Cavitation-abrasive wear working collectors of pumps

Oleg Glovatsky\textsuperscript{1,2}, Rustam Ergashev\textsuperscript{2}, Azamat Saparov\textsuperscript{1}, Mustafo Berdiev\textsuperscript{2} and Bobur Shodiev\textsuperscript{2}

\textsuperscript{1}Research Institute of Irrigation and Water Problems, Karasu-4 Street, Tashkent 100187, Uzbekistan
\textsuperscript{2}Tashkent institute of irrigation and agricultural mechanization engineers, 39 Kari Niyaziy Street, Tashkent 100000, Uzbekistan

E-mail: erustamrah@mail.ru

Abstract. The main results of the study of hydraulic losses in the suction line and mechanical damages of the impellers of pumps due to cavitation-abrasive wear are given in the article. The scientific task of using theoretical bases for justifying factors affecting the wear rate of pump parts is being solved. On the basis of these theories, a technique is proposed for calculating the wear rate of the elements of the flow-through part of the pumps. During the experimental studies, standard methods of laboratory-bench testing of pumps were used. The operating modes of pumps with minimal wear of their parts are established. Poor hydraulic flow conditions with swirl zones cause an increase in energy losses and a redistribution of flow rates across sections. Wear the parts that are flowing directly proportional to the concentration in the sediment flow, the cube of the flow velocity, the time of action on the pump units. The presence of unsteady vortex regions, especially when the effect of eddy formation increases, leads to fluctuations in the velocities and pulsations of the flow pressure. Cavitation in the pump occurs when the operating modes of the pump differ from the nominal. The increase in volumetric efficiency, the improvement of hydraulic flow conditions to the pump impeller and the reduction of cavitation wear were achieved by the authors in a new pump design that contains guide planes fixed to the throttle plate parallel to the suction nozzle axis with an elastic outer surface. In the same areas of constructive improvement of pump assemblies, it is necessary to search for ways to reduce the negative impact of cavitation and hydroabrasive erosion on the life of pumps.

1. Introduction

In practice, one of the main operational problems is the cases of prolonged operation of the pumps with greatly increased compared to the design hydraulic losses in the suction line and mechanical damage to individual elements due to cavitation-abrasive wear\cite{1}.

Practical value: the developed constructive measures aimed at creating wear-resistant pump elements lead to an increase in pumps, energy and resource saving. Many researchers have dealt with the issues of modernizing the flowing part of irrigation pumps, among which the works of Balzannikov M.I., Vissarionov V.I., Glovatsky O.Y., Karelin V.Y., Mamazjonov M., Muhammadiev M.M. An analysis of the study of issues of hydroabrasive and cavitation-abrasive wear of hydraulic machine elements according to literary sources shows a lack of work on their combined influence\cite{2-6}.
2. Methods

In carrying out this work, the basic principles of the theory of paddle hydraulic machines and the
theory of hydroabrasive and cavitation-abrasive wear of metals were used. Based on these theories, a
method for calculating the intensity of hydroabrasive wear of the elements of the flowing part of the
pumps is proposed. In conducting experimental studies, generally accepted standard methods of
laboratory bench testing of pumps were used.

3. Research results

Purpose of work: study of abrasive-cavitation erosion of full-scale pumps. Wear protection of
hydromechanical equipment based on the use of theoretical foundations of the justification of factors
affecting the wear rate of pump parts and improving the hydraulic processes of their flow part.

Research objectives: development of a methodology for calculating cavitation-hydroabrasive wear
of pump impellers and recommendations for choosing rational operating modes, taking into account
the minimum wear of working parts.

Cavitation-abrasive wear of irrigation pumps causes significant costs for the repair and
maintenance of machine water-lifting systems [7]. With an average concentration of solid particles in
water (2.15 kg/m³) and an average supply of one pump unit (PU) of 1.5 m³/s type 24 VAT, up to 1150
kg of solid particles flow through the flow parts of each unit in 1 hour, and per day - 27830 kg.
Therefore, the presence of solid particles in the pumped water is one of the main factors in the
intensive wear of the flow part of the pumps.

Full-time observations of the operation of hydraulic machines and many years of operating
experience show that the leading role in the destruction of parts of hydraulic turbines and pumps
operating on high turbidity streams is played by abrasive and erosion-abrasive types of wear, while the
rest are insignificant[1,8,9]

By establishing the intensity of cavitation erosion J, the authors were able to draw contours of the
function J at dimensionless coordinates in $\frac{\mu P}{\eta}$ (figure 1).

![Figure 1. Relative cavitation-erosion characteristic model centrifugal pump](image)
here

\[ J = \varphi(q, \overline{p}) \]  

(1)

Functional dependence of the erosion intensity on the geometric, kinematic and energy parameters of the pump:

\[ q = \frac{60Q}{n_0 D_1^2}; \quad \overline{p} = \frac{\Delta P}{\rho \left( \frac{n_0 D_1}{60} \right)^2} \]  

(2)

here \( Q \) is the feed; \( n_0 \)-speed; \( D_1 \)-diameter of the wheel at the entrance; \( \rho \) is the fluid density; \( \Delta P = P_{en} - P_v \) - excess pressure at the inlet to the pump over the pressure of saturated vapor of the liquid.

As can be seen from fig. 1, the isolines of cavitation erosion intensity in different modes have different shapes, which convinces of the complexity of the relationship between erosion processes, pump energy indicators and hydrodynamic flow characteristics. The operational experience necessitated the justification and experimental verification of the efficiency of the pumps during pumping water with conditions close to cavitation – abrasive wear of their parts, associated with high operating costs.

According to the research results, it can be argued that in each particular machine there are optimal working areas with minimal cavitation erosion, which can be established experimentally [4], [10–12].

Figure 2 shows the results of experimental studies of the effect of cavitation stock on the main energy parameters of a centrifugal pump in the form of the dependences of \( H, \eta, \) and \( N \) on \( \Delta h \).
A break in the pressure curve in mode means the occurrence of cavitation, and a decrease in pressure with a decrease in $\Delta h$ is its subsequent development. The vertical branch of the pressure curve in mode II indicates a failure of the pump due to fully developed cavitation. Along with a decrease in pressure, developing cavitation causes a decrease in efficiency, which, in turn, determines an increase in power on the pump shaft in all modes of operation with cavitation up to failure.

The dependence of the pump parameters on the cavitation reserve allows using this reserve for a numerical assessment of the degree of cavitation development. Indeed, all characteristic operating modes of the pump correspond to well-defined numerical values of $\Delta h$. For the conditions under consideration, the beginning of cavitation (critical mode I) is observed at $\Delta h = 4$ m, fully developed cavitation (critical mode II) is observed at $\Delta h = 1$ m, modes with partially developed cavitation...
correspond to values \( \Delta h > 1 \) m. possible for operation limits of deterioration of the pump due to cavitation, it is possible to determine the minimum value of the cavitation margin \( \Delta h_{\text{min}} \) [13–17].

Changes over a wide range of operating parameters of hydraulic machines (pressure, flow rate, power), as well as the different state of the pumped stream, lead to the fact that in some cases, despite the measures taken by the operator, they work in conditions of intense abrasive wear. As a result of this, the energy characteristics of machines are deteriorating. Mechanical damage to the working elements of the scientific equipment due to intensive hydroabrasive wear can reach dimensions in a relatively short time that impede their normal operation and even make it practically impossible[19].

At the Kuyu-Mazar National Park of the Amubukhara Canal, OP10-185 pumps are subject to intense abrasion. Power of pumping units is 5000 kW. Lifting height \( N_g = 21 \) m with a factory characteristic of 18.6 m, flow 15.9 m/s.

The impeller blades turned out to be the most worn. On the front side of the blades, 4 areas can be distinguished that differ in the degree and nature of wear:

a) Vertical, adjacent directly to the input edge, having medium- and large-scaled wear;

b) The horizontal part of the input edge, which has deep wear in the form of a gap with a maximum depth of 25 mm;

s) A strip with a width of approximately 200 - 250 mm adjacent to the first and second regions is a region of deep furrowed wear, directed at an angle to the vertical part of the blade and diverging in a fan shape in the lower part;

d) The output edges, serrated in curved sections, they are severely damaged. Breakouts of metal penetrate into the depth along the width of the blade up to 200 mm, the area of breakouts reaches 300 \( \text{sm}^2 \).

The wear of the two blades is slightly different from the one described above, which is characteristic of most impeller blades. The main difference is that deep metal tears occur at the exit edge. This difference in wear can be explained mainly by the heterogeneity of the impeller metal that occurs during the casting process.

The Amubukhara Canal also monitored the operation of centrifugal pumps at the Dustlik pumping station. Power of pumping units is 1600 kW. Lifting height \( H_g = 60 \) m. Inspection of the pumps showed that the impeller is subjected to the greatest wear. Basically, it wears out in one season. At the same time, its blades wear out most. The outer surfaces of the blades have deep furrowed wear, the output edges are notches, the input edges at the points of contact with the outer rims are smoothed deep gaps. The entire surface of the outer rims has deep scaly wear.

The pump is equipped with protective sealing rings: two stationary in the housing and the same on the outer rim of the impeller. Fixed O-rings made of cast iron are usually replaced 1-2 times per season. The pump bal in places of epiplons is supplied with two protective plugs. The factory supplies a pump with cast iron bushings. Operators strive to replace them with steel failure 1-2 times a season as they fail.

The dynamics of the wear of the impeller along the outer diameter increases to 100 hours of operation of the pump along the parabola (figure 3). Further it changes rectilinearly.
This can be explained by the fact that up to 100 hours of pump operation, abrasive particles more actively affect wear, since the gap between the impeller and the chamber is still small, and on the other hand, during this period, the concentration of solid particles in the pumped water is usually the highest. With further operation of the pump there is a uniform increase in impeller wear.

When clarifying the effect of hydro thermodynamics on the cavitation characteristics of the pump, it was found that one of the main parameters determining the suction capacity of the pump, and therefore its cavitation characteristic, is the value of $H$ or excessive suction head \cite{20}.

In figure 4 shows the results of the elimination of cavitation-abrasive wear of the working bodies of the pumps.

The obtained experimental data showed that the intensity of hydroabrasive and cavitation-abrasive wear of parts of the flow part of the pumps are directly dependent on the operating mode. Comparison of specific values of wear, per water supply unit $\Delta G/Q$, for different operating modes of the axial pump 05-35 show that the modes with supply $Q \geq Q_{opt}$ in the working area of the characteristic are also optimal from the point of view of minimum specific wear \cite{21}.

4. Conclusions
- The deterioration of individual elements of hydro mechanical equipment due to cavitation and abrasion leads to a deterioration in the operating mode of the pumps, a decrease in their efficiency and
significant losses. The reasons for the decrease in pressure during cavitation may be the incorrect location of the unit in relation to the water level of the downstream basin, associated with the peculiarities of their operation.

- The operating modes of the pumps with the minimum wear rate of their parts are established. Rational from the point of view of reducing the wear of axial pump parts are modes with a supply of \( Q \geq Q_{\text{opt}} \).
- The increase in volumetric efficiency, the improvement of the hydraulic conditions for supplying flow to the impeller of the pump, and the reduction of cavitation wear were achieved by the authors in the new pump design, which contains guide planes mounted on the throttle washer parallel to the axis of the suction pipe.

References

[1] O. Glovatskiy, T. Djavburiyev, Z. Urazmukhamedova, A. Gazaryan, and F. Akhmadov, “Interconnection of influent channel and pumping station units,” E3S Web Conf., 97.

[2] Shaazizov F, Badalov A, Ergashev A, and Shukurov D 2019 Studies of rational methods of water selection in water intake areas of hydroelectric power plants E3S Web of Conferences 97.

[3] A.I.Dzhurabekov, Sh.R. Rustamov, 2017 “The mechanism of cavitation and hydroabrasive wear of centrifugal pumps of irrigation pumping stations,” in Collection of scientific works, SIC ICWC of Central Asia, pp. 157–159.

[4] G. Beglov I.F., Glovatsky O.Y., 2001 “Analysis of fault diagnosis systems for pumping units,”, pp. 61–65.

[5] Fakhriddin Bekchanov, Rustam Ergashev, 2019 “Mathematical model of vibrating air pump unit,” 4015, pp. 4015.

[6] Nasyrova N.R., Rustamov Sh.R., 2015 “Reliability management of pumping stations to ensure operational safety,” in Problems of Water and Land Management, pp. 160–167.

[7] M. Mamajonov, D. R. Bazarov, B. R. Uralov, G. U. Djumabaeva, and N. Rahmatov, 2020 “The impact of hydro-wear parts of pumps for operational efficiency of the pumping station,” in Journal of Physics: Conference Series, 1425(1).

[8] Nasyrova N.R., O.Y. Glovatsky, 2018 “On the issue of reconstruction of irrigation systems with machine water-lifting,” Ways to Improv. Effic. Irrig. Agric., 1(69), pp. 58–64.

[9] Carter R., 2005 “Specific speed chart for centrifugal pumps,” Ind. Power, (3).

[10] O.Y.Glovatsky, Ergashev R.R., 2013 Improvement to usages and studies large pumping station.

[11] E. S. M. and P. S.Menon., 2010 “Working Guide to Pumps and Pumping Stations,” in Calculations and Simulations Book.

[12] E. Kan and Nazir Ikramov, “Effect of parallel connection of pumping units on operating costs of pumping station,” 2019, 05008, p. 5008.

[13] Q. Z. Liu, W. T. Su, X. Bin Li, and Y. N. Zhang, “Dynamic characteristics of load rejection process in a reversible pump-turbine,” Renew. Energy, 146, pp. 1922–1931.

[14] W. Yu-qin and D. Ze-wen, 2019 “Influence of blade number on flow-induced noise of centrifugal pump based on CFD/CA,” Vacuum, 172.

[15] R. Tao and Z. Wang, “Comparative modeling and analysis of the flow asymmetry in a centrifugal pump impeller at partial load,” Proc. Inst. Mech. Eng. Part A J. Power Energy, 234(2), pp. 237–247.

[16] C. Wang, Y. Zhang, H. Hou, and Z. Yuan, “Theory and application of two-dimension viscous hydraulic design of the ultra-low specific-speed centrifugal pump, 2020 ” Proc. Inst. Mech. Eng. Part A J. Power Energy, 234(1), pp. 58–71.

[17] J. M. C. Cubas, H. Stel, E. M. Ofuchi, M. A. Marcelino Neto, and R. E. M. Morales, 2019 “Visualization of two-phase gas-liquid flow in a radial centrifugal pump with a vaned diffuser,” J. Pet. Sci. Eng., 187.
[18] R. M. Perissinotto, W. Monte Verde, C. E. Perles, J. L. Biazussi, M. S. de Castro, and A. C. Bannwart, “Experimental analysis on the behavior of water drops dispersed in oil within a centrifugal pump impeller,” Exp. Therm. Fluid Sci., 112.

[19] I. N. M. and T. T.N., 2013 “Factors affecting the operational and energy mode of operation of pumping stations,” in Materials of the International scientific-practical conference “Problems of complex arrangement of techno-natural systems”, part 1 “Land reclamation, recultivation and protection of lands,”, 220, pp. 215–220.

[20] S. Zhang, S. Jiang, and X. Lin, “Static and dynamic characteristics of high-speed water-lubricated spiral-groove thrust bearing considering cavitating and centrifugal effects,” Tribol. Int., 145.

[21] V. Nenha, S. Khovansky, 2012 “Providing of the law of pumping station parameters’ regulation by means of throttling elements,” Proc. Eng., pp. 175–181.