Recommendations for improving the operation efficiency of electric pumping units of mine drainage installations

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Abstract. This paper presents recommendations for improving the efficiency of operation of electric pump units used in mine drainage plants of Russian underground kimberlite mines. The obtained research results may be useful to specialists involved in the design of mine drainage systems and the operation of electric pump units of mine drainage plants.

1. Introduction
Practice shows that electric pump units are one of the most important types of stationary machines used in underground mining of solid mineral deposits, since their sudden failure can lead to deterioration or even cessation of pumping of constantly arriving water inflow into the mine workings of an underground mine, which ultimately may result in partial or total flooding.

Thus, it can be seen that fundamental and applied scientific research in the field of improving the structural and operational reliability of mine electric pump units currently remains extremely popular.

It is worth noting that interest in these scientific studies has grown significantly after the August events of 2017 that occurred at the Mir underground kimberlite mine (Russian Federation, Republic of Sakha (Yakutia), Mirny).

As you know, the structural and operational reliability of any technological machine, including the electric pump unit, largely depends on the durability and reliability of the parts and assemblies included in it [1].

A thorough comprehensive analysis of publications on research topics [1-4] showed that in most cases, the results of these scientific studies were aimed at development or improvement of the operating conditions of the mechanical part of the electric pump unit, i.e. centrifugal pump, in most cases, sectional type (figure 1). In the long term, this type of centrifugal pump in underground mining of solid mineral deposits has no alternative among pumping equipment, since unlike other types of centrifugal pumps, sectional pumps are both high-performance and high-pressure vane machines, which makes it possible to limit them to a small number during drainage.

As the operating experience of electric pump units of mine drainage plants based on sectional pumps shows, their electrical part (usually an asynchronous squirrel-cage rotor motor) is to a lesser extent, but still at the risk of unplanned failures..

For example, the share of electric motors of pumping units based on sectional pumps of the NTSSK 180-700, TsNS 180-200 and TsNS 180-255 models used in the drainage systems of the Mir underground kimberlite mine accounted for 14% of the total number of breakdowns of these pumping units (figure 2).
Figure 1. Electric pumping unit of a mine sump installation based on a sectional pump

Figure 2. Distribution of failures of pumping units of drainage plants by components of the discharge pipe: 1 – node heel; 2 – pump bearings; 3 – electric motor; 4 – failures of other components.

Practice shows that when motor failures occur, pumping equipment completely loses its functionality. Thus, it is clear that failures of the electrical part of the pump unit entail more serious consequences than failures of the mechanical part.

Based on all the above material, we note that the development of recommendations to improve the efficiency of operation of electric pump units of mine drainage plants in terms of minimizing the occurrence of unplanned failures of their electric motors is certainly an urgent task for research.

2. Materials and methods

When studying the collected practical material on the operation of electric pump units of ten drainage plants of underground kimberlite mines of the Russian Federation, it was found that all the studied electric pump units have excessive pressure $\Delta H$, which, admitting a number of formal omissions, can be considered as the difference between the nominal pressure $H$ developed by them and the sum of the geodetic lifting heights $h$ and total pressure losses due to static and dynamic resistance in the pipeline network (1) [5].

$$\Delta H = H - h$$  

(1)
The publication [5] also notes that the excessive pressure of the electric pumping unit of a mine sump installation is dictated by extensive mechanical and corrosive wear of parts of the flow part of the sectional pump — impellers, impellers, and hydraulic heel assembly, which entail a decrease in its supply and pressure.

At the same time, in the author's publications [6, 7] it is noted that in the underground kimberlite mines of the Russian Federation the excessive pressure of electric pump units is explained not only by the high rate of metal wear, but also to a greater extent by the increased specific gravity of pumped mine water. The high specific gravity of mine water is due to the high content of soluble salts and insoluble solids in its composition.

According to the publication [6], the theoretical power of the electric pump unit when working on clean (2) and mine water (3) is equal to:

\[ P_w = Q_w H_w \gamma_w, \]  
\[ P_m = P_w \frac{\gamma_m}{\gamma_w}, \]

where \( P_w, Q_w, H_w, \gamma_w \) - theoretical power, theoretical supply, theoretical pressure of the electric pump unit when operating in clean water and the specific gravity of clean water; \( P_m, \gamma_m \) is the theoretical power of the electric pump unit when working on mine water and the specific gravity of mine water.

Combining these formulas in one (4), we note that in both cases of operation of the electric pump unit, the flow and pressure values are the same, only its power consumption changes.

\[ P_m = Q_w H_w \gamma_w \frac{\gamma_m}{\gamma_w} = Q_w H_w \gamma_m \]

In other words, when operating on mine water, the electric pump unit produces the same hydraulic parameters as when operating on clean, but with high power consumption, which in the future can lead to a failure of its electric motor due to operation in non-nominal mode.

Based on the foregoing material, we note that the use of electric pumps with excessive pressure in the conditions of operation of mine drainage plants minimizes the risk of unplanned failures of electric motors, as it eliminates their overload.

At the same time, excessive pressure of the electric pump unit can contribute to the activation of cavitation phenomena and increased energy costs [6].

3. The results of the study and their analysis

In connection with all the above material, for the optimal selection of the electric pump unit, depending on the physicomechanical and physico-chemical characteristics of the pumped mine water, it was proposed to use the following formula:

\[ Zk = \frac{H}{h} \]  

where \( Z \) is a coefficient that takes into account the aggressiveness and abrasiveness of the pumped mine water, \( (min = 1.05; max = 1.1) \); \( k \) - weighted average density of pumped mine water, t/m³.

Note that the above expression is advisable to use subject to the following requirements for electric pump units of mine drainage plants:

1. Electric pump units have negative suction;
2. Electric pump units are equipped with a variable frequency drive.

Practice shows that the servo-drive of a valve mounted on the suction line of a mine sump installation should be equipped with an electric motor capable of ensuring its unobstructed closure and opening with maximum back pressure. Usually the maximum backwater is 3-5 meters of water column.
As studies [7] show, the optimal acceleration and braking time of an electric pump unit is about 10 seconds. If possible, put into operation only 1 electric pump unit per pipeline stand. It is advisable to launch two or more electric pump units on a pipeline stand between 23:00 h and 07:00 h, as at this time the minimum (night) electricity tariff applies.

As applied to the pumping equipment of domestic underground kimberlite mines, the nominal head \( H \) must exceed the actual total head \( h \) 1.15 ... 1.4 times.

As can be seen (figure 3), for the majority of the studied sectional pumps of sump plants used in Russian underground kimberlite mines, nominal pressures are in the range required from the point of view of reliability of the power plant. However, among the sectional pumps investigated there is pumping equipment with an excessively excessive nominal pressure (pumping equipment of a number of Mir and Aikhal RCC drainage plants), which ultimately leads to unreasonably high financial costs for electricity, as well as the risk of activation of cavitation phenomena.

![Figure 3. The dependence of \( h \) on \( H/h \).](image)

4. Conclusion
As a result of scientific research, a formula was proposed that makes it possible to rationally select the electric pump unit of a mine drainage plant depending on the physicomехanical and physicochemical characteristics of the pumped mine water. The obtained research results may be useful to specialists involved in the design of mine drainage systems and the operation of electric pump units of mine drainage plants.

Acknowledgements
This work was carried out as part of the initiative research work of the M.K. Ammosov North-Eastern Federal University (NEFU) "Ensuring the Efficiency of Operation of Drainage Units in the North", No. 07-03 Г.216 dated September 15, 2014.

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