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Influence of hydroabrasive wear of impeller blades on head of centrifugal pump

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Abstract. The results of experiments on studying the nature of changes in the concentration and dispersion of solid suspended particles showed that the highest average monthly sediment concentration is $2.5 \ldots 3.8\ kg/m^3$, and sometimes in rainy weather, the maximum water turbidity reaches $7\ kg/m^3$. In the composition of solid mechanical impurities, a significant amount consists of particles with a grain size of $0.1 - 0.05\ mm$. Observations have established that particles larger than 0.01 mm at a low flow velocity in the supply channel and the water intake chamber of the pumping station were easily deposited in them. Siltation volumes at various stations ranged from 20 to 60%. As a result, the hydraulic resistance increased, which led to a decrease in the pump head. The wear of parts of centrifugal pumps in natural conditions was also studied, and the dependences of wear on the characteristic dimensions and duration of their operation are given. The results of micrometering of the working parts of the pumps showed that the blades of the impellers along the length and width wear out unevenly both in size and shape. This is explained by the fact that when the hydroabrasive flow moves in the interblade space, the kinetic energy of solid particles and their local concentration increase due to an increase in the values of centrifugal and Coriolis forces along the radius of the impeller.

1 Introduction

The dependences of the wear of the impeller blades on the concentration and fineness of sediments, as well as the duration of the centrifugal pump operation presented in Figures 1, 2, and 3, confirm the results obtained in [1-7]. Methodical studies of the influence of the concentration and size of solid particles, as well as the duration of the impact of the hydroabrasive flow on the wear rate of the elements of the flow path of a centrifugal pump, confirm the validity of the physical model. To determine the degree

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of influence of the operating mode of a centrifugal pump on the intensity of hydroabrasive wear, special studies were carried out at constant values of sediment concentration $P = 20\ kg/m^3$, particle diameter $d = 0.25 \ldots 0.5$ mm, test duration $T = 2$ hours and rotational speed shaft n_0=2900 rpm. The experiments were carried out at pump flows from $0.5Q_{exp}$ to $1.25\ Q_{exp}$ with various materials and polymer coatings, which were applied to the surfaces of the blades made of steel - St. No.3. [8-12]. The procedure for applying a polymer coating to metal surfaces was as follows: ED-6 epoxy resin was applied to the surface of the blades with various fillers. To obtain polymer coatings, you need 100 parts by weight of resin, 15-solvent (dibutyl phthalate), 10-hardener (polyethylene polyamine), and 120-filler (silicon carbide, i.e., sand) with a particle diameter of $d = 0.2\ mm$, monocorundum (sand) - $d = 0.2\ mm$ and ferromanganese - d less than $0.1\ mm$.

2 Methods

An analytical method for determining the wear of metals, a method for applying a polymer coating to metal surfaces, and generally accepted methods for laboratory and full-scale testing of centrifugal pumps.

3 Results and Discussion

It has been established that the best adhesion of the polymer coating is obtained at a metal temperature of 21°C.

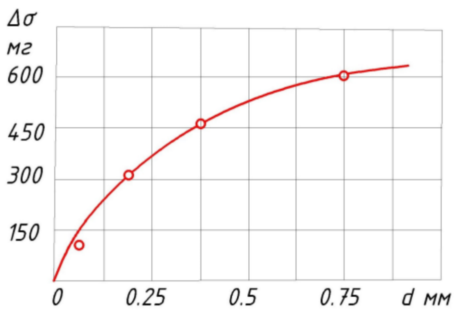

Fig. 1. Influence of fineness of deposits on the value of hydroabrasive wear of the blades of the impeller of a centrifugal pump.

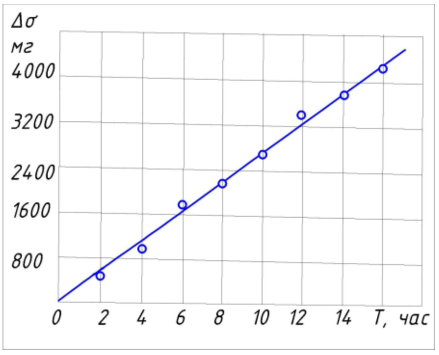

Fig. 2. The dependence of the intensity of wear of the impeller blades on the duration of the centrifugal pump

Figure 3 shows the wear rate of the impeller blades made with different polymer coatings, depending on the operating mode of the pump. As can be seen from the figure, the shape and nature of the dependencies for various materials remain similar when the pump delivery is changed. Still, there are significant differences in the quantitative ratio.

Polymeric materials based on epoxy resin with silicon carbide have the highest wear resistance, silumin shows low wear resistance. When testing soil pumps [13-16], it was found that parts made of electrocorundum on an epoxy-phenol-formaldehyde binder, compared with parts made of wear-resistant cast iron, increased the service life of pumps by 3-8 times. But the use of wear-resistant polymeric materials for the manufacture and coating of pump parts has not been widely used in practice due to the following reasons [17, 18]: 1) polymer compositions do not provide satisfactory wear resistance at high flow rates; 2) the rough surface of polymer coatings creates additional hydraulic resistance and degrades hydraulic efficiency; 3) the quality of polymer coatings is highly dependent on strict adherence to the application technology.

If we compare the wear values with the pressure characteristic of the pump (see Fig. 3), then three characteristic zones can be seen:

- zone A - with a minimum wear rate corresponding to the mode $0.75 < Q/Q_{exp} < 1.15$ (where Q is the pump water supply according to the catalog; Q_{exp} is the experimental water supply of the pump);

- zones B and C with a sharp increase in wear corresponding to the modes $Q < 0.75Q_{exp}$ and $Q > 1.15\,Q_{exp}$.

The smallest wear value ΔG/Q related to the pump flow corresponds to the mode $0.9 < Q/Q_{exp} < 1.15$. An increase and decrease in a feed from the limits as mentioned above leads to vortex formation on the working or back surfaces of the blades, which contributes to their increased wear.

Figure 4 shows the dependence of the wear intensity of the impeller blades of a centrifugal pump 4K-8 (n_0=2900 rpm) presented in [19, 20]. Comparing the curves in fig.3 and fig. 4 for pumps 3K-6 and 4K-8, it should be noted that the form and nature of the dependencies approximately correspond to each other, but the mode of operation with a minimum wear rate for the pump 4K-8 corresponds to $0.7 < Q/Q_{exp} < 1.15$, and for pump 3K-6 - $0.8 < Q/Q_{exp} < 1.10$. This means that centrifugal pumps with a lower speed ($n_s = 60 < 80$) have a narrower limitation mode in terms of the minimum wear rate of the impeller. The obtained results show that an increase or decrease in the pump flow by 3-5% from the specified limitation zone leads to a sharp increase in the wear intensity and significantly reduces the life of the pump impeller.

It should be noted that for centrifugal pumps operating on water sources with a high content of sediments, to reduce the intensity of wear of parts, it is necessary to limit the operating area of the characteristic from $0.6 < Q/Q_{exp} < 1.2$, which are recommended by the manufacturer to $0.8 < Q/Q_{exp} < 1.10$. Reducing the recommended zone on the characteristic will not only increase the pump's life but also its average efficiency during the period of operation.

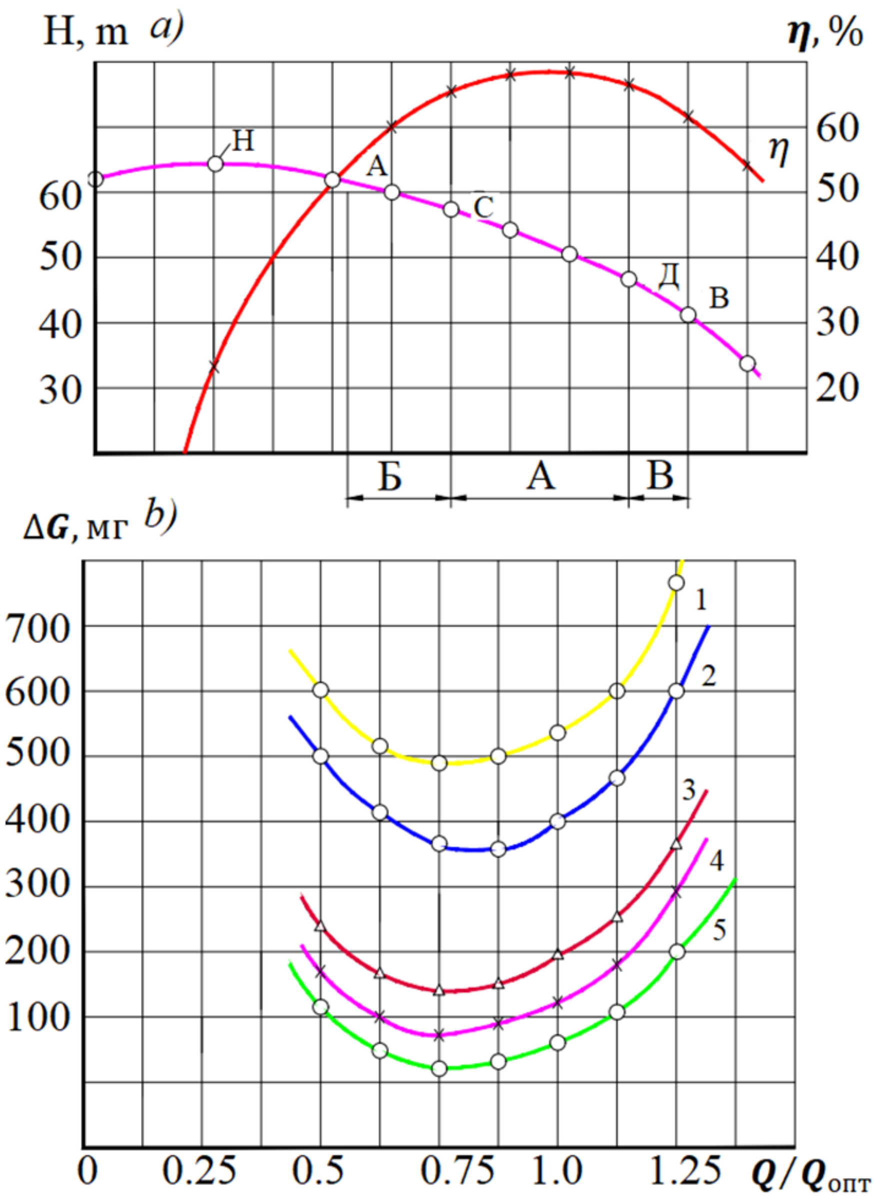

Fig. 3. The intensity of wear of the impeller blades from the operating mode of the centrifugal pump 3K-6 (n_o = 2900 rpm): *a* is pump characteristic, *b* is wear of blades made of various materials; 1 is silumin, 2 is ferromanganese with epoxy resin, 3 is steel (St. No. 3) 4 is monocorundum with epoxy resin, 5 is silicon carbide with epoxy resin.

An analysis of worn surfaces shows that at the length of $\ell/3$ of the end part of the working surface of the blade, noticeable traces of wear are observed, which increases in thickness towards its trailing edge due to an increase in the local concentration of sediment due to separation and convergence of solid particles to the surface of the blade in the inter-blade channel working wheel.

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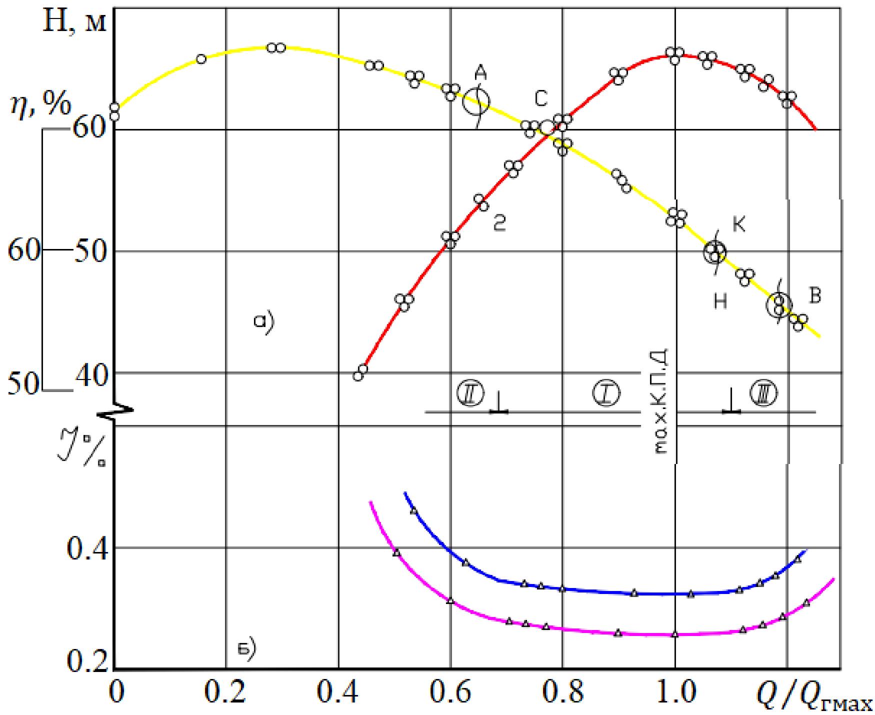

Fig. 4. Influence of the operating mode on the intensity of hydroabrasive wear of the impeller of a centrifugal pump 4K-8 (n_o=2900 rpm): *a* is pump characteristic, *b* is wear of the blades.

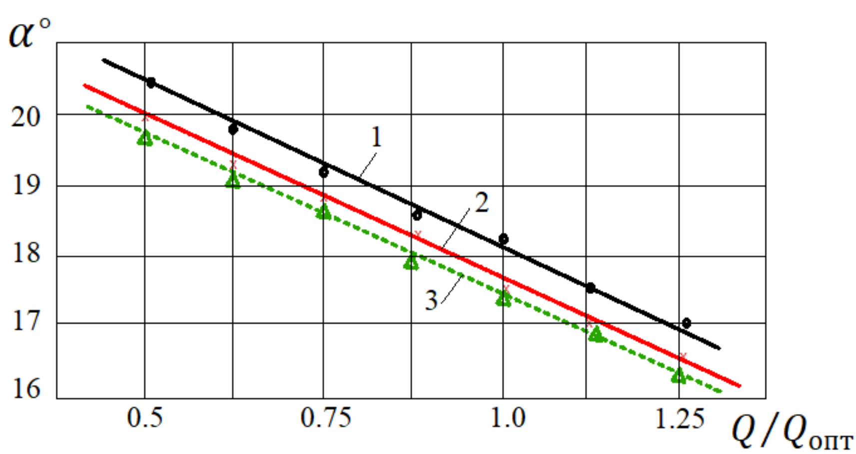

Fig. 5. Influence of the operating mode of a centrifugal pump on the interaction α of a solid particle with the surface of the blade: 1-3, respectively, for the middle and end parts of the blade, 2, for the radius $R = 0.75 \cdot R_2$

Therefore, to determine the angle of the interaction of solid particles α with the blade's surface, special experiments were carried out with the installation of silumin balls with a diameter of 6 mm on the working surface of the blade. Experiments carried out under various operating modes showed (Fig. 5) that the angle, α, of the interaction of solid particles with the surface of the blade of a centrifugal pump is within $\alpha =$

$16^{\circ} \dots 21^{\circ}$, which is close to the corresponding angle α for axial pumps (where α is the angle of the interaction of solid particles with the surface of the pump part) [3, 20].

4 Conclusions

1. The conducted studies of the centrifugal pump made it possible to identify their mode of operation with a minimum intensity of wear of parts.
2. Tests of a centrifugal pump have shown that reducing the cavitation reserve to a certain value helps to reduce the intensity of cavitation-abrasive wear compared to hydroabrasive wear.
3. Experimental studies make it possible to develop constructive protection measures and recommendations on the methodology for calculating the elements of sealing and slotted gaps of centrifugal pump impellers.

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