Polymer materials used to reduce waterjet wear of pump parts

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Abstract. The article presents the results of studies of the degree of influence of the operating mode of the centrifugal pump on the intensity of the water jet at constant values of the sediment concentration $P = 20 \text{ kg/m}^3$, particle diameter $d = 0.25...0.5 \text{ mm}$, test duration $T = 2 \text{ hours}$ and shaft speed $n_0 = 2900 \text{ rpm}$. Experiments were carried out on pump feeds from $0.5 Q_{\text{opt}}$ to $1.25 Q_{\text{opt}}$ with various materials and polymer coatings that were applied to the surfaces of the blades made of St.3. The best adhesion of the polymer coating is obtained at a metal temperature of 21°C. Polymer materials based on epoxy resin with silicon carbide have the highest wear resistance, while silumin shows low wear resistance. When testing ground pumps, it was found that parts made of electro corundum on an epoxy-phenol-formaldehyde bond, in comparison with parts made of wear-resistant cast iron, increases the service life of pumps 3 - 8 times.

1. Introduction

The experience in the operation of centrifugal and axial pumps has led to the need for scientific justification and experimental verification of the efficiency of their operation when pumping water with a high sediment content, which leads to intensive cavitation-abrasive wear of their parts, associated with high operating costs [1, 2, 3, 4, 5].

The technical and economic consequences of pump wear as a result of cavitation and abrasive impact are manifested in a complex way. Firstly, the energy performance of the pump deteriorates and the associated energy consumption increases, and secondly, it is necessary to periodically carry out repair work to eliminate the consequences of wear. Third, crop yields are reduced due to reduced water supply from pumps.

The conducted studies have established that the energy overruns caused by a decrease in the efficiency of pumps can be estimated in the range of 6 - 7 % of the total amount of electricity consumed by pumps. The problem of maintaining a high efficiency of pumping equipment is extremely relevant and important [6, 7].

Improving the efficiency of the pumping station operation is possible only with systematic scientific and production work aimed at improving the design of equipment and structures, studying local conditions and factors that affect the efficiency of the entire complex of the hydraulic unit of the machine water lifting.
2. Materials and methods
To determine the degree of influence of the operating mode of the centrifugal pump on the intensity of waterjet wear, special studies were carried out at constant values of the sediment concentration \( P = 20 \text{ kg/m}^3 \), particle diameter \( d = 0.25...0.5 \text{ mm} \), test duration \( T = 2 \text{ hours} \) and shaft speed \( n_0 = 2900 \text{ gpm} \). The experiments were carried out on pump feeds from \( 0.5 Q_{\text{opt}} \) to \( 1.25 Q_{\text{opt}} \) with various materials and polymer coatings that were applied to the surfaces of the blades made of St.3. The technology of application and modes of heat treatment of polymer coatings were developed by employees of the laboratory of operation of pumping stations of the Andijan Institute of Agriculture and Agrotechnologies [8]. The method of applying the polymer coating on metal surfaces was as follows: epoxy resin ED - 6 was applied to the surface of the blades with various fillers. To obtain polymer coatings, we need 100 parts by weight of resin, 15 parts by weight of solvent (dibutyl phtholate), 10 parts by weight of hardener (polyamine polyethylene), and 120 parts by weight of filler (silicon carbide, i.e. sand) with a particle diameter of \( d = 0.2 \text{ mm} \), moncorundum (sand) - \( d = 0.2 \text{ mm} \) and ferromanganese - \( d \) less than 0.1 mm.

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

Figure 1 shows the wear rates of the impeller blades made with different polymer coatings, depending on the operating mode of the pump. As it can be seen from the figure, the shape and nature of the dependencies for different materials remain similar when changing the pump supply, but there are significant differences in the quantitative ratio.

Polymer materials based on epoxy resin with silicon carbide have the highest wear resistance, while silumin shows low wear resistance. When testing ground pumps, it was found that parts made of electro-corundum on an epoxy-phenol-formaldehyde bond, in comparison with parts made of wear-resistant cast iron, increases the service life of pumps 3 - 8 times [9]. However, the use of wear-resistant polymer materials for the manufacture and coating of pump parts has not been widely used in practice due to the following reasons [10]:
1) polymer compositions do not provide satisfactory wear resistance at high flow rates;
2) the rough surface of polymer coatings creates additional hydraulic resistances and worsens the hydraulic efficiency;
3) the quality of polymer coatings strongly depends on strict compliance with the application technology.

If you compare the wear values with the pressure characteristic of the pump, (see Figure 1), you can see three characteristic zones:
- zone A - with a minimum wear rate corresponding to the re-press \( 0.75 < Q / Q_{\text{opt}} < 1.15 \);
- zones B and C with a sharp increase in the amount of wear corresponding to the modes \( Q < 0.75 Q_{\text{opt}} \) and \( Q > 1.15 Q_{\text{opt}} \).

The lowest wear value \( \Delta G/Q \) related to the pump flow corresponds to the mode \( 0.9 < Q / Q_{\text{opt}} < 1.15 \). An increase and decrease in the feed from the above-mentioned limits leads to eddy formation on the working or rear surfaces of the blades, which contributes to increased wear of them.

Figure 2 shows the dependence of the wear rate of the blades of the impeller of the centrifugal pump 4 K-8 (\( n_0 = 2900 \text{ gpm} \)), presented in the work, during the experiments of which the author took part [11]. Comparing the curves in Fig. 1 and 2 for pumps 3 K-6 and 4 K - 8, it should be noted that the shape and nature of the dependencies approximately correspond to each other, but the operating mode with the minimum wear rate for the pump 4 K - 8 corresponds to \( 0.7 < Q / Q_{\text{opt}} < 1.15 \), and for the pump 3 K - 6 - \( 0.8 < Q / Q_{\text{opt}} < 1.10 \). This means that centrifugal pumps with lower speed (\( n_0 = 60 < 80 \)) have a narrower restriction mode in terms of the minimum wear rate of the impeller. The results obtained show that increasing or decreasing the pump supply by 3 - 5 % from the specified restriction zone leads to a sharp increase in the wear rate and significantly reduces the service life of the pump impeller.
Figure 1. The wear rate of the blades of the impeller on the mode of operation of a centrifugal pump 3 K-6 (n₀= 2900 gpm):
a - characteristic of the pump, b - wear and tear of the blades of various materials; 1-silumin, 2 - ferromanganese with epoxy, 3 - steel St. 3, 4 – monocrundum with epoxy resin, 5 - silicon carbide with epoxy.

It should be noted that for centrifugal pumps operating on water sources with a high sediment content, in order to reduce the intensity of wear of parts, it is necessary to limit the working area characteristics from 0.6 < Q / Q_{opt} < 1.2, which are recommended by the manufacturer, to 0.8 < Q / Q_{opt} < 1.10. Reducing the recommended area on the characteristic not only increases the service life of the pump, but also increases its average efficiency during operation.

3. Results and discussion
The analysis of worn surfaces shows that the length b/3 of the end part of the working surface of the blade shows noticeable signs of wear, which increases in thickness to its output 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 of the impeller.
Figure 2. Influence of the operating mode on the intensity of water jet wear of the impeller of the centrifugal pump 4K-8 ($p_o = 2900$ gpm): a - pump characteristics, b - blade wear.

Therefore, to determine the angle of interaction of solid particles $\alpha$ with the surface of the blade, 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 conducted under various operating modes have shown that the angle, $\alpha$, of the interaction of solid particles with the surface of the blade is within the range $\alpha = 16 \ldots 21$, which is close to the corresponding angle $\alpha$ for axial pumps.

4. Conclusion
1. The experimental studies conducted on laboratory stands with centrifugal and axial pumps have obtained the dependences of wear of their parts on the concentration and size of solid particles, the duration of operation, the speed of rotation, the angle of installation of the impeller blades, the cavitation reserve and the operating modes of the pumps.
2. The conducted researches of centrifugal and axial pumps allowed revealing the mode of their operation with the minimum intensity of wear of details.
3. Tests of centrifugal and axial pumps have shown that reducing the cavitation reserve to a certain value reduces the intensity of cavitation-abrasive wear compared to waterjet wear.
4. The experimental studies make it possible to develop design measures for protection and recommendations for the calculation of the elements of the sealing and slot gaps of the impellers of centrifugal and axial pumps.

References
[1] Glovatsky O Ya, Ochilov R A 1990 Improving the operation of large reclamation pumping stations (Moscow: Technical Information of the Ministry of Water Construction)
[2] Glovatsky O Ya 1992 Improving the operation of pumping stations Agriculture of Uzbekistan 10 27 – 29
[3] Glovatsky O Ya, Isakov Kh Kh, Pak O Yu, Talipov Sh G 2004 Some environmental aspects of energy-saving modes of reclamation pumping stations Journal Modern problems of water resources management 2 19 – 24
[4] Karelin V Ya 1983 Building machine (Moscow: Stroitel)
[5] Kim V A, Kabulov I N 1991 Experience in operating centrifugal pumps *Melioration and water management* 5 37-39

[6] Aynakulov Sh, Karimova Kh, Alibekov S, Mamajonov M 2020 Constructive device for sediment flushing from water acceptance structure *International Conference on Materials Physics, Building Structures and Technologies in Construction, Industry and Manufacturing (IPCPE 2020)* (Russia: Vladimir Russian Federation Vladimir State University named after Alexander and Nikolai Stoletov) 121-125

[7] Matyakubov B, Mamazhonov M, Shakirov B M, Teplova G, Shakirov B B 2020 Forebays of the poligonal cross - section of the irrigating pumping station *IOP Conference Series: Materials Science and Engineering* 883(1) 012050

[8] Ulugojaev K Kh 1989 *Removal of axial pumps* (Tashkent: Mehnat)

[9] Leonidov L D J 1987 Erosion of pump metals *Flower metals* 6 26-28

[10] Zhivotovsky L S, Samoylovskaya L A 1986 *Mechanical engineering* (Moscow: Mechanica)

[11] Karelin V Ya, Mamazhonov M 1978 Wear of axial-flow pumps by suspended flow *Hydraulic engineering* 1 29-32.