrifugal sectioned high-pressure pumps (TsNS) that are used when pumping water flows out to the surface or overlying formations, operate in conditions of corrosion and hydroabrasive wear process that eventually negatively affect their readings: the technical (throughput, pressure, capacity and efficiency), ergonomic (level of sound pressure, vibration acceleration, vibration speed, and vibration displacement), and reliability (failure rate, time between failures), etc. [1 – 16].

One of the required methods of ensuring the operability of mine (shaft) water removal installations is to decrease their standards of operating time prior to major maintenance, which method is actively applied, for example, at the mining enterprises of the Urals and Yakutia.

In the Southern Urals copper-sulphide mines, the operating time of TsNS(K) pumps before major overhaul is 248 – 1000 h, and at the kimberlite mines of Western Yakutia, major overhauls of TsNS(K) pumps are done after 3500 – 3900 h, with a total standard at 6500 h [17, 18].

Even despite a shortening of intermediate overhaul periods, the rotor wheels of TsNS(K) pumps lose approximately 3 to 10% of their initial weight in the course of pumping mineralized waters rich with mechanical impurities, depending on the order number of the placement of the wheel on the shaft, which may result in a shift of the operating mode of the electric pump unit from the optimal region on the pressure curve, disbalance of the rotor, and other significant problems.

Hence, carrying out experimental studies of the operability of a pump installation with a rotor wheel having reduced specific metal content due to wear of 3 – 10% of the initial state is an urgent scientific and practical task.

The research on which this this article is based was executed in the APM Win Machine software environment under the authority of the Mining Machines Department of Federal State Autonomous Educational Institution (FGAOU) VPO M. K. Ammosov North-Eastern Federal University.

A full-scale experiment was carried out on the pump installation based on the K8/18 console pump in two stages (Fig. 1):

— Stage 1 was measurement of working parameters: pressure at input to the pump M_1, at the volute M_2, and at output from the pump M_3, throughput Q, frequency of rotation of the electric motor n, power of the three phases $N_{A, B, C}$; root mean square (SD) vibration speed $v_{r.m.s}$, and temperature t at measuring points during pump operation with the new rotor wheel having mass 1.008 kg (Fig. 2);

— Stage 2 was measurement of the above-stated parameters during pump operation with the worn-out rotor wheel mass 0.952 kg, i.e., with the specific quantity of metal reduced by 5.5% in comparison with a new rotor wheel.

A full-scale experiment was carried out according to GOST 6134–2007 [19], GOST ISO 10816-1–1997 [20], and GOST R 18434-1–2013 [21]. Five measurements were taken for each working parameter.

Repeated readings of the measured parameters were taken at various time intervals, but not less frequently than every 10 seconds [19]. There were three measurements of the SD of vibration speed and temperature at each measuring point [20].

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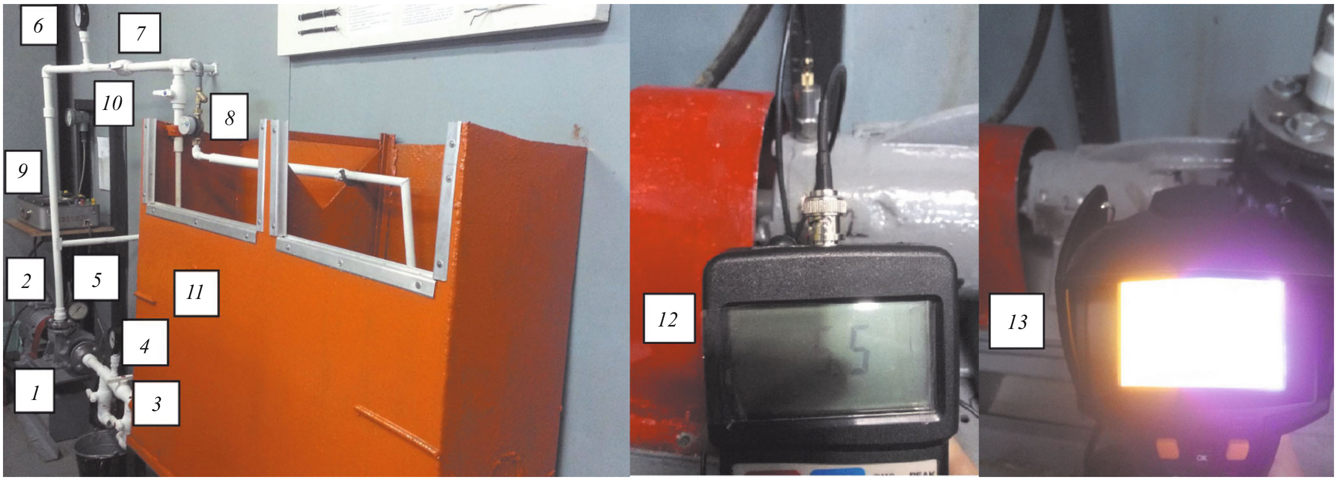

Fig. 1. Pump installation and the set of measurement and recording devices used to conduct the full-scale experiment: *1*, K8/18 pump; *2*, AIR80V2 electric motor; *3*, Du-40 ball valve; *4*, OBMV1-100 pressure-and-vacuum gauge; *5*, TM5 manometer; *6*, AM1001U2 manometer; *7*, Du-32 ball valve; *8*, Unimag TU4 flowmeter; *9*, K50 type measuring set; *10*, mechanical tachometer; *11*, storage container; *12*, ATT-9002 vibration meter; *13*, Testo 875-1 thermal imaging camera.

Repeated readings of the SD of vibration speed and temperature were taken at various time intervals, but not less frequently than every 10 sec.

There were 16 measuring points to measure vibration speed and 4 for temperature measurement. Air temperature during tests was 18°C.

The electric pump unit was run in before the tests. Unit run-in before each stage of the tests took 15 min [19].

Table 1 presents the values of operating parameters measured during the course of the full-scale experiment and calculated according to [19, 22].

According to the date of Table 1, when the specific metal content of the rotor wheel decreased by 5.5% from the initial state, the output of the electric pump unit was reduced by 3.85%, the pressure was reduced by 4.5%, and its capacity, to the contrary, increased by 14.3%.

The most used method for estimating the current technical condition of electric pump units is vibration monitoring [23 – 26].

The K8/18 pump belongs to class 1 of rotor machines with maximum permissible SD of vibration speed 4.5 mm/sec (lower bound of zone "C") [20.27].

Table 2 shows the SD of the vibration speed, measured by a vibration meter at the measuring points during operation of the electric pump unit (Fig. 3).

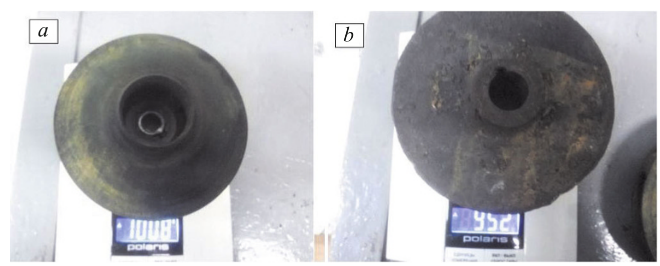

Fig. 2. Rotor wheel of K8/18 pump: *a*, new; *b*, worn.

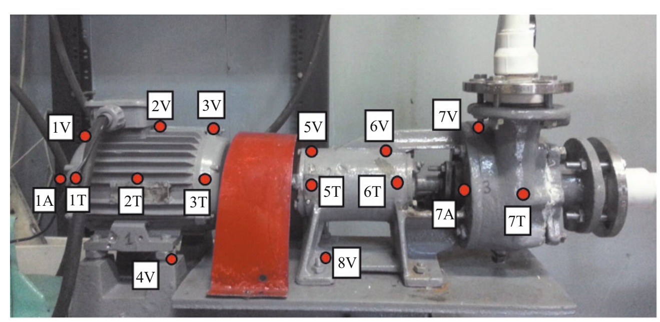

Fig. 3. Layout of measuring points for vibration monitoring: T, installation direction for piezoelectric accelerometer to measure transverse vibrations; V, installation direction for piezoelectric accelerometer to measure vertical vibrations; A, installation direction for piezoelectric accelerometer to measure axial vibrations.

TABLE 1. Results of Full-Scale Experiment

Stage of tests	Measured values										
	M_1, kgf/cm^2	M_2, kgf/cm^2	M_3, kgf/cm^2	Q, liters/sec	N_A, W	N_B, W	N_C, W	n, rpm	Q, m^3/h	H, m H_2O	N, kW
1	–0.08	2	1.99	0.52	167.5	162.5	160	≈2950	1.872	22.28	0.49
2	–0.02	1.95	1.95	0.5	200	182.5	177.5	≈2950	1.8	21.27	0.56