Development and Substantiation of Energy-Saving Methods for Controlling the Modes of Operation of Centrifugal Pumping Units in Complicated Operating Conditions

Javokhir Toshov[1], Azamat Makhmudov[2], Oybek Kurbonov[2], Golib Arzikulov[1,3] and Gulnoza Makhmudova[1]
[1]*Tashkent State Technical University named after Islam Karimov, University Str. 2, Tashkent, Uzbekistan*
[2]*Navoi State University of Mining and Technology, Tarobiy Str. 76V, Navoi, Uzbekistan*
[3]*University of Tashkent for Applied Sciences, Gavhar Str. 1, Tashkent, Uzbekistan*
javokhir.toshov@yandex.ru, azamat.maxmudov2015@yandex.ru, Oybek7001@mail.ru, miss.gulnoz@gmail.com

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Abstract: Rational and energy efficient operation of pumps for pumping and transporting liquids used in difficult conditions of mining is possible due to the implementation and use of modern methods of managing the operating modes of the pumps. Nowadays, the methods and resources used to regulate the operating modes of pumping units do not meet modern requirements, and many mines still use outdated methods of regulating the operating modes of pumps, which entails significant energy losses and an increase in the cost of the transported liquid. In the article, the methods of reducing electricity losses and the impact on the performance of pumping units were considered. It is concluded that this method of regulating work makes it possible to operate pumping units in the working area. Our article considers and experimentally substantiates the possibility of achieving savings in electrical energy, as well as increasing the reliability of the operation of pumping units based on the use of modern methods of regulating operating modes.

1 INTRODUCTION

Polymer One of the most effective ways to improve the performance and efficiency of pumps operating with a variable load and a sharp change in the content of the transported liquid, perhaps, is the use of adjustable electric drive. The performed studies of the results of the use of the adjustable electric drive showed that in some cases its installation leads to tangible energy savings, and in others it is insignificant, and thirdly, the installation of the drive does not provide economical operation. To study of the methods and forms of application of an adjustable drive indicates that in practice the technically simplest, but economically least effective ways of controlling pumping units, such as stabilizing the pressure at the pump outlet, are most often used. The degree of use of the energy saving potential, in this case, is no more than 16-26%, which leads to the fact that most of the potential, even after the installation of an adjustable drive, remains unclaimed. One of the main reasons for this situation is the insufficient knowledge of the influence of an adjustable electric drive on the operation of pumping units for pumping and transporting liquid [1].

However, the issues of choosing the optimal operating modes of pumps depending on the operating conditions have not been thoroughly studied. The study and determination of the optimal operating modes of pumping units under various operating conditions is an urgent scientific and practical problem, the solution of which leads to an increase in the reliability and efficiency of pumping units of industrial enterprises [2].

The aim of the research is to develop effective methods of energy saving in the operation of pumps based on the use of modern automation tools and optimization control methods.

The problem of the growing shortage of electricity can be solved most effectively on the basis of the development of energy saving systems and means. The reduction of energy costs is primarily achieved by increasing the efficiency of its use.

Pumping equipment of various technological cycles is one of the most significant consumers of electricity in industry [3].

The issues of energy saving during the operation of pumping units in complicated operating conditions is very relevant and requires increased attention from both designing and operating organizations.

2 METHODS

Operation of the pump in rational operating modes ensures its reliability, while operation in irrational modes is characterized by a decrease in efficiency [4].

In case of irrational operation, the following mechanical problems arise: failure of bearings, failure of mechanical seals, shaft failure and increased vibration [5].

The most common causes of equipment failure and the corresponding pump reliability curve depending on the location of the operating point are shown in Figure 1.

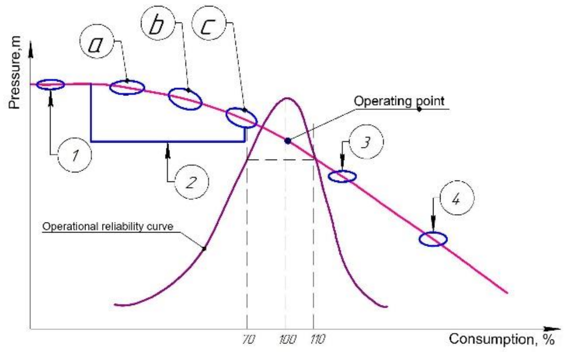

Figure 1: The reliability curve of the pump depending on the position of the working point: 1) a significant increase in temperature 2) a decrease in the service life of bearings and seals: a) due to vibration due to: possible cavitation, b) and c) the occurrence of flow recirculation at the inlet and outlet of the impeller, 3) a decrease in the service life of bearings and seals due to vibration caused by the separation of the flow in the flow part, 4) cavitation, overload of the electric motor.

Due to the occurrence of these problems, consumers often have a false opinion about the unreliability and inefficiency of pumps, while it is overlooked that the cause of the problems is incorrect operation in irrational modes. One of the main conditions for efficient and reliable operation of the pump is to find the operating point within its optimal operating range. The implementation of energy-saving measures determines the need to improve the performance of centrifugal pumps, which are the most common type of pumping equipment [6]. The basis for increasing the efficiency of centrifugal pumps is the improvement of operating conditions depending on the operating conditions, which significantly affect the efficiency of the centrifugal pump [7, 8].

In order to solve the problem associated with exceeded pump head and supply, it becomes necessary to change the operating parameters, which causes a change in the characteristics of the pump and system. The lack of regulation of pumping units significantly affects its efficiency. Since the volume of the transported liquid at enterprises is not constant and with small needs, part of the energy is lost [9, 10].

Choosing the optimal operating modes of a pump is a difficult task that determines the effectiveness of the main indicators of the installation as a whole, determining the optimal operating modes of a pump requires experimental research.

The issues of energy-saving modes and methods of effective control of pumping units have been considered by many authors who have studied the problems of optimization and improvement of operational parameters, while many dependencies affecting the operation of pumping units, such as changes in static and dynamic fluid levels, as well as external factors and fluid composition, have not been investigated [8-10].

To determine the main dependencies affecting the efficient operation of pumping units, we conducted experimental studies of the operating modes of the installation. The study of the performance characteristics of a centrifugal pump with various control methods was carried out on a laboratory installation SGU-SNS-012-6LR-PC, which contains a centrifugal pump, a pressure meter, a flow meter, controls and controllers. The general view of the laboratory installation SGU-SNS-012-6LR-PC, on which the experimental work was carried out, is shown in Figure 2.

During the experiments, the pressure-flow characteristics of the pump and the pumping station were measured, and the pressure and flow rate of the liquid were determined at various points in the system. During controlling the automation system of the stand with a PC, it is possible to implement a program-information action (PID) of regulation. For the toggle switch on the electronic control unit selects the automatic type of control, the control signal to the control device comes from the PC through the digital-to-analog conversion board (DAC).

To select the pressure and flow process variable PV to control the operation. It is possible to regulate according to the following variables: pressure in front of the consumer, flow H, total flow.

Once a process variable has been selected, the electronic control unit screens display its current value. Next, enter the set value SP, to which the value of the process variable should come as a result of automatic control. The current error value e=SP-PV is displayed on the screen.

The current error value e=SP-PV is displayed on the screen. As a result of regression studies of the results, a mathematical model of calculation was established, in which the output signal at the i-th control step is generated by the program according to the following dependence (1):

$$u_i = K_P \cdot e_i + K_E \cdot \frac{e_i - e_{i-1}}{\Delta t} + K_U \cdot \sum e_i \cdot \Delta t, \quad (1)$$

where: Δt -is the time step between the control points.

The minimum time step is 0.4 s, if you set a smaller value, the real time step will be equal to the specified one.

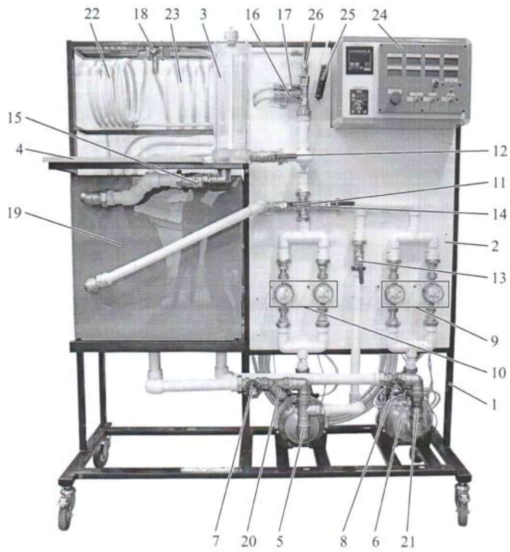

Figure 2: Laboratory stand SSU-CNS-012-6LR-PC: 1) frame, 2) mounting plate, 3) dimensional container, 4) shelf for PC (laptop), 5) centrifugal pump with frequency control, 6) centrifugal pump, 7), 8) valves, 9), 10) flow meters, 11), 12), 13), 14), 15) ball valves, 16), 17), 18), 26) taps, 19) tank, 20), 21) filters, 22), 23) pipelines, 24) electronic control unit, 25) stopwatch control knob.

This minimum step is determined by the time of input of information from the sensors through the analog-to-digital conversion board (ADC) in the PC. The step should be set in the text field of the screen. Factors of performance (KP), changes in engine power input (KE), changes in utilization (KU) should be set in the corresponding text fields of the zone on the screen. The range of the output signal and is 0-10 V. The dimension of the coefficients KP, KE, KU is determined by the choice of the process variable.

3 RESULTS AND DISCUSSION

During the experiments, the pressure and flow characteristics of the pump and pumping station were measured, the pressure and flow rate of the liquid at various points of the system were determined.

The results of the experimental studies made it possible to obtain the following results, which will lay the foundation for energy saving during the operation of pumping units in various conditions for the quality of the transported liquid.

Experimental work allowed us to obtain the following results:

- the dependence of the pump power consumption (W) on the pump supply when regulating the supply using a proportional valve;
- the dependence of the pump power consumption (W) on the pump supply when regulating the supply using a frequency converter;
- the dependence of the pump power consumption (W) on the pump supply when regulating the supply using a frequency converter and a PC.

Figure 3 shows the graphical dependence of the pump power consumption (W) on the pump supply (l/min) when regulating the supply using a proportional valve. On which it is observed that with an increase in the pump supply for every 14 l/min, the power consumption increases by 150 watts.

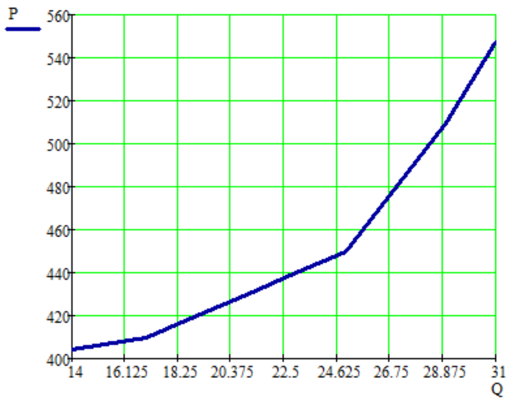

Figure 3: Graphical dependence of the pump power consumption (P, W) on the pump supply (Q, l/min) when regulating the supply using a proportional valve.

Figure 4 shows the graphical dependence of the pump power consumption (W) on the pump supply (l/min) when regulating the supply using a frequency converter.

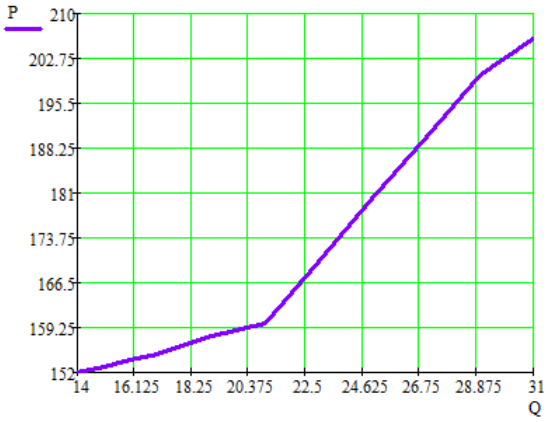

Figure 4: Graphical dependence of the pump power consumption (P, W) on the pump supply (Q, l/min) when regulating the supply using a frequency converter.

Figure 4 also shows an increase in power consumption, in this case, with an increase in the pump supply for every 14 l/min, there will be an increase in power consumption by 50 watts. Thus, the use of a frequency converter allows you to get the required supply, using only 60 watts of electrical energy.

The savings when using a frequency converter instead of a proportional gate valve is about 250 watts, for 14 l/ min, which is also presented in the form of a graph in Figure 5.

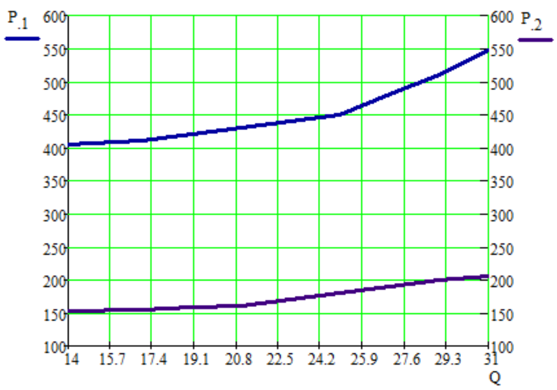

Figure 5: Graphical dependence of the pump power consumption (W) on the pump supply (Q, l/min) when regulating the supply using a proportional valve (P1, W) and a frequency converter (P2, W).

The most economic benefits of the operation of pumps can be obtained by using a frequency converter and PC when regulating operating modes. Figure 6 shows the graphical dependence of the pump power consumption (W) on the pump supply when regulating the supply using a frequency converter and a PC.

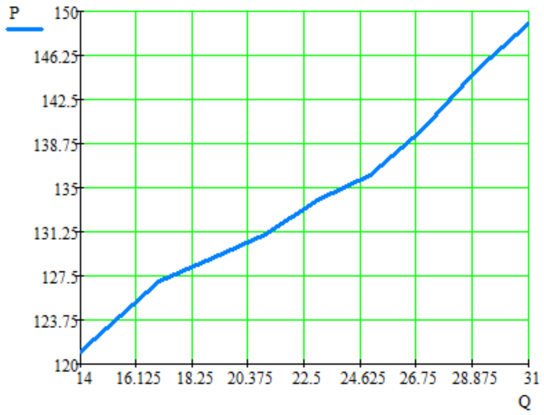

Figure 6: Graphical dependence of the pump power consumption (P, W) on the pump supply (Q, l/min) when regulating the supply using a frequency converter and a PC.

From Figure 6, it is observed that the use of a frequency converter and a PC to regulate the pump supply contributes to significant savings in electrical energy consumed by the pump drive, while the savings in electrical energy consumed for the same received supply is 110 watts.

The effectiveness of a particular method of regulation is determined by the characteristics of the system and its change over time. In each case, it is necessary to make a decision depending on the operating conditions and characteristics of the system. When choosing a method of regulation, it is very important not to fall under the influence of stereotypes that have developed recently. So, according to one of them, the use of a frequency converter helps to reduce energy consumption. However, frequency control does not always lead to a reduction in power consumption, and sometimes even has the opposite effect. The use of frequency control is advisable when pumps are operating in a system where friction losses prevail (friction losses in pipelines and shut-off valves [11].

CONCLUSIONS

The research carried out by us allowed us to obtain the following main conclusions, which in the future allow us to successfully choose the optimal methods for regulating the operating modes of centrifugal pumping units. Due to the difference in water inflow, an unregulated motor gives the pumping unit a change in operating mode, which contributes to an increase in the occurrence of accidents in the operation of pumping units. The proposed control method makes it possible to control pumping units with optimal engine performance. Contributes to the operation of pumping units in a reliable operating area, in which the occurrence of reasons for stopping pumps is less than at other points of operation.

In the course of the conducted research, it was found that the use of the proposed equipment allows to reduce energy costs by 67% during the operation of pumps.

In addition, it helps to increase the efficiency of pumps, reduces the likelihood of sudden failures, increases the safety of workers.

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