Mechanized complex of mine water purification from large mechanical impurities

N P Ovchinnikov
North-Eastern Federal University named after M.K. Ammosov, 58 Belinsky str., Yakutsk, 677000, Russia
E-mail: ovchinnlar1986@mail.ru

Abstract. It is well known that the main reason for the failure of sectional pumps in underground mines is the extensive hydroabrasive wear of their impellers. The rate of hydroabrasive wear of the impellers of sectional pumps largely depends on the size of solid particles contained in mine waters. Within the framework of this research work, in order to reduce the rate of hydroabrasive wear of parts of the flow path of sectional pumps of mine drainage installations, in particular impellers, a mechanized complex was developed and sufficiently substantiated for cleaning mine water from large solid particles. It is based on the use of a hydrocyclone and a high-frequency screen. Introduction of the developed technical solution in mine drainage systems will reduce the intensity of hydroabrasive wear of sectional pump impellers.

1. Introduction

The mining industry is the base of Russia's industrial potential, which largely determines the economic performance of other industries in the country. Currently, there is a positive trend in the development of deposits of solid minerals by the underground method.

Mine drainage is one of the most important auxiliary technological processes in the underground development of solid mineral deposits, since the volume of extraction and the quality of the mineral, as well as the safety of mining operations under the ground, depend on its efficiency.

Practice shows that the main reason of the failure of sectional pumps of the CNS type, which is a key element in the structure of a mine drainage system, is the extensive hydroabrasive wear of the pump impellers (figure 1) [1, 2].

Figure 1. Extensive waterjet wear of the section pump impeller.
It is well known that the greater the amount of mechanical impurities contained in the pumped liquid collides with the surface of the parts of the flow path, the faster they will fail. The results of theoretical studies [3] indicate that only a certain fraction \( \varepsilon \) of the pumped liquid is in contact with the impeller. Formula (1) shows that it depends on a number of factors:

\[
\varepsilon = 0.4 \cdot \sqrt{\frac{0.75}{1 + 0.35 \frac{\rho_1}{\Delta \rho} \frac{D}{d}}}
\]

where \( \rho_1 \) is the density of mechanical impurities; \( \Delta \rho \) is the difference between the densities of mechanical impurities and water; \( D \) is the diameter of the impeller; \( d \) is the size of the solid particle.

Under ideal conditions, the intensity of hydroabrasive wear of the impeller of a sectional pump reaches its maximum value only if the speed of movement of all mechanical impurities contained in the pumped medium is higher than the speed of its liquid component, i.e. water.

In the process of pumping mine water, the following forces act on each individual solid particle \( m \) in its composition (figure 2) [4]:

\[
\overline{ma} = \vec{F}_t + \vec{F}_a + \vec{F}_k + \vec{F}_n + \vec{F}_c
\]

Taking into account the fact that the forces \( F_a \) and \( F_t \) balance each other, and the force \( F_k \) is sufficiently small compared to other forces acting on a solid particle, then expression (2) can be reduced to the following simplified form:

\[
\overline{ma} = \vec{F}_n + \vec{F}_c
\]

If the force \( F_c \) is large enough, then the solid particle is carried away by the water along a given trajectory without coming into contact with the impeller surface. According to expression (4), the effect of the force \( F_c \) on a solid particle decreases with an increase in its size (diameter \( d \)) [3]:

\[
\frac{F_n}{F_c} = \frac{d}{D}
\]

Thus, it can be seen that the rate of hydroabrasive wear of parts of the flow path of sectional pumps, in particular impellers, largely depends on the size of mechanical impurities contained in the pumped mine waters.

In connection with all of the above, we state that at present, scientific research on the development and substantiation of technical solutions aimed at combating large inclusions contained in mine waters is highly relevant.
2. Materials and methods

To remove large mechanical impurities from mine waters in underground mines, a technical solution was proposed (figure 3), the principle of which is as follows. Submersible pump 1, installed in the niche of clarification tank 2, pumps out mine water and supplies it to hydrocyclone 3. The clarified mine water coming out of the drain pipe of hydrocyclone 3 is transported to drainage tank 4 and then is pumped out by sectional pumps to the mine surface. The thickened pulp leaving the sand packing of hydrocyclone 3 enters the mobile inclined belt conveyor 5, from where it is transported to the high-frequency screen 6, in which the sludge is dehydrated.

After dewatering the sludge on a screen, the liquid phase of the slurry moves by gravity into the catchment. The dewatered product 7 itself enters the sludge collector 8, from where it is then pumped out by a pneumatic pump 9 into the storage hopper.

Ultimately, the dewatered sludge is discharged from the storage hopper into a skip and transported to the day surface, where it is stored in dumps.

![Figure 3. Mechanized complex of mine water purification from mechanical impurities.](image)

For the effective implementation of the proposed technical solution at the existing underground mines in Russia, it is necessary to solve a number of the following scientific and practical problems:

- Select the necessary technological equipment;
- Determine the location of installation of technological equipment;
- Ensure the highest possible efficiency of the technological equipment;
- Calculate the minimum required working volume of the sludge collector.

3. Research results and their analysis

Since mine waters pumped out of underground mines are contaminated chemically active media, it is recommended to use Flygt submersible pumps as pumping equipment for the hydrocyclone. It should be noted that the submersible pumps of this company have already proven themselves well in the drainage systems of domestic underground kimberlite mines [5]. Due to seasonal fluctuations in the volume of atmospheric water entering the mine workings of underground mines, it is imperative to use several submersible pumps, each of which feeds a separate hydrocyclone.

It should be noted that the performance of submersible pumps directly depends on the total water inflow into the underground mine:
\[ Q_p = Q_w \] (5)

where \( Q_p \) and \( Q_w \) are the total hourly capacity of all operating submersible pumps and the maximum hourly water inflow into the mine.

Submersible pumps are installed in the niche of the clarification tank, since the mine water is almost static in it. The pumps must be necessarily equipped with automation devices that will be responsible for their automatic start and stop, depending on the filling of the clarification tank.

Practice shows that in mine waters pumped out of underground mines, small quantities of wood chips and rubber are found, which can lead to clogging of the impellers of sectional pumps (figure 4).

![Figure 4. Plugging the flow channels of the impeller of the first stage of a sectional pump model JSH-200 with chips, Udachny mine.](image)

In order to exclude the ingress of foreign objects into submersible pumps and hydrocyclones, the niche of the clarification tank must be fenced off with a mesh with a mesh size of 20 mm (the mesh size is selected based on the maximum size of foreign materials). It is recommended to clean the mesh 1 or 2 times a day from accumulated industrial debris.

Hydrocyclones are installed in the immediate vicinity of the sludge collector. Hydrocyclones must be lined with polyurethane. It should be noted that polyurethane has the following advantages in comparison with other lining materials (stone casting, steel, cast iron and rubber) [6]:

- Cheapness;
- High chemical resistance;
- High abrasion resistance;
- Low coefficient of adhesion.

For efficient operation of the proposed technical solution, the total hourly productivity of all operating hydrocyclones \( Q_g \) must be equal to the productivity \( Q_p \):

\[ Q_g = Q_p \] (6)

As previously noted, mine waters pumped out of domestic underground mines are characterized by systematic density fluctuations. Fluctuations in the density of mine water lead to variability of pressure in the supply line of the hydrocyclone \( P \) [6]:

\[ P = \rho \cdot g \cdot H \] (7)

where \( \rho \) is the density of mine water; \( H \) is the head of the submersible pump.

It is known that pressure surges \( P \) affect the content of the solid product in sands [6]. In this regard, for effective clarification of mine water in a hydrocyclone, the operating pressure \( P \) (usually 0.1 ... 0.13 MPa) must be maintained at the same level throughout the entire period of its operation. For this, the
supply and discharge lines of the hydrocyclone must be equipped with shut-off and adjustable equipment.

The required hourly productivity of the inclined conveyor $Q_k$ and the high-frequency screen $Q_{gr}$ is calculated as follows:

$$Q_k = Q_{gr} = n \cdot Q_q$$  \hspace{1cm} (8)

where $n$ is the maximum number of simultaneously operating hydrocyclones; $Q_q$ - hourly performance of a hydrocyclone on sands (volume of unloading flow).

For efficient dewatering of large classes of sludge, the mesh size of the high-frequency screen should be about 0.2 ... 0.25 mm.

The pneumatic pump is recommended to be used by Brain Industries. Pneumatic pumps of this company can effectively pump out dewatered sludge and transport it over long distances. In the conditions of underground kimberlite mines in Russia, this is confirmed by the experience of using the Mudskipper pump at the Udachny mine [7]. In order to avoid clogging of the pneumatic pump with sludge, it is recommended to use a pump with a capacity of at least 25 m$^3$/h.

The total hourly productivity of all operating pneumatic pumping equipment is calculated based on the following expression:

$$Q_{pn} > 0.8 \ldots 0.9 \cdot n \cdot Q_q$$  \hspace{1cm} (9)

where 0.8 ... 0.9 is a coefficient that takes into account the decrease in the amount of unloading products due to settling in the sludge collector.

The minimum required working volume of the sludge collector $V_{min}$ is as follows:

$$V_{min} = Q_q$$  \hspace{1cm} (10)

4. Conclusion
To reduce the rate of hydroabrasive wear of parts of the flowing part of the pumping equipment of mine drainage installations, a mechanized complex was developed and sufficiently justified for cleaning mine water from large mechanical impurities. The introduction of this technical solution into the drainage systems of underground mines will reduce the intensity of hydroabrasive abrasion of the elements of sectional pumps, in particular, impellers.

References
[1] Ovchinnikov N P 2017 Experience in operating sectional pumps for the main drainage of the underground mine "Udachny" Bulletin of the Kuzbass State Technical University 3 154-61
[2] Dolganov A V, Islent’ev A V, Cherakov E O and Toropov E Y 2014 Analysis of the efficiency of unloading devices for shaft centrifugal sectional pumps Izvestia of the Ural State Mining University 2(34) 31-5
[3] Aleksandrov V I, Avksentyev S Yu, Gorelkin I M and Toropov E Yu 2012 Specific energy consumption of hydraulic transportation of products of processing of mineral raw materials Enrichment of ores 3 39-42
[4] Mokhnatkin V G, Solonshchikov P N and Filinkov A S 2014 Investigation of the motion of a particle of the impeller of an installation for preparing liquid feed mixtures Bulletin of the Nizhny Novgorod State Engineering and Economic University of the Ural State Mining University 2(33) 312-40
[5] Ovchinnikov N P 2018 A method of combating siltation of catchment areas of district drainage plants of kimberlite mines Notes of the Mining University 231 317-20
[6] Bauman A V 2018 Hydrocyclones Theory and Practice (Novosibirsk: Gormashexport)
[7] Ovchinnikov N P and Smyslov A G 2018 Increasing the resource of sectional pumps for the main drainage of the underground kimberlite mine "Udachny" Engineering bulletin 9 48-52