Development of Energy-Saving Modes of Irrigation Pump Stations

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Abstract. The article substantiates the need to develop energy-saving modes of large irrigation pumping stations and pumping units. The Object studies are centrifugal pumps residing in usages on the pumping station of the Republic. In the process of performing, the studies were used main positions theoretical mechanical engineers, hydraulics, theories blade pump, processing result field and laboratory experiment, graphic and analytical methods. The Purpose thesis work is increasing to efficiency to usages centrifugal pump irrigation systems by development scientifically-motivated ways of the discovery rational state of working and complex action on increasing of the working factors them, on the base of the use theoretical bases motivations factor, influencing upon the intensity of wear-out details pump and improvements of the hydraulic processes in running part pump unit. The new features of the pump is designed on the base of the methods calculation corner of the entry and output of working water travel about changed designs of the pump. The substantiation of technological, environmental factors is given. Considering that are pumping units are energy-consuming objects, recommendations are given on upgrading the flow part of the pumps.

1. Introduction
In the Republic of Uzbekistan, more than 1600 pumping stations (PS) and 5000 units are in operation. This emphasizes the importance of work aimed at developing methods for assessing the mutual influence of climate and optimizing the energy-saving modes of the PS [1–5].

Annually up to 8 billion kW/h, not including diesel fuel is spent on the PS of irrigation systems. A decrease in power consumption at the PS approximately up to 10-15% is possible, mainly due to the management of energy conservation of machine water-lift systems. In connection with the sharp rise in price and the growing deficit of energy resources, the problem of reducing their consumption by large PS comes to the fore. The lack of priority work on this issue makes it impossible to optimize the PS modes at the current level of operation [6–12].

2. Methods
In process of the performing, the studies were used main positions theoretical mechanical engineers, hydraulics, theories blade pump, processing result field and laboratory experiment, graphic and analytical methods, introduction in the practical person of the usages, and designing result studies designed new design of the centrifugal pump.

3. Results and Discussion
At present not have completely settled the problems of the determination constructive parameter centrifugal pump of the irrigation systems and questions of the development of the mode of their work.

The main reasons for this are:

- the high content of abrasive particles and fin in the pumped water, severe climatic conditions associated with high temperatures of water and air;
- significant dimensions and speeds of the water flow in the elements of the flow path, large water supplies and complex transients associated with their operation;
- design flaws of hydraulic machines and hydraulic structures, including inefficient technical water supply systems;
- an imperfect level of operation of pumping units (PU) and facilities, scientifically based methodological, regulatory and other technical documents on the management of the water-lifting workflow and environmental conditions of equipment operation.

The need for energy-saving PU is usually justified by technological and economic factors. Currently, the environmental aspects of the problem are being identified. Large PU are very energy-intensive facilities. They annually consume about 20% of the generated electricity, which for the Republics of the Commonwealth of Independent States is about 300 billion kWh per year.

Electricity production harms the environment [13]. With an annual increase in electricity generation of 3-4%, the commissioning of new energy capacities as a result of energy-saving modes at the PS can be reduced by 1/3. As a result, the combustion of 1.8-2 million tons of standard fuel or 2-3 million tons of real coal will be prevented. Thus, a significant environmental effect will be obtained by reducing harmful emissions into the air and water. Also, these systems reduce the likelihood of water hammer, prevent the destruction of pipelines, and, as a result, spill water onto the surface of the earth and into water bodies.

The software developed at present at the Scientific Research Institute of Irrigation and Water Problems and Tashkent Institute of Irrigation and Mechanization allows calculating complex water supply systems in real-time using station devices on the PS control panels.

In the PS operation practice, 30–40% of the total number of parameters to be controlled are controlled, which undoubtedly worsens the environmental aspects of the operation of the units, since the PS operation mode changes following the water consumption schedule and due to other factors.

In technical terms, it is necessary:

- develop the scientific foundations of energy-saving modes, their regional features (especially in the context of reconstruction and renovation of large PS);
- establish reasonable volumes of the water supply of the PS, ensured by the technical condition of the equipment, taking into account the optimal level of environmental parameters;
- elimination of water overruns on the PS allowed during start-up periods and due to deviation of the actual modes from the design ones, the imperfection of the designs of the main elements of the water supply structures;
- to carry out work on the introduction of modernized PU equipment, resistant to cavitation when the temperature of water and air rises, combined floating devices providing a uniform flow of a hydraulically formed flow to the pump and protection against fin and suspended sediment;
- adjustment and integration of the observing network at the PS as part of the environmental monitoring of irrigation systems, taking into account world experience.

From an environmental point of view, most large PU, and especially diesel pumping units, according to experts, may pose a great danger in the near future, due to the progressive wear of sealing units and large leaks in the pumped water.

An important consequence of the use of systems during reconstruction is to increase the unit capacity of the adjustable PU, which gives additional energy savings and reduces the technological volume of the buildings of the PS by 15-20%.

The average kinetic energy of the flow behind the impeller at high costs is about 30-60% of all
available energy. The beneficial use of this energy depends on the quality of the PU.

For each pump, there is a certain minimum value of $H_{sv\min}$, which determines $H_{sv\max}$, the so-called critical value of the suction height

$$H_{sv\max} = \frac{P_0}{\gamma} - \frac{P_{up}}{\gamma} - H_{sv\min} - h_{oh,1}$$

(1)

Considering equations (1), we can conclude that due to an increase in water temperature, while maintaining all other operating conditions unchanged, the vapor pressure of water increases and cavitation occurs in the pump. If the pressure $\frac{P_0}{\gamma}$ is equal to the vapor pressure $\frac{P_{up}}{\gamma}$, equation (1) takes the form

$$H_{sv\max} = -H_{sv\min} - h_{oh,1}$$

(2)

This means that for cavitation-free pump operation, an inlet pressure ($-H_{sv\min} - h_{oh,1}$) is required. To prevent vaporization, additional overpressure is required in excess of this value.

In figure 1 shows the curves of the minimum backwater values for pumps pumping water in the regional conditions of the Republic of Uzbekistan [14–17]. The amount of backwater in these graphs is accepted with a certain safety factor. The last one (5) was taken in such a way as to compensate for the change in water temperature compared to the calculated value by 2%.

![Figure 1. Dependence of the necessary backwater on the supply and the number of revolutions of pumps with an impeller of unilateral suction for water at $t = 20^\circ$ C.](image)

- 1 – $n = 2950$, head more than 100 m, $n_s = 50 – 60$; 2 – $n = 2950$, head 35 – 100m, $n_s = 60 – 80$; 3 – $n = 2950$, head less than 35 at, $n_s = 80 – 120$; 4 – $n = 1450$, head 35-50m, $n_s = 60 – 80$; 5 – $n = 1450$, head less than 35 m, $n_s = 80 – 100$.

Typically, cavitation tests of centrifugal pumps are carried out in cold water. The change in the suction height when pumping warmer water or water that is different in its properties from water is made according to equation (1) following the value $\frac{P_{steam}}{\gamma}$ for a given temperature.

At the same time, the results of our experiments showed that the value of $H_{sv}$ included in equation (1) is determined primarily by the design features of this pump, and then depends on the temperature of the pumped water and its physical properties.
The experiments with a centrifugal pump consisted of taking cavitation characteristics with a gradual decrease in the value of $H_{sv}$ at constant pump flow and the temperature of the pumped water. Figure 2 shows several of the obtained dependencies. The decrease in $H_{sv}$ was due to a decrease in the level in the tank due to a decrease in the total volume of pumped water in the experimental setup system.

The value corresponding to the pressure drop due to cavitation by 3% of the initial value was considered as the minimum value of $H_{sv\text{min}}$. The experiments were carried out with water at a temperature of 10 to 21.5°C corresponding to the pump operating mode with the highest efficiency.

The authors created a number of fundamentally new technical solutions to improve the efficiency of pumps in regional climatic conditions. These solutions eliminate water losses in the flow part of the pumps.

The test results show deterioration in the cavitation characteristics of the pump with increasing water temperature.

The parametric test results are shown in figure 3.
To eliminate water losses a vertical pump containing housing with upper and lower seals connected by pipelines to a source of cooling and lubricating fluid. To increase the service life, in severe climatic conditions, a casing was made and attached to the pump and bearing housings [18].

Further work continues in the following areas: expansion and identification of the design scheme for the reconstruction of the water supply structures of the PS and PU unit with the introduction of new regulation tools and optimization of the operation of the elements of the PS; organization of a system for collecting and processing operational information; optimization of the treatment technology at the water supply facilities of the PS, taking into account the environmental benefits of saving water by reducing the accumulation of fuel and litter [19]. As a result of the development of a new design of a centrifugal pump, an increase in the efficiency of the pump (efficiency) by 5% was achieved [20, 21].

4. Conclusions

1. The Studies pumping station irrigation systems have shown that work in rational mode at usages of the centrifugal pump designed on the base of the new design, enabled to enlarge his reliability, increase lifetime and coefficient of efficiency, provision energy-saving.

2. The use of new constructions of the flow part of the pumps, which are resistant to cavitation when the temperature of the water and air increases, mating with the water supply structures of the PS, significantly improved the environmental conditions of their operation.

3. For the hydrotechnical unit of irrigation water pumps, the implementation of scientifically based methodological, regulatory, and other technical documents on the management of the pumping unit working process, energy-saving modes of water lifting in various conditions of equipment operation is being introduced.

4. A new pump with changed radii of the inlet of the flow into the impeller, blades at the entrance and exit of the impeller was introduced at the pumping stations as part of the Amu-Bukhara and Samarkand Charhin machine channels. As a result of the development of a new design of a centrifugal pump, an increase in the efficiency of the pump (efficiency) by 5% was achieved.
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