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THE EFFECT OF HYDROABRASIVE WEAR OF CENTRIFUGAL AND AXIAL PUMPS UNITS ON OPERATION EFFICIENCY OF IRRIGATING PUMPING STATIONS

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Abstract

Cavitation occurrence in hydroabrasive flows which can lead to rather complex phenomena and complicate the understanding of the process essence is considered in the paper. To date, the wear of operating units in centrifugal and axial pumps, depending on the mode of their operation, has not been sufficiently studied and the methods to choose the operating modes considering the wear of their parts have not been developed. The paper presents the results of comprehensive laboratory and field studies on the wear rate of units in the flow part of centrifugal and axial pumps. An alternating pulsating load leads to an increase in the interaction force of the hydroabrasive flow with the chamber surface and by 10% increases its wear, reducing the pumping device productivity to 9%.

Key words: centrifugal and axial pumps, cavitation and hydroabrasive wear, sediment motion, flow, fluid, solid, technological processes, pumping units, pump parts, cavitation reserve.

The aim of the study. Operational experience of centrifugal and axial pumps has shown that their interrepair life does not exceed one irrigation season. One of the main reasons for the decrease in operational parameters of centrifugal pumps is an intensive wear of the blades and sealing gaps of the impeller in a hydroabrasive medium. As the operating practice shows, to date, the wear of working units of centrifugal and axial pumps, depending on the mode of their operation, has not been studied well, and the methods to choose the operating modes considering the wear of their units have not been developed. So, to reveal the causes of wear under various modes of pumping units operation is the aim of this paper.

Methods of research. Laboratory studies were carried out to identify the causes of wear of centrifugal and axial pumps units.

Main part. Before starting the operation of experimental pumps, the initial thickness measurements of the inlet and outlet edges of the blades and impeller disks were done at pre-determined points. The blade thickness was measured using a specially made indicator plug at five points along six sections. The diameters of the sealing ring and the impeller disk were measured in four places, along two mutually perpendicular diameters of the circle. The results of pump working parts micrometering showed that the impeller blades wear out non-uniformly both in size and in shape [1, 2, 3].

As seen from Fig.1,a, after 2680 hours of pump operation, the thickness of the impeller blades wear in the inlet part was negligible, 0.3-0.5 mm. In the outlet part, the thickness of the blades wear increased to 2.6-2.86 mm; this can be explained by an increase in kinetic energy of solid particles and their local concentration on the blade working surface due to an increase in centrifugal and Coriolis forces values along the impeller radius. In the zone of outlet edges on the blade working surfaces, the more deepened rows of furrows (up to 1.5 mm deep) were observed, which are the result of the shearing properties of solid abrasive particles in water.

No noticeable signs of wear were observed on the back surfaces of the blades. In pumps impellers of the "Turakurgan-1" and "Turakurgan-2" pumping stations (PS) the inlet edges of the blades took a sawtooth shape with deep smoothed indentations over the entire width.

a)
b)
c)

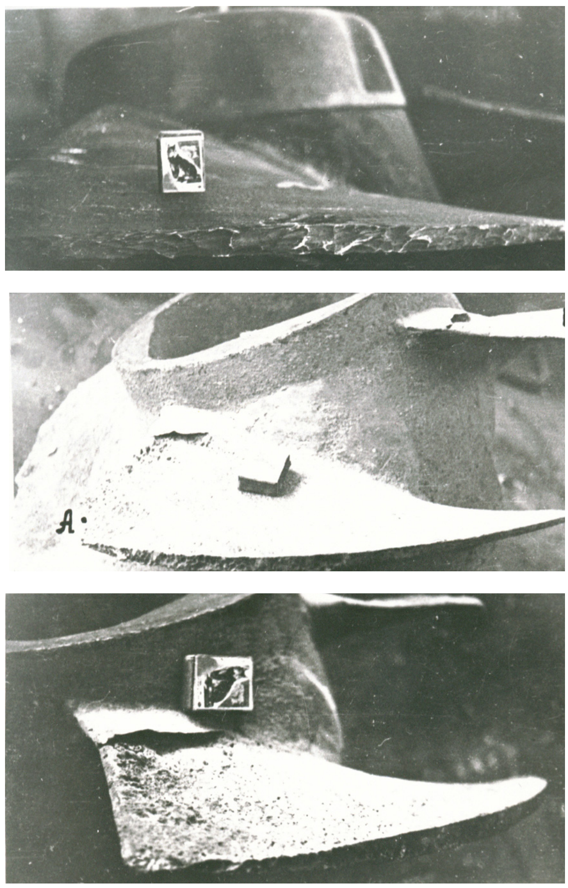

Fig. 1. **General view of wear of axial pumps impellers.**

Here: a) is the wear of the end edge of the OP10-185 pump blades after 7781 hours of operation; b) and c) show the wear of the back surface and end face of the 30PrV-60 pump blades after 5486 hours of operation.

This is explained by the fact that sometimes, in rainy weather, larger solid particles of bottom sediments enter supply pipelines; maybe this occurred at this station (Figs. 2,a and 2,b), [4, 5].

The inner surfaces of the impeller disks also wore unevenly both in radius and in channel width. The greatest wear of the disks inner surface occurred near the working surfaces of the blades at the outlet (2.17 mm). In a spiral discharge device, the maximum hydroabrasive wear was observed at the interface with the diffuser, i.e. in the "tongue" area and on its walls along the entire length, which had lamellar forms. An increase in the surface roughness of the discharge device as a result of wear leads to a decrease in the pump head due to an increase in the hydraulic resistance of its flow part. Protective bushings were exposed to significant wear at the locations of pressure seals. Although the wear of the protective bushings affects the pump characteristics to a lesser extent, it contributes to a large loss of metal mass and its replacement with new ones [6, 7]. A more significant impact on the centrifugal pumps performance has the gap between the seal ring and the outer rim of the impeller disk. As a result of wear, the surfaces of the impeller seal rings take an uneven wavy form of a lamellar shape. The greatest wear of the working surface of the seal ring occurs at the place of the flow rotation in its end part, which has a trench shape in radius.

Apparently, when the flow enters the narrow slit trench, the jet is compressed, which leads to an increase in local velocity and a decrease in pressure down to a critical value. This leads to the cavitation in the gap and increases the wear intensity in the end part of the seal ring surface. In addition, a vortex flow arises from the disk rotation, which is an additional source of wear intensification.

a)

b)

Fig. 2. Sedimentation in water receiving chamber of the "Turakurgan-1" (a) and the forechamber of the "Turakurgan-2" (b) pumping stations.

Figures 3,a and 3,b show the dynamics of impellers sealing gaps increase in the D6300-80 and 200D-90 centrifugal pumps.

The most intensive increase in gap from the effect of cavitation-abrasive slit flow occurs in the initial periods of operation. The maximum gap after 2000 hours of pump operation is 3.1 ... 3.3 mm [8, 9].

The tests of unit No. 3 of the "Dustlik" PS were carried out to find out the reasons for the decrease in water supply of the D6300-80 pump. As a result, it was stated that the change in head during the irrigation season was insignificant (3.5-4.2 m). The water supply of the pump, calculated by the average flow rate in the pipeline and measured using the Pitot tube, at the beginning of operation was 1.5 m^3/s, and at the end of the irrigation season it decreased to 1.42 m^3/s, i.e. by 80 l/s. This is a consequence of the increase in impeller sealing gaps, which is proved by calculations carried out according to the method described in [10, 11, 12].

Research results and discussion. Observations revealed that on the impeller blades of an axial pump of OP10-185 brand, cavitation-abrasive wear occurs mainly in four places: on the working surface, on the back surface, on the end edge and in the area between the end edge and the inlet. The wear of the impeller end part of the OP10-185 pump in the Kuyumazar PS made of X18N9TL stainless steel (Fig. 1,a) due to slit cavitation and sediment effect is characterized by the presence of a wavy surface. The surface of the end face of the 30PrV-

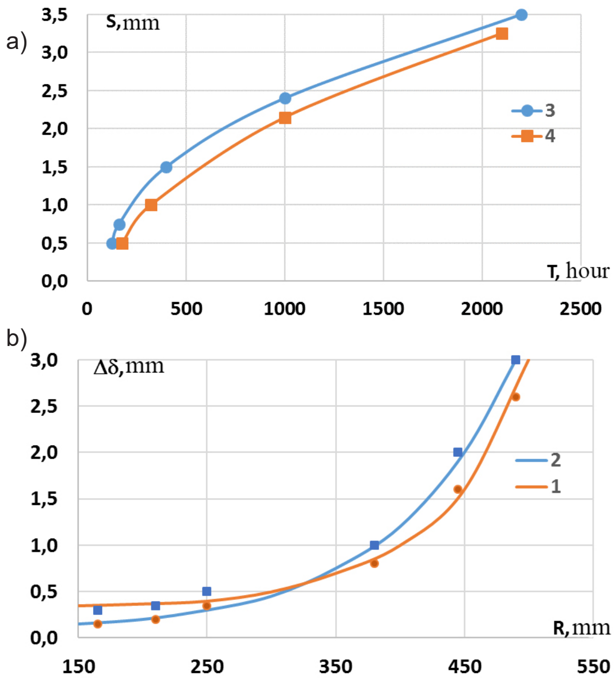

Fig. 3. Graphs of dependence (a) of blade wear thickness on the impeller radius; b) of the size of the sealing gap on the operation time of centrifugal pumps

Here: 1, 3 are for the D6300-80 pump of the "Dustlik" PS; 2 - for the D6300-80 pump of the "Mustakillik-1" PS; 4 - for the 200D-90 pump of the "Khozhabosmon" PS.

60 pump blade of the Dangarinsk PS (Fig. 1,c), made of ordinary steel St 25, has punctures, small ulcerations with indentations [13, 14, 15].

In the Dangarinsk PS the impeller blades of the 30PrV-60 pumps of the same type have different nature and wear zones depending on operating conditions. The inlet part of the blade adjacent to the end edge (zones A and B in Fig. 1, b) displayed the highest wear in the first pump, which was not observed in the second pump. Moreover, on the back surface of the blade in the second pump of a more friable, spongy structure than the first one, the cavitation destruction predominated.

By comparing the operating seasons of each of these units, it was found that the first pump worked longer in the spring-summer periods, when the water level and turbidity in the river is the greatest, and the second one operated at reduced water level and water source turbidity. This means that the first pump was subjected to more hydroabrasive wear, as for the second pump the cavitation destruction was predominant.

In axial pumps, the surfaces of the impeller chamber suffered the greatest wear. The graphs in Fig. 4a characterize an increase in the gap between the end face of the blade and the impeller chamber of the OP11-193 pumps of the Kuyumazar PS and OP5-110 pumps of the Alat PS (Bukhara region) depending on operation time. The gaps most intensively grow under cavitation-abrasive action of targeted suspended solid particles flow in the initial periods of operation. At an increase in the gap, the leading role is played by the pump heads: in the OP11-193 pump with a head of H = 17 m, the gap increases more intensively than in the OP5-110 pump with H = 8.5 m. Using the data given in Fig. 4a, an increase in the gap due to wear can be calculated depending on the pump head; it amounts to 1.5-1.2. At increase in the gap S, the volume efficiency and the pumping capacity are reduced. As calculations show, for one year of operation, the capacity of the OP5-110 pump decreases by 0.35 m³/s, and that of the OP11-193 pump - by 1.1 m³/s (Fig. 4, b).

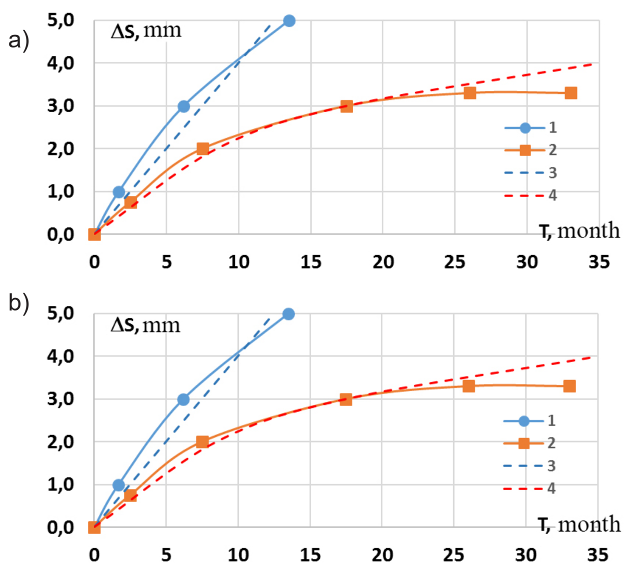

Fig. 4. The dynamics of an increase in the gap (a) and the amount of leak between the impeller and the chamber wall of the axial pumps (b).

Here: 1 - for the unit No. 5 of the "Kuyumazar" PS, 2 - for the unit No. 1 of the "Alat" PS, 3 - 4 - the calculated data.

The nature of destruction along the height of the OP5-110 pump chamber of the Alat PS shows the difference in the forces acting on the chamber walls (Figs. 5, a, b). The first zone is characterized by the presence of large deep shells and cavities penetrating deep into the metal.

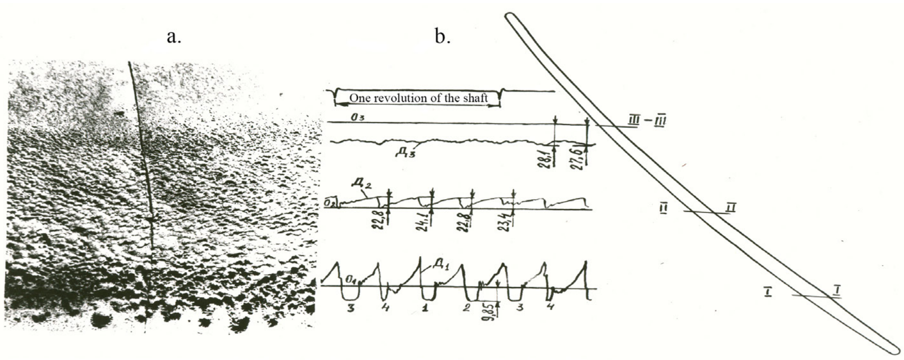

Fig. 5. The destruction of the chamber wall of the OP5-110 axial pump

This section is affected by the largest pulsating alternating load. In the second section, the surface of the wall is spongy. A variable pulsating load of a relatively lower magnitude acts in the upper zone of the chamber and on the surface of the chamber the point ulcerations appear, which relatively shallow penetrate into the metal [16].

The fixed blades of straightening apparatus of almost

Fig. 6. Damage to the straightening apparatus of the OP10-185 pump of Kuyumazar PS after 6100 hours of operation

all pumps are subjected to cavitation-abrasive wear in the inlet part of the outer section adjacent to the rim, where the flow separation and the vortex formation occurs (Fig. 6). The fracture zone has a width from 50 to 200 mm, the erosion depth varies up to through holes, which, for example, in the OP10-185 pump appear after 6100 hours of operation.

The nature and the dynamics of working parts wear of the PG-35MA axial pump were studied by observing the operation of two pumping units installed in the shirkat farm of the Dangarinsk district of the Fergana region. Fig. 7a shows the curves of changes in the wear thickness of the axial pump blades along the length and width after 1800 hours of operation [17, 18].

A change in the wear thickness of the impeller blades along its width shows that with an increase in impeller radius, the wear rate increases too (Fig. 7, b). The dependences obtained for the inlet and outlet edges, and for the middle part of the blade show that in all sections the pattern of wear has a curvilinear increasing character. The largest value of wear corresponds to the outlet edge, and the least – to the inlet edge of the blade [19, 20].

If to ignore the gravity force of a solid particle, which is relatively small in comparison with other forces, then a particle located in the inter-blade channel of the axial pump impeller is mainly subject: to hydrodynamic force in the direction along the axis; to centrifugal force in the direction of the radius, to the Coriolis force in the direction opposite to impeller rotation.

Based on the resultant force of these three forces,

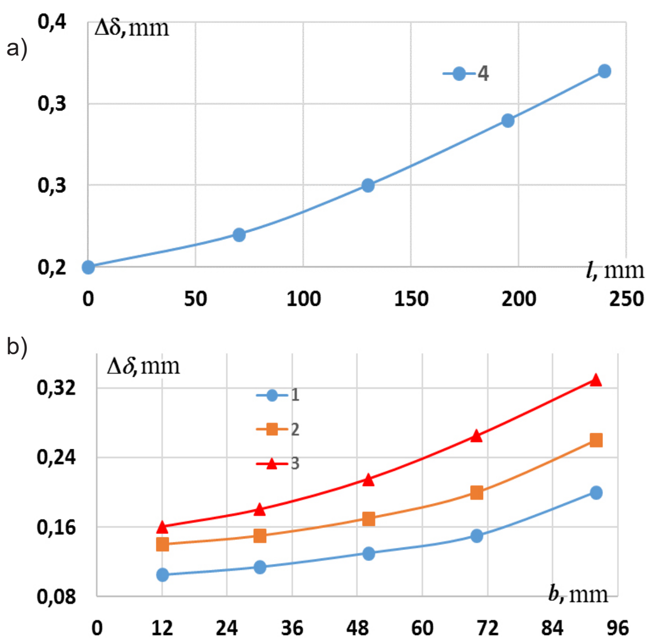

Fig. 7. Graphs of changes in the wear thickness of the impeller blades in the axial pump along its length (a) and width (b).

Here: 1 - for the inlet edge, 2 - for the outlet edge, 3 - for the middle part of the blade, 4 - for the peripheral part of the blade.

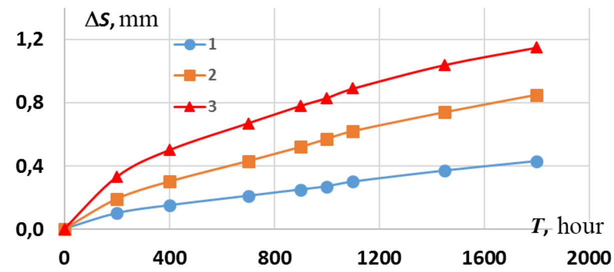

Fig. 8. The increase in the end gap of the impeller depending on the time of operation of the PG-35MA axial pump: 1 — increase in the gap, 2 and 3 —the thicknesses of the chamber wear and the end edge of the blade, respectively.

the magnitude of the force and the interaction angles of solid particles with the surfaces of the blade and the impeller chamber are determined. Based on the above considerations, it can be stated that the number of particles hitting the unit surface (the surface and end edge of the blade, the chamber wall) increases from the inlet to the outlet along the length of the inter-blade channel.

Fig. 8 shows the dynamics of the gap increase between the chamber and the impeller blades of axial pump after 1800 hours of operation. The graphs of the wear increase at the beginning of operation are curvilinear in pattern, and then change according to a rectilinear law. Apparently, this is a consequence of the fact that at the beginning of the irrigation season the pumped water has the highest sediment concentration.

Conclusions. The structure of cavitation-abrasive wear of the blade end edge indicates that for stainless steel with the highest resistance to cavitation, the abrasive particles play a predominant role, and for ordinary steel, cavitation destruction is ahead of hydro-abrasive one.

The wear intensification, characterized by the angle of inclination of the line to the abscissa axis, increases with an increase in blade length. This phenomenon is explained by an increase in local sediment concentration due to the Coriolis force and the kinetic energy of solid particles on the blade surface along its length, or when the hydroabrasive flow moves along the impeller blade length. At an increase in kinetic energy and Coriolis force acting on solid particles the peripheral speed, and accordingly, the centrifugal force along the impeller radius increase as well and the particles are separated along the width of the blade.

A more intensive wear of the chamber than of the end part of the impeller blades of axial pump is observed, though the flow rate of the hydroabrasive flow relative to the chamber is significantly lower than the one relative to the end part of the blade. This is due to the fact that an alternating pulsating load acts on the surface of the chamber due to the change of pressure on the blade surfaces. The frequency of change and the magnitude of the alternating pulsating load depend on the number of blades and the head created by the pump impeller, i.e. an alternating pulsating load leads to an increase in interaction force of hydroabrasive flow with the chamber surface and increases its wear by 1.1 times, reducing the productivity of the pump unit to 9%.

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