



## IMPROVEMENT OF ENERGY EFFICIENCY AND RELIABILITY OF CENTRIFUGAL PUMP EQUIPMENT ON THE BASIS OF DIGITAL CONTROL AND MANAGEMENT SYSTEMS

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**Abstract:** *The article addresses pressing issues related to improving the efficiency of centrifugal pump installations in industrial systems. Special attention was paid to the key operational parameters necessary for automating and intellectually controlling the operation of pump units, including the electric motor's rotation speed, pressure and power regulation, fluid consumption indicators, and the use of temperature, energy consumption, and equipment corrosion sensors. The role of modern monitoring and automated control systems in ensuring energy efficiency, reliability, and industrial safety of pumping systems has been substantiated.*

**Keywords:** *centrifugal pump, asynchronous motor, automation, monitoring, energy efficiency, control sensors.*

### **Introduction**

In the mining industry, pump equipment is an integral part of technological processes. Such processes as water extraction (drainage and drainage) in underground and open-pit mines, hydraulic transport, pulp transfer at processing plants, technological water supply, and supply of circulating water systems cannot be carried out without pumping units. Therefore, pumping stations have a direct impact on the reliability, safety, and production efficiency of mining enterprises.

Regular water extraction from underground deposits is necessary to maintain geotechnical stability and protect the working areas from flooding. In drainage



systems, multi-stage centrifugal pumps are typically used, as they can generate high pressure and operate continuously. At open-pit mines, high-performance pumping units are used for pumping out quarry water. In enrichment plants, pumps are an integral link in the technological chain for transporting pulp, reagent, and technical water. Centrifugal pump installations are widely used in the oil and gas, chemical, energy, metallurgical, mining, and municipal industries. They ensure the transportation, circulation, transfer, and accumulation of various liquid media - water, oil, chemical reagents, and technological solutions.

Pump equipment is one of the largest consumers of electricity in mining enterprises. In practice, pumping units can account for up to 20-40 percent of a company's total electricity consumption, and in some cases, this figure is even higher. Energy consumption depends on the following factors:

1. pump operating mode and load level;
2. Hydraulic resistance and the condition of pipelines;
3. technical condition of the unit (friction, wear, cavitation);
4. efficiency of the electric motor;
5. control method (dropping or frequency control).

In many cases, the pumps operate under conditions that do not correspond to the nominal operating mode. If there is a discrepancy between the pump characteristics of the operating point and the hydraulic system characteristics, excessive energy consumption occurs. The practice of reducing consumption through throttling reduces energy efficiency, as excess pressure is lost in the pipeline.

The high degree of involvement of pump units in technological processes makes them critical elements of production infrastructure. The reliability and stability of pump operation directly affect the enterprise's productivity, the quality of technological operations, and the level of industrial safety.

In modern conditions, improving the operating modes of pumping units is of particular importance, as their operational efficiency is determined by a combination of hydraulic, energy, mechanical, and operational factors. Unoptimal operating



modes lead to excessive energy consumption, accelerated wear of assemblies, and an increased likelihood of accidents.

## **Improvement of the operating modes of pumping units**

Optimizing the operating modes of centrifugal pumps requires comprehensive monitoring of key operating parameters. Effective operation is possible only if the relationship between productivity, energy consumption, and the technical condition of the equipment is systematically analyzed.

### **1. Electric motor rotation speed**

The rotational speed of the asynchronous electric motor is one of the determining factors of the centrifugal pump's performance. A change in rotational speed directly affects the fluid supply, the created pressure, and the power consumed [1-10].

With an increase in rotational speed, the pump's productivity increases, but at the same time, the energy consumption and the load on the mechanical elements increase significantly. Working at high speeds can lead to increased vibrations, accelerated wear of bearing assemblies and seals.

Modern frequency control systems allow adapting the engine's rotational speed to the current requirements of the technological process. This ensures the pump's operation within optimal load ranges, reduces starting currents, decreases mechanical stresses, and contributes to energy savings [11-22]. Thus, determining and maintaining the optimal rotational speed is the most important condition for energy-efficient and reliable operation of the pump unit.

### ***Pump pressure and power***

The stability of the pump system's operation largely depends on maintaining a balance between the operating pressure and the actual output. Changes in the network's hydraulic resistance, fluid level fluctuations, or variable technological loads lead to a shift in the pump's operating mode.

If the pump operates outside the optimal operating zone, additional hydraulic losses occur, the load on the electric motor increases, and energy consumption

increases. Prolonged operation under such conditions can lead to overheating, cavitation phenomena, and a decrease in equipment life [23-29].

Constant monitoring of pressure and power consumption allows for the timely detection of deviations from the nominal regime. Modern automatic control systems are capable of adjusting the pump's operating parameters in real time, ensuring the stability of the technological process and reducing operating costs.

### 3. Systematic monitoring and automated management

One of the main directions for improving the efficiency of pumping units is the implementation of automatic monitoring and control systems. Such systems ensure continuous monitoring of the unit's technical condition and analysis of operational indicators in real time [23-29].

The pump's hydraulic efficiency is determined by the ratio between the volume of pumped liquid and the energy consumed. Automated systems allow tracking this ratio, identifying trends in declining efficiency, and taking corrective measures.

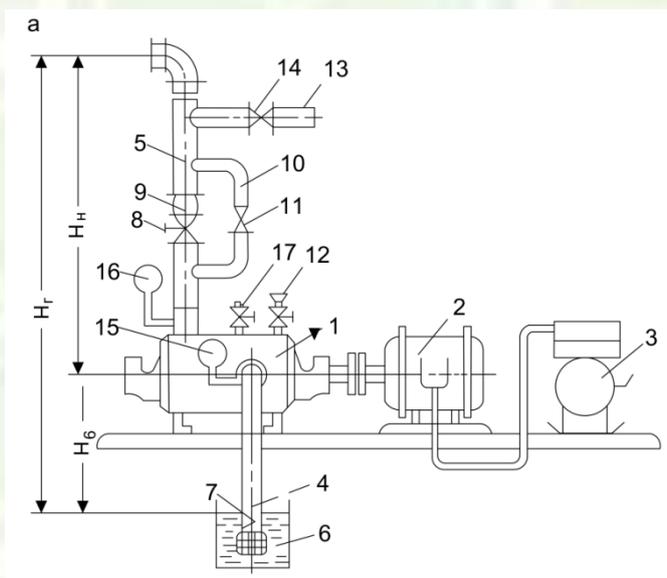


Fig.2. Principal diagram of a centrifugal pump unit.

1-Pump; 2-electric motor; 3- starting unit; 4-suction pipeline; 5- discharge pipeline; 6- reservoir; 7- protective mesh and check valve; 8, 11, 14 - gate valves; 9-reverse valve; 10-reserve pipeline; 12-filler; 13-

drainage pipe; 15-vacuum gauge; 16-manometer; 17- pump exhaust valve;  $H_6$ -suction pipeline;  $H_H$  - discharge pipeline;  $H_g$  - geodetic height.

Various types of sensors are used to implement intelligent control:



- Pressure sensors provide control of the system's input and output parameters, allowing for the detection of overloads and regime instability.
- Flow sensors record the volume of pumped liquid and help assess the actual pump capacity.
- Liquid level sensors are used to prevent "dry" operation and protect equipment from emergency modes.
- Temperature sensors monitor the heating of the housing, bearings, and electric motor. Temperature increase may indicate overload or wear of elements.
- Energy consumption sensors allow for the analysis of electrical parameters and assessment of the unit's energy efficiency.
- Corrosion and moisture sensors are used to monitor equipment conditions in aggressive environments and prevent premature destruction of structural elements.

The integration of these sensors into the automated control system ensures a comprehensive analysis of the pump unit's condition. This allows not only to maintain the optimal operating mode but also to implement elements of predictive diagnostics aimed at preventing failures. Modern requirements for energy efficiency and industrial safety necessitate the transition from periodic monitoring of pumping units to continuous systematic monitoring of their technical condition. Traditional maintenance methods based on regulatory inspections do not ensure the timely detection of hidden defects and do not allow for prompt response to changes in operating mode.

Systematic monitoring involves continuous collection, processing, and analysis of the operating parameters of the pumping unit in real time. Data comes from a complex of measuring devices and is transmitted to a centralized control system, where their visualization, archiving, and analytical processing are carried out.

The main element of automated control is the integration of the pump unit into a single digital environment of the enterprise. Within such an architecture,



programmable logic controllers (PLC), dispatch control systems (SCADA), and industrial data transmission modules are used.

This ensures:

1. centralized control of work parameters;
2. Automatic maintenance of specified modes;
3. formation of emergency signals;
4. registration and analysis of deviations;
5. remote control of equipment.

The implementation of closed control circuits is of particular importance. In such systems, the actual parameters (pressure, flow rate, temperature) are compared with the given values, after which a control influence on the actuators is formed - for example, a change in the rotational speed of the electric motor through a frequency converter. This allows maintaining the stability of the technological process even under changing loads.

An important direction in the development of automated systems is the introduction of elements of intelligent data analysis. The accumulated information about the pump's operating modes allows for the identification of patterns in parameter changes, forecasting possible failures, and determining trends in the deterioration of the technical condition. This approach corresponds to the concept of predictive maintenance, where repair measures are carried out not according to the schedule, but based on the actual state of the equipment.

Additionally, automated control systems contribute to:

1. reduction of the influence of the human factor;
2. minimization of the probability of emergencies;
3. increasing the overall reliability of the technological chain;
4. reduction of equipment downtime;
5. optimization of energy consumption in dynamic modes.

In conditions of aggressive or explosive environments, automated monitoring is of particular importance, as it allows for monitoring critical parameters without the



constant presence of service personnel. This significantly increases the level of industrial and environmental safety.

Thus, systematic monitoring and automated control are integral components of modern pump infrastructure. Their implementation ensures the transition from a reactive operating model to an intelligent model focused on optimization, stability, and long-term reliability of equipment.

## Conclusion

Increasing the efficiency of centrifugal pump installations is an important task of modern industry. Comprehensive monitoring of the electric motor's rotational speed, pressure, power, and flow rate, as well as the application of modern monitoring and automation systems, allows for a significant increase in the energy efficiency, reliability, and safety of equipment operation.

The implementation of intelligent control systems contributes to a reduction in operating costs, an increase in the service life of pumping units, and an increase in the overall stability of technological processes.

Thus, further development of methods for automated control and optimization of centrifugal pump operating modes is a promising area of scientific research and practical modernization of industrial systems.

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