AIP Conference Proceedings

Improving the efficiency of irrigation pumps

Cite as: AIP Conference Proceedings **2612**, 020030 (2023); https://doi.org/10.1063/5.0113295
Published Online: 15 March 2023

O. Glovatskii, A. Dzhurabekov, U. Sadiev, et al.

View Online
Export Citation

AIP Publishing

© 2023 Author(s).

Improving the Efficiency of Irrigation Pumps

O. Glovatskii[1,3], A. Dzhurabekov[2], U. Sadiev[1], Sh. Rustamov[2], J. Rashidov[3, a)], and A. Saparov[1]

[1]*Research Institute of Irrigation and Water Problems, Tashkent, 100187, Uzbekistan*
[2]*JSC "SUVMASH", 13, Kh.Baykaro Street, district Bektemir, Tashkent, Uzbekistan*
[3]*Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, 100000, Tashkent Uzbekistan*

[a)]Corresponding author: jaloliddin5@mail.ru

Abstract. The article presents the main goals of the development of pumping stations based on the development of criteria and the allocation of priorities for increasing the efficiency of operation, which the authors formulate for the strategic, functional, morphological structure of the pumping system. The main criterion for research is the modernization of vane pumps, considering the operation of the main structures, their modes of operation and structures. The importance of internal flow in the flow path of the pump is emphasized with the use of new impellers, in which the blades rotate in three-dimensional space from axial to radial direction. If you combine a free vortex flow with a point source, you get a flow with a logarithmic spiral. The recommended design speed in the discharge nozzle of the pumps is -6 - 7 m / s, and to reduce losses, it is recommended to install a conical diffuser with a central angle of 10-12 ° at the discharge nozzle. Changing the hydraulic characteristics of the intake structure can be achieved: by improving the shape of its inlet part, for example, the bell of the front chamber, or by reducing the angle of the diffuser of the bell.

INTRODUCTION

The experience of operating pumping stations (PS) on machine channels shows that their operation has several significant shortcomings due to imperfect design solutions for the main elements of the stations. The safety and efficiency of operation of front chambers, water intakes, trash holding structures, suction pipes do not meet modern requirements [1, 2].

Currently, there is a need to consider the scientific and methodological side of the reliability problem to determine the tasks of energy efficiency, the main directions for the development of reliability management during the operation of pumps. At the same time, the processes of complete loss of working capacity acquire prevailing importance due to the possibility of optimal supply or removal of water, a sharp increase in cavitation and vibration phenomena that threaten the efficiency of operation of the units.

The main objects of research implementation are the PS of machine channels of Amu-Bukhara and Karshi with new pumps at the PS "Alat" of the Amu-Bukhara cascade.

The aim of the research is to determine the economic efficiency of large pumping stations based on the formulated criteria for accounting for mechanical and hydraulic processes. The reasons for failures and forced shutdown of pumps are considered as a result of pump operation in an unfavorable cavitation mode.

Fulfillment of the development goal of the PS - its reconstruction is carried out based on the development of criteria and the allocation of priorities for the short-term and long-term periods, which the authors formulate for the strategic, functional, morphological structure of the system. The main research criterion is the modernization of pumps taking into account the work of the main structures.

In the literature, there has recently been a shortage of works devoted to the use of new impellers based on three-dimensional impellers of vane pumps, in which the blades rotate in three-dimensional space from axial to radial direction. The authors are aware of only two experimental references reporting experimental work with 3D impellers. Jong-Woong Choi, Fischer K. and Thoma D. made a very valuable comparison of flows in 2D and 3D

The Third International Scientific Conference Construction Mechanics, Hydraulics and Water Resources Engineering (CONMECHYDRO 2021 AS)
AIP Conf. Proc. 2612, 020030-1–020030-10; https://doi.org/10.1063/5.0113295
Published by AIP Publishing. 978-0-7354-4337-2/$30.00

impellers. The flow near the outlet of the impeller was studied only because the twisting of the blades rendered the crossing probe system in the early part of the impeller useless [3,4].

MATERIALS AND METHODS

For a comprehensive assessment of the efficiency of irrigation pumps operation, the cases of pump failure due to mechanical impact when changing the hydraulic characteristics of the water intake structure are analyzed. Methods for determining the probability state of hydromechanical equipment of the irrigation system pumping stations based on the Kolmogorov-Chapman equations using dynamic matrix transitions are improved. The results of the conducted field studies and diagnostics showed the need for a connection between theoretical and experimental studies [1,4]. The authors used the main provisions of the theory of blade hydraulic machines and applied the concept of "theoretical pressure of a new working process". For vane pumps, the theoretical head has a very specific physical meaning: the amount of energy transferred from the impeller to a unit of weight of the flowing water.

The authors' studies have established the action of axial forces on the working bodies of the pumps. Suppose the coefficients are established empirically for a certain pump operating in a given mode. In that case, the derived equations can be used to determine the maximum permissible suction height or the minimum required to head for cavitation conditions.

RESULTS AND DISCUSSION

Operational measures according to modern requirements should be aimed at reducing the cost of pumped water, which is the main technical and economic indicator of the PS [5,6]. The problems of increasing the level of pump operation include saving, first of all, water and energy resources. Satisfying the robust growth of energy requirements is part of deploying an energy reduction technology strategy. The energy performance of this EPBD directive obliges EU members to set minimum energy performance standards.

The design and modernization of new hydraulic machines are based on theoretical and experimental research. The question of the location of the optimum head efficiency in a unit of any type cannot currently be investigated due to the small number of experimental materials for their testing. The maximum efficiency of work occurs at various pressure values [7,8].

In a modern natural, economic and economic conditions, when the cost of operating costs increases by tens and hundreds of times, their savings on pumping stations must first of all be carried out by reducing the cost of cleaning water supply structures from fin and sediments, optimizing operating conditions and pump characteristics. Water drops due to clogging of the grids increase the geodetic head of the pumps, and the cavitation-abrasive wear of the working bodies sharply reduces their parameters, especially the efficiency [9, 10].

The results of the conducted field studies and diagnostics showed that a wide range of level fluctuations and increased turbidity of water in the Amu Darya river, the variability of its channel, the presence of a large amount of debris complicate the water intake conditions of the head PS systems Amu-Zang, Jizzak, Amu-Bukhara and Karshi [11,12]. In general, the quality of pumped water is characterized by a set of n-parameters; concentration of suspended particles, floating bodies, chemical properties, density, temperature. [13,14].

Cases of failure of pumps due to the mechanical action of floating bodies are analyzed. As a result of the studies carried out at the PS, cases of penetration and clogging of the flow path by floating bodies and even breakage of the impellers were established. New technology and technical means of retaining fins and preventing them from entering the suction pipes have been proposed to prevent such cases.

As a result of the analysis of the operation of pumping units in the cavitation mode, it was found that they, firstly, arise due to a decrease in the water level in the front chamber and the water intake, and secondly, the accumulation of floating bodies in front of the gratings of the trash-holding structures and the backwater on them.

Obtaining universal characteristics of cavitation-abrasive wear is based on the analysis of the main operating modes and the state of the vane pump units.

Under any operating modes of the pumping station, lateral whirlpools are observed in the water supply structures - on both sides of the transit stream. In the presence of sediments in the water, the latter is deposited on the slopes and in the bottom part. In some cases, the volume of deposits can reach 40-50% of the volume (Figure 1).

FIGURE 1. Accumulation of driftwood and silting of slopes in the front chamber of the PS "Amu-Bukhara 1" Amu-Bukhara machine channel.

A new centrifugal pump with changed radii of flow entry into the impeller was introduced at the Alat PS of the Amu-Bukhara machine channel (Fig. 2). As a result, it is possible to protect the working parts of the flow path of the pump, a method for calculating the minimum wear and an increase in efficiency by 5% [15, 16].

FIGURE 2. Modernization of pumps on the Amu-Bukhara machine channel

During the operation of the PS, various emergency disturbances are possible on the main elements of the suction pipe, siphon water outlet with a vacuum breakdown valve on the siphon hood, which affects the stability of the impeller (Fig. 3). Restoration of normal operation is carried out in the following ways (for a synchronous motor of large PS): complete stop of the machine followed by normal operational start; resynchronization; automatic reclosing with self-starting and self-synchronization.

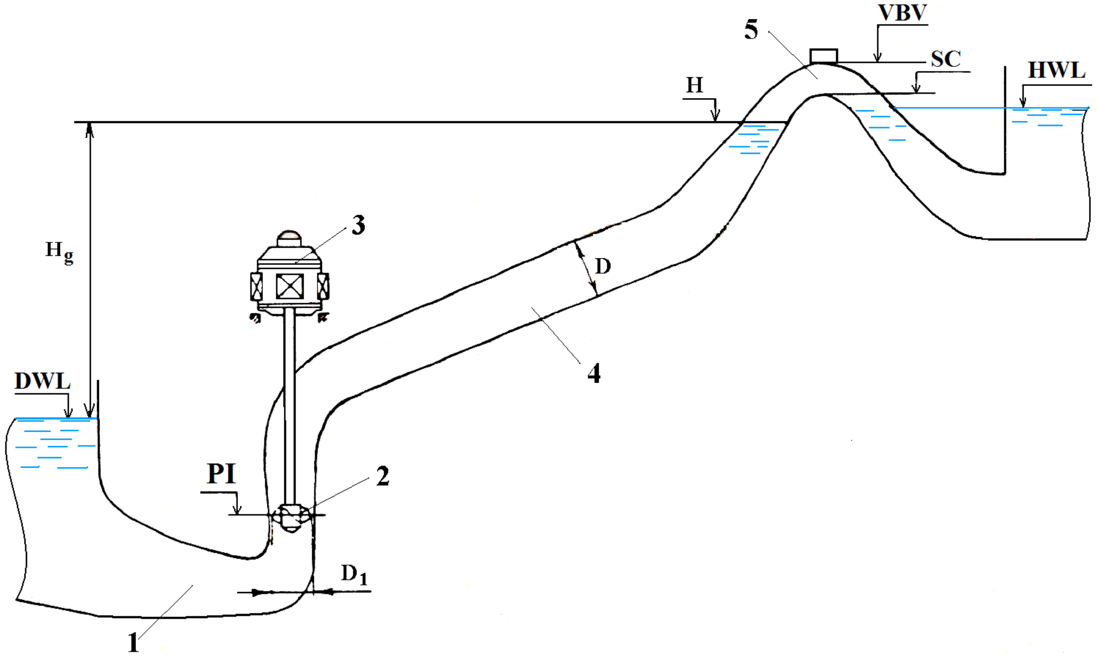


FIGURE 3. Pumping station diagram: 1 is suction pipe; 2 is pump; 3 is electric motor; 4 is pressure pipeline; 5 is siphon outlet; SC is siphon crest; VBV is vacuum break valve on the siphon hood; PI is pump impeller; WL is water level

The first method takes the longest. In the event of a short-term power outage, prerequisites are created for the implementation of the second and third methods, in which the total recovery time to the normal mode is much less and can be only a few seconds. This makes it possible to ensure the continuity of the technological process for water consumers to reduce their costs for unforeseen downtime. For water supply systems with increased requirements for operational reliability, the failure to consider the possibility of self-starting leads to an excessively strong dependence of the reliability of the operation of the entire facility on the reliability of one auxiliary link - water supply.

For each specified method, the output of the pump unit to normal operation is accompanied by hydraulic, mechanical and electromagnetic transient processes in the equipment and structures of the PS.

The hydraulic transient process in the case when the elasticity of the water of the walls of pressure water conduits is taken into account is described by the following equations [17, 18]:

$$\left.\begin{aligned} &\frac{\partial H}{\partial t}+\frac{c^2}{gf}\cdot\frac{\partial Q}{\partial x}=0; \\ &\frac{\partial H}{\partial x}+\frac{I}{gf}\cdot\frac{\partial Q}{\partial t}+\frac{\lambda}{2Df^2g}Q|Q|=0, \end{aligned}\right\} \tag{1}$$

where H is head in the section of the pipeline; x is distance along the axis of the pipeline from the origin to the given section; Q is cross-sectional flow rate; *f* is cross-sectional area of the pipeline; *D* is pipeline diameter; *c* is the propagation speed of the wave of water hammer along the pipeline.

In the presence of a short water-conducting path, the hydraulic transient process can be described by the equation of unsteady motion of an incompressible fluid in a rigid water conduit

$$H = H_g + h_M + h_L + h_i \tag{2}$$

where H is pump head;

H_g is geometric head

$$h_M + h_L = \frac{8Q|Q|}{\pi g}\left(\sum^{n} \frac{\xi}{D_i^4} - \sum^{n} \frac{\lambda_j I_j}{D_i^s}\right) \tag{3}$$

h_M, h_L is head loss, local and on length; ξ_j, λ_j are pressure loss coefficients are local and along the length of the j-th section; l_j and D_j are length and diameter of j - part of the water conduit; *n is* number of sections of the conduit filled with water;

Q is pump feed;

$$h_{in} = \frac{dQ}{dt} \cdot \frac{1}{g} \int_L \frac{dL}{f(L)} \tag{4}$$

h_{in} is inertial head; *L* is pipeline axis coordinate.

The process of filling or emptying a water conduit is described by the flow balance equation, in the case of a siphon outlet having the form:

$$Q = \frac{dV}{dt} + Q_W \tag{5}$$

where V is volume of the part of the pipeline filled with water; Q_W is the flow rate of water overflowing through the comb of the siphon, equal to: O at

WL $\leq$ SC, mb $\sqrt{2gh}^{3/2}$ with SC < WL <SP Q in other cases:

WL, SC and SP are marks, respectively, of the water level in the pipeline, the crest of the siphon and the pressure of the siphon; h is geometric head on the weir, numerically equal to the excess of the water horizon over the siphon ridge; *b* is the width of the overflowing layer of water; m-flow rate.

In this case, the values of H and V are related by the dependence:

$$H_r = f(V). \tag{6}$$

The mechanical transient equation is written as

$$2\pi J \frac{n}{dt} - M_{mot} - M_g - M_{abr}, \tag{7}$$

where M_{mot} is motor torque; M_g is hydraulic torque of the pump; n is rotation frequency;

$$M_{abr} = (0{,}01\ldots0{,}03)M_0,$$

M_{abr} is bearing friction moment; M_0 is rated torque.

To determine the hydraulic torque M_g, you can use the four-quadrant pump characteristic in the form of dependencies between the reduced flow $\overline{Q}$ rate $\overline{n}$ and the hydraulic torque $\overline{M}$:

$$\overline{n} = f(\overline{Q}.);\ \overline{M} = f(\overline{Q}.), \tag{8}$$

Where

$$\overline{Q} = \frac{Q}{D_1^2\sqrt{g|\mathrm{H}|}}; \qquad \overline{n} = \frac{nD_1}{\sqrt{g|\mathrm{H}|}}; \qquad \overline{\mathrm{M}} = \frac{\mathrm{M}_\tau}{\gamma|\mathrm{H}|D_1^2};$$

D_1 is pump impeller diameter; γ is specific gravity of water.

Before installing the paddle pump with respect to the water level, it is necessary to carefully determine its permissible elevation relative to the level in the lower basin (DWL). This elevation depends on the suction head h_s, which is calculated as follows:

$$h_в \; h_s \geq \frac{\rho_{atm}}{\gamma} - \Delta h_{allow} - h_{sl} - \frac{\rho_{V,P}}{\gamma} \tag{9}$$

where $\frac{\rho_{\alpha m}}{\gamma}$ is atmospheric pressure; Δh_{allow} is allowable suction head; h_{sl} is head loss in the suction line of the pumping unit; $\frac{\rho_{V,P}}{\gamma}$ is saturated vapor pressure of the pumped liquid.

The values H_{vac}^{add} Δh_{add} are found according to the characteristics of the pump, and the most unfavorable mode is taken.

Equation (9) shows that h_s depends on the losses in the suction line h_{sl}. In this regard, to increase the permissible height h_s and reduce the risk of cavitation, the losses in the suction line should always be reduced as much as possible. To do this, its length should be minimal, which will facilitate the start of the pump since it will reduce the volume of water to be filled in or air drawn off. It is better to reduce the supply speed and increase the diameter. Unnecessary bends in the suction line must be avoided in order not to create additional local losses. If a foot valve or trash screen is installed, then the determination h_{sl} should consider the hydraulic losses in the screen and in the valve itself.

Reliability of operation and ease of starting the pump largely depend on the quality of the suction piping. First of all, the suction pipeline must be completely sealed since during operation, a rather deep vacuum is created in it, and air will be sucked in through leaks (especially often in the joints and in the flanges), which not only causes a decrease in supply but can lead to vacuum breakdown, i.e. to a complete cessation of supply to the discharge pipeline. Air suction through the vortex funnels causes periodic changes in pressure in front of the impeller and increased wear [9, 19].

The shape and laying of the suction pipeline must be such that during filling, no "air bags" can be created for this, the confuser and the suction pipeline must be made taking into account that air remains in the upper part during filling and when the impeller starts to rotate and the vacuum rises, then this air cavity will expand, block all sections and make it impossible to start the pump. Such cases are quite common in practice, especially when the pump is temporarily installed.

In the absence of wear, the pressure pipeline influences the pump operation much less. The actual flow rate depends on the magnitude of the losses and, therefore, the diameter of the discharge line must be selected accordingly. Since the design speed in the discharge pipe of the pumps reaches 6 - 7 m / s, and in pressure pipelines it is usually 2–3 m/s, to reduce losses, it is recommended to install a conical diffuser with a central angle of 10-12° at the discharge pipe.

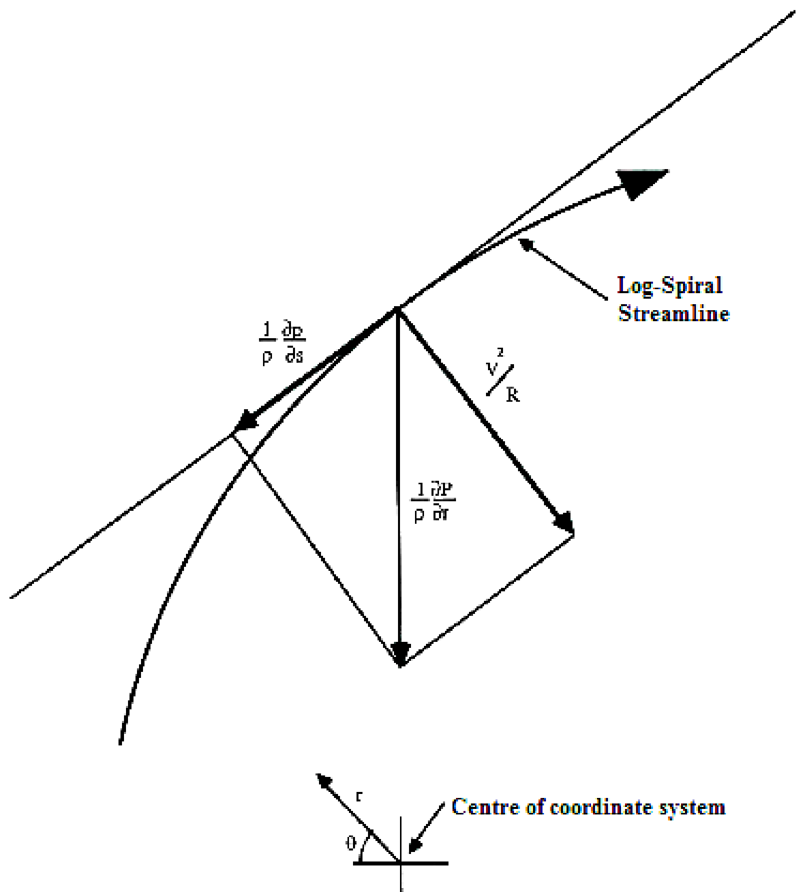
One of the main difficulties in designing vane pump impellers is defining the shape of the blades. This question of the shape of the blades is important in the body of knowledge about centrifugal compressors [20, 21]. The question of the shape of the scapula can be approached in different ways. The approach was dominated by simple concepts of smoothness, curvature, and changes. If the flow is exclusively in a plane perpendicular to the axis of rotation, the 3D approach is useful, and the impellers are also described as 3D. Some simple pumps use circular arc vanes that meet the requirements for smoothness and curvature.

However, they are only used for low power pumps, where efficiency is not an issue, so this article does not cover them. It is useful to consider the basic mechanisms of operation of three-dimensional impellers. If this is done for both radial bladed and forward swept impellers, their similarities and differences can be explored. Having understood these basic ideas, it is better to move on to 3D geometry and flow patterns as well. As an alternative to blades with an arc of a circle, as the basic shape of the blade, you can take a picture with a non-vortex incompressible fluid flow without losses.

If you combine a free vortex flow with a point source, you get a flow with a logarithmic spiral.

The log-spiral streamline is shown in Figure 4, and the coordinates (r, θ) for the resulting expression of the resulting streamlines are shown, where the subscript i refers to the impeller inlet.

$$\theta = \theta_i + \frac{1}{\tan_\beta} in\left[\frac{r}{r_1}\right] \quad (10)$$



V is velocity, R is radius of curvature, p is static oressure, ρ is density, r is radius, s is distance along streamline

FIGURE 4. Log-Spiral streamline with force vectors

This spiral shape is the basic shape adopted in almost all vane pump impellers. It looks like a streamlined shape that meets the requirements of smoothness and curvature well. The authors put forward various considerations about the basic properties of the lossless logarithmic spiral flow to support later arguments [16,22]. A flux with logarithmic streamlines in an absolute frame of reference is a flux with constant angular momentum. No pump torque is required to create the curvature of streamlines. There is a balance between the accelerations caused by the curvature of the streamline, its longitudinal diffusion, and the forces due to the radial pressure gradient (Fig. 4).

Log-spiral flow in radial geometry (r, θ) is equivalent to straight parallel flow in linear geometry (x, y). In the radial case, no force will be applied to the non-rotating blades of the spiral, and in the linear case, the stationary flat elements of the blade will also not experience loads. When a vane with a log spiral is used in the pump impeller, the relative streamlines have approximately this shape as well. Deviations arise from sliding effects associated with relative vortex and viscous effects.

Considering that the efficiency of a unit operating with variable load can be determined as a part of the maximum efficiency at full load, we present the approximate values of the multipliers in the formula compiled from the data of catalogs and reference books [6]: the efficiency of motors at full load is -0.84-0,96, non-compressor diesel engines -0.34-0.37, hydraulic turbines and pumps -0.85-0.95.

With a decrease in the cross-section of the water supply structure, the speed of water flow increases, and therefore the loss of pressure and electrical energy E_{los}. Their value on average per year will be kW / h / year:

$$E_{los} = 9.81 \int_{0}^{8760} Q \Delta h dt, \tag{11}$$

where Q is water consumption, m^3/s; Δh is pressure loss, m.

The calculation includes the cost of lost energy, sum/year:

$$L = c^{/} E_{los}, \tag{12}$$

where $c^{/}$ is specific estimated costs for the electricity being replaced, sum / kWh.

The economically most advantageous section of the water supply structure will be determined by the minimum amount of construction costs and the cost of lost energy. The criterion is: C + L = min.

Changes in the hydraulic characteristics of the intake structure can be achieved: either by improving the shape of its inlet part (for example, the bell of the front chamber, the outline in plan, the angle of rotation of the suction pipes, etc.) or by changing the dimensions of the intake structure (for example, by reducing the diffuser angle of the bell, placing between the socket and the water conduit of the additional transitional section), which will require additional capital investments.

Improving a water intake structure, leading to a decrease in hydraulic losses, requires additional investment, and the effectiveness of such an improvement should be justified by a technical and economic calculation [1,23].

For a comprehensive assessment of the efficiency of PS, the following are used: specific capital investments per 1 m^3 of annual water supply, per 1 m^3 / s of maximum water supply and the cost of 1 m^3 of water. This elementary calculation is used for two reasons: due to the lack of a tariff for some water consumers and significant difficulties in determining the net income.

The economic efficiency of the PS operation should be determined by the indicators of the overall (absolute) economic efficiency. The simplest method can be considered to determine economic efficiency by the rate of return on capital investments. In this case, one should adhere to the principle of determining the effectiveness of the final result. So, the efficiency of the PS for irrigation should have been determined by the income received from the increase in the yield of agricultural crops.

However, there are great difficulties in objectively determining the increase in the yield obtained through irrigation. To one degree or another, this method can be applied to determine the economic efficiency of PSs built or modernized at the expense of their resources of farms.

CONCLUSIONS

1. The forecast and construction of a comprehensive program for the development of the irrigation system, including the diagnosis of the existing system, the selection of reconstruction options, the effectiveness of the planned measures, is based on the analysis of the reasons for the failure of the main pumping equipment. The reasons for failures and forced shutdowns, which are manifested as a result of the operation of pumps in an unfavorable cavitation mode, have been established. Based on the obtained universal characteristics of cavitation-abrasive wear, it is possible to estimate the suction height h_s, the permissible cavitation margin, depending on the

operating mode for the vane pump. To increase the permissible height h_s and reduce the risk of cavitation, the losses in the suction pipe must always be reduced. Regulation within the recommended zone, determined by the cavitation headroom, does not lead to cavitation.

2. Criteria are formulated for assessing the success of the self-starting of the pump unit when it is turned on again after a short power interruption. Carrying out numerical experiments on the combined model of a hydraulic transient process with a four-square pump characteristic proposed in the article, it is possible to correctly assign the operating mode of a modern automation system for this equipment.

3. To assess the reliability of structures and equipment of pumping stations of an irrigation system, it is required to study them as interconnected systems. One of the main difficulties in the design of vane pump impellers is defining the shape of the blades. On the question of the shape of the blades, the article is dominated by simple concepts of smoothness, curvature and their changes. If the flow is exclusively in a plane perpendicular to the axis of rotation, the 3D approach is useful, and the impellers are also described as 3D.

REFERENCES

1. O.R. Azizov, O.Ya. Glovatskiy, R.R. Ergashev *Some problems of assessing and improving the technical condition of pumps in the water management and reclamation complex* Scientific and practical journal "Ways to improve the efficiency of irrigated agriculture" - Novocherkassk, **2**(74), Pp.32-38, (2019)
2. S. Khidirov, R. Oymatov, B. Norkulov, F. Musulmanov, I. Rayimova and I. Raimova, "Exploration of the hydraulic structure of the water supply facilities operation mode and flow" *in E3S Web of Conferences* **264**, (2021), doi:10.1051/e3sconf/202126403024
3. O. Rakhimov, S. Eshev, M. Rakhmatov, I. Saidov, F. Boymurodov and I. Rayimova, "Improved pump for transporting liquid feed mixtures through pipes on farms", *in E3S Web of Conferences* **263**, 04046 (2021), doi.org/10.1051/e3sconf/202126304046
4. S. Eshev, I. Gaimnazarov, S. Latipov, N. Mamatov, F. Sobirov and I. Rayimova, "The beginning of the movement of bottom sediments in an unsteady flow" *in E3S Web of Conferences* **263**, 02042, (2021), doi.org/10.1051/e3sconf/202126302042
5. K. Fischer and D.Thoma *Investigation of the Flow Conditions in a Centrifugal Pump*. Trans. ASME HYD **54(**8) (2011)
6. Jong-Woong Choi, Young-Do Choi, Chang-Goo Kim, Young-Ho Lee *Flow uniformity in a multi-intake pump sump model* Journal of Mechanical Science and Technology **24**(7) Pp.1389–1400, (2010)
7. A.Demeulenaere, A.Purwanto, A.Ligout *Design and optimization of an industrial pump: Application of genetic algorithm and neural network* Proceedings of ASME Fluid Engineering Summer Conference. Houston (USA). Pp.1519-1527, (2005)
8. A.F. Barton, H.Mala-Jetmarova *An Algorithm for Minimization of Pumping Costs in Water Distribution Systems using a Novel Approach to Pump Scheduling* Mathematical and Computer Modeling, L., pp-79-86, (2017)
9. O. Glovatsky, R., N. Nasirova, B. Kholbutaev and Kh. Khusanbayeva *Estimation of the forecast of pump ready rate for reclamation systems* (IPICSE 2020) *IOP Conf. Series: Materials Science and Engineering* ***1030*** (2021) 012115IOP Publishingdoi:10.1088/1757-899X/1030/1/0121151
10. R.Ergashev, O.Azizov, N.Dehkanova, A.Bozorov *Development of energy-saving modes of irrigation pump stations* IOP Conference Series: Materials Science and Engineering, **883**(1), 012017, (2020)
11. O. Glovatsky, R. Ergashev, A. Saparov, M. Berdiev and B. Shodiev *Cavitation-abrasive wear working collectors of pumps* (FORM-2020) *IOP Conference Series: Materials Science and Engineering* **869** 042006.
12. N.Nasyrova, A.Gazaryan, Zh.Rashidov *Hydraulic balancing and restoration of impellers and bearings of vane pumps* Modern problems in agriculture and water management, pp.535-539, **2,** Tashkent, (2021)
13. D. Bazarov, B. Norkulov, O. Vokhidov, F. Artikbekova, B. Shodiev and I. Raimova, "Regulation of the flow in the area of the damless water intake" *in E3S Web of Conferences* **263**, 02036 (2021), doi.org/10.1051/e3sconf/202126302036
14. D. Bazarov, I. Markova, S. Khidirov, O. Vokhidov, F. Uljaev and I. Raimova, "Coastal and deep deformations of the riverbed in the area of a damless water intake", *in E3S Web of Conferences* **263**, 02031 (2021),
15. B. Obidov, O. Vokhidov, J. Suyunov, K. Nishanbaev, I. Rayimova and A. Abdukhalilov, "Experimental study of horizontal effects of flow on non-erosion absorbers in the presence of cavitation", *in E3S Web of Conferences* **264**, 03051 (2021), doi:10.1051/e3sconf/202126403051

16. B. Norkulov, G. Safarov, J. Kosimov, B. Shodiev, A. Shomurodov and S. Nazarova, “Reduce the intensity of siltation of bulk reservoirs for irrigation and hydropower purposes”, *in E3S Web of Conferences* **264**, 03052, (2021), doi.org/10.1051/e3sconf/202126403052
17. D. Bazarov, B. Norkulov, O. Vokhidov, F. Artikbekova, B. Shodiev and I. Raimova, “Regulation of the flow in the area of the damless water intake” *in E3S Web of Conferences* **263**, 02036 (2021), doi.org/10.1051/e3sconf/202126302036
18. D. Bazarov, I. Markova, S. Khidirov, O. Vokhidov, F. Uljaev and I. Raimova, “Coastal and deep deformations of the riverbed in the area of a damless water intake”, *in E3S Web of Conferences* **263**, 02031 (2021),
19. B. Obidov, O. Vokhidov, J. Suyunov, K. Nishanbaev, I. Rayimova and A. Abdukhalilov, “Experimental study of horizontal effects of flow on non-erosion absorbers in the presence of cavitation”, *in E3S Web of Conferences* **264**, 03051 (2021), doi:10.1051/e3sconf/202126403051
20. B. Norkulov, G. Safarov, J. Kosimov, B. Shodiev, A. Shomurodov and S. Nazarova, “Reduce the intensity of siltation of bulk reservoirs for irrigation and hydropower purposes”, *in E3S Web of Conferences* **264**, 03052, (2021), doi.org/10.1051/e3sconf/202126403052
21. R.Ergashev and others Technology of water supply to water inlets of pumping stations *IOP Conference Series: Materials Science and Engineering*, **1030**(1), 012156, (2021)
22. R.Ergashev, F.Bekchanov, Sh.Akmalov, B.Shodiev, B.Kholbutaev New methods for geoinformation systems of tests and analysis of causes of failure elements of pumping stations *IOP Conference Series: Materials Science and Engineering*, **883**(1), 012015, (2020)
23. D. Bazarov, S. Umarov, R. Oymatov, F. Uljaev, K. Rayimov and I. Raimova, “Hydraulic parameters in the area of the main dam intake structure of the river” *in E3S Web of Conferences* **264**, 03002 (2021), doi:10.1051/e3sconf/202126403002
24. E.Kan, M.Mukhammadiev, N.Ikramov, Methods of regulating the work of units at irrigation pumping stations *IOP Conference Series: Materials Science and Engineering*, **869,** 042009 (2020)
25. A.B.Nasrulin, S.R.Zhuraev, F.S.Saidov Study of the influence of hydrological and hydraulic parameters on the operating mode of pumping stations, Republican collection of scientific papers, pp.302-306, Tashkent (2018)
26. D. Bazarov, B. Norkulov, O. Vokhidov, F. Jamalov, A. Kurbanov and I. Rayimova, “Bank destruction in the middle section of the Amudarya River” *in E3S Web of Conferences* **274**, p. 03006 (2021), doi.org/10.1051/e3sconf/202127403006
27. O.N. Pomerantsev, E.E. Nazarkin *Regulation of the centrifugal pump by supplying air to the suction pipeline* Environmental Engineering WITH, **4**, pp.15-19, (2017)
28. I.Borshev, E.Ivanov, A.A.Zharkovskii, A.Donskoy and A.Klyuyev *Assessment of acoustic and pulsation characteristics of centrifugal pumps* (2019) E3S Web of Conferences, **91**, article № 07006 DOI:10.1051/e3sconf/20199107006.
29. N.Zhurkin and A.Donskoj *Numeric modeling and estimating the performance characteristics of a pneumatic driven high pressure pump* (2018) MATEC Web of Conferences, **245**, 09014, DOI:10.1051/matecconf/201824509014
30. D.G.Svoboda, E.A.Ivanov, A.A.Zharkovskii *Influence of the Geometric Parameters of the Impeller of a Free-Vortex Pump on the Energy and Cavitation Characteristics of the Pump Chemical and Petroleum Engineering*, Springer US, **54**, (2019) DOI: 10.1007/s10556-019-00532.
31. U. Umurzakov, B. Obidov, O. Vokhidov, F. Musulmanov, B. Ashirov and J. Suyunov, “Force effects of the flow on energy absorbers in the presence of cavitation” *in E3S Web of Conferences* **264**, 03076 (2021), doi:10.1051/e3sconf/202126403076
32. S. Latipov, J. Sagdiyev, S. Eshev, I. Kholmamatov and I. Rayimova, “Acceptable water flow rate in sandy channels” in E3S Web of Conferences **274**, 03002, (2021), doi.org/10.1051/e3sconf/202127403002