(E) ISSN: 3030-3214
Volume 4, № 1
2026

UDC: 681.5:621.7:66.017

10.70769/3030-3214.SRT.4.1.2026.20

ENHANCING THE RESISTANCE TO HYDROABRASIVE WEAR OF CENTRIFUGAL PUMP IMPELLERS BY STRENGTHENING THE SURFACE LAYER WITH FUNCTIONAL COATINGS

Kayumov Umidjon Erkinovich

Senior Lecturer, Navoi State Mining and Technology University, Navoi, Uzbekistan
E-mail: kayumov_umidjon@mail.ru
ORCID ID: 0000-0002-2147-8973

Pardayeva Shahlo Saxibjonovna

Docent, Navoi State Mining and Technological University, Navoi, Uzbekistan
E-mail: pardayevashahlo33@gmail.com
ORCID ID: 0009-0008-4847-6901

Istamov Muhammad Farxodovich

Assistant, Navoi State Mining and Technology University, Navoi, Uzbekistan

Abstract. *The article analyzes issues related to improving the operational reliability of centrifugal pumps widely used in the mining industry. It has been established that the primary causes of failures in pumping equipment operating in hydrotransport systems are hydroabrasive wear of impellers, casings, and covers. Based on statistical and experimental data obtained from pump stations of mining enterprises in Uzbekistan, the service life and failure causes of centrifugal pump components were investigated. The research results indicate that up to 70–75% of failures are associated with intensive wear of the surface layer of pump impellers.*

Methods for extending the service life of pump impellers through strengthening their surface layer with functional coatings are analyzed, and the advantages of cold gas-dynamic spraying technology are scientifically substantiated. Using this approach, metallic and metal–ceramic composite coatings are formed, which increase the resistance of impellers to hydroabrasive and cavitation effects. It is demonstrated that the application of such coatings makes it possible to reduce the operating costs of centrifugal pumps and significantly extend their service life.

Keywords: *centrifugal pump, impeller, hydroabrasive wear, functional coating, cold gas-dynamic spraying, hydrotransport, efficiency, operational reliability.*

ПОВЫШЕНИЕ УСТОЙЧИВОСТИ К ГИДРОАБРАЗИВНОМУ ИЗНАШИВАНИЮ РАБОЧИХ КОЛЕС ЦЕНТРОБЕЖНЫХ НАСОСОВ НА ОСНОВЕ УПРОЧНЕНИЯ ПОВЕРХНОСТНОГО СЛОЯ ФУНКЦИОНАЛЬНЫМИ ПОКРЫТИЯМИ

Каюмов Умиджон Эркинович

Старший преподаватель, Навоийский государственный горно-технологический университет, Навои, Узбекистан

Пардаева Шахло Сахибжоновна

Доцент, Навоийский государственный горно-технологический университет, Навои, Узбекистан

Истамов Мухаммад Фарходович

Ассистент, Навоийский государственный горно-технологический университет, Навои, Узбекистан

(E) ISSN: 3030-3214
Volume 4, № 1
2026

Аннотация. *В статье проанализированы вопросы повышения эксплуатационной надежности центробежных насосов, широко применяемых в горнодобывающей промышленности. Установлено, что основными причинами отказов насосного оборудования, работающего в системах гидротранспорта, являются гидроабразивный износ рабочих колес, корпусов и крышек. На основе статистических и экспериментальных данных насосных станций горнодобывающих предприятий Узбекистана исследованы показатели срока службы и причины отказов элементов центробежных насосов. Результаты исследований показывают, что до 70–75% отказов связано с интенсивным изнашиванием поверхностного слоя рабочих колес.*

С целью увеличения срока службы рабочих колес проанализированы методы упрочнения их поверхностного слоя функциональными покрытиями, а также научно обоснованы преимущества технологии холодного газодинамического напыления. С применением данного подхода формируются металлические и металлокерамические композиционные покрытия, обеспечивающие повышение стойкости рабочих колес к гидроабразивному и кавитационному воздействию. Доказана возможность снижения эксплуатационных затрат центробежных насосов и увеличения их ресурса за счет использования указанных покрытий.

Ключевые слова: *центробежный насос, рабочее колесо, гидроабразивный износ, функциональное покрытие, холодное газодинамическое напыление, гидротранспорт, коэффициент полезного действия, эксплуатационная надежность.*

MARKAZDAN QOCHMA NASOSLARI ISHCHI G‘ILDIRAKLARINING SIRT QATLAMINI FUNKSIONAL QOPLAMALAR BILAN MUSTAHKAMLASH ORQALI GIDROABRAZIV YEDIRILISHGA CHIDAMLILIGINI OSHIRISH

Kayumov Umidjon Erkinovich
Katta o‘qituvchi, Navoiy davlat konchilik va texnologiyalar universiteti, Navoiy, O‘zbekiston

Pardayeva Shahlo Saxibjonovna
Dotsent, Navoiy davlat konchilik va texnologiyalar universiteti, Navoiy, O‘zbekiston

Istamov Muhammad Farxodovich
Assistant, Navoiy davlat konchilik va texnologiyalar universiteti, Navoiy, O‘zbekiston

Annotatsiya. *Maqolada konchilik sanoatida keng qo‘llaniladigan markazdan qochma nasoslarning ekspluatatsion ishonchliligini oshirish masalalari tahlil qilingan. Gidrotransport tizimlarida ishlovchi nasos uskunalarining asosiy nosozlik sabablari sifatida ishchi g‘ildiraklar, korpus va qopqoqlarning gidroabraziv yedirilishi aniqlangan. O‘zbekiston konchilik korxonalaridagi nasos stansiyalarining statistik va eksperimental ma’lumotlari asosida markazdan qochma nasos elementlarining xizmat muddati va nosozlik sabablari o‘rganilgan. Tadqiqot natijalari shuni ko‘rsatadiki, nosozliklarning 70–75% gacha qismi ishchi g‘ildiraklarning sirt qatlamining intensiv yedirilishi bilan bog‘liq.*

Ishchi g‘ildiraklarning xizmat muddatini uzaytirish maqsadida ularning sirt qatlamini funksional qoplamalar bilan mustahkamlash yo‘llari tahlil qilingan, shuningdek sovuq gaz-dinamik purkash texnologiyasining afzalliklari asoslab berilgan. Ushbu yondashuv yordamida metall va metall-keramik kompozit qoplamalar hosil qilinib, ishchi g‘ildiraklarning gidroabraziv va kavitatsion ta’sirlarga chidamliligi oshirilishi, shuningdek markazdan qochma nasoslarning ekspluatatsion xarajatlarini kamaytirish va xizmat muddatini uzaytirish imkoniyati isbotlangan.

Kalit so‘zlar: *Markazdan qochma nasos, ishchi g‘ildirak, gidroabraziv yedirilish, funksional qoplama, sovuq gaz-dinamik purkash, gidrotransport, foydali ish koeffitsienti, ekspluatatsion ishonchlilik.*

Introduction. At mining enterprises of Uzbekistan, hydraulic transport represents a critical component of the technological chain involved in the extraction and processing of mineral resources. This method of material handling is characterized by economic efficiency and operational effectiveness, and the hydraulic transport systems currently in use remain competitive compared to alternative transportation methods.

An analysis of the operation of hydraulic

(E) ISSN: 3030-3214
Volume 4, № 1
2026

transport systems at mining facilities indicates that their actual performance efficiency does not fully correspond to their technical capabilities. This discrepancy is associated with a number of operational factors, including the complexity of equipment operation, intensive hydraulic-abrasive wear of centrifugal pumps and pipelines, the limited service life of pumping units, as well as the high metal consumption and significant energy demand of hydraulic transport systems [1].

It is well known that pumping equipment is characterized by a high level of energy intensity. In various industries, the share of energy consumed by pumps accounts for approximately 25–60% of the total electricity demand [2]. According to data from the European association of pump manufacturers, EuroPump, the distribution of electrical energy consumption by pumping equipment is presented in Figure 1 [3].

At the same time, nearly three-quarters of the total energy consumption is associated with dynamic pumps (see Figure 1).

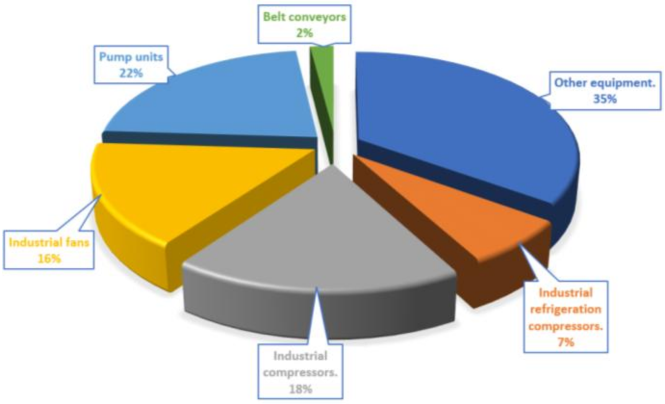


Fig.1. Distribution of electrical energy consumption among different types of equipment.

It is known that the primary function of a hydrodynamic pumping unit is to ensure the effective transfer of energy to the working fluid as it flows through the pump. The key element responsible for energy transfer to the fluid is the impeller, which forms the main stage between the inlet and outlet elements of the pump.

In a centrifugal pump, the principal integral characteristic of the energy transfer process in the impeller is the head, which represents the mechanical energy imparted to each kilogram of fluid passing through the pump [4].

Materials and Research Methods. Due to the depletion of service life and the physical deterioration of technological equipment, one of the main causes of failures in the operation of pumping systems in the country at present is the low mechanical reliability of the equipment in use. As a result, up to 80% of emergency incidents and operational shutdowns occur in pumping installations, with approximately one-third of these failures associated with centrifugal pumps [5].

Large-scale mining enterprises in Uzbekistan are incurring significant economic losses as a consequence of the above-mentioned problems.

The enterprise's expenditures consist of the costs associated with the repair of technological equipment and the downtime of pumping system complexes, as well as electricity costs arising from the operation of pumping units under inefficient operating conditions.

According to operational data from the largest mining enterprises in Uzbekistan, the economic performance indicators of pumping stations show that, within the overall operating costs, the repair expenses for centrifugal pumps have the greatest impact, accounting for approximately 40–50%. At the same time, production losses associated with downtime of pumping equipment reach 65–70% of the total losses [6].

The data on failure occurrences of centrifugal pumping equipment at the pumping stations of the Mining and Technological Equipment Repair Shop of **"NMZ"** in Navoi are presented in Table 1.

Table 1

Distribution of failure causes in pumping units

№	**Types of failures occurring in pumping units**	**Share in the total number of shutdowns, %**
1	Impellers	**43**
2	Rupture of pipelines within centrifugal pumping stations or leakage of working fluid	**24**
3	Shutdowns related to the pump electric motor or the pump itself	**20**
4	Malfunctions in the lubrication supply to pump unit components	**11**
5	Other causes	**2**
	Total	**100**

The data presented in Table 1 indicate that the most heavily loaded and failure-prone component of centrifugal pumps is the impeller.

(E) ISSN: 3030-3214
Volume 4, № 1
2026

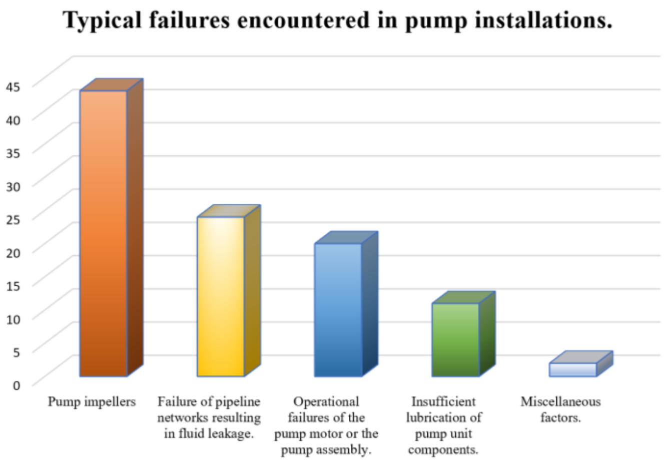


Fig.2. Failure distribution in pumping units.

The average service life of the main components of centrifugal pumps, determined during operational monitoring of pumping stations at the **Kyzylkumsement,** Almalyk, and Muruntau mining and processing enterprises, is presented in Table 2.

Table 2

Service life of main centrifugal pump components

№	Component name	Service life, hours		
		Kyzylkumsement	Almalyk	Muruntau
1	Impellers	780	1320	800
2	Casing	804	480	740
3	Front cover	700	360	805
4	Rear wear plate (back shroud disc)	610	580	595
5	Bearings	600	470	650
6	Stuffing box seals (gland seals)	400	380	450

Under various operating conditions of centrifugal pumps, the service life of impellers typically ranges from 780 to 1320 hours of continuous operation [7].

Wear of the impellers, in turn, leads to the transmission of significant vibration loads to the bearing assemblies of the pump support units. As a result, the bearing service life is substantially reduced, which ultimately contributes to a decrease in the overall efficiency of the pumping equipment [8].

The data on the service life of centrifugal pumps presented in Table 3 were obtained through the analysis of experimental results.

Other typical causes of failures in pumping systems include the poor quality of gland seals, improper mounting of bearing assemblies and impellers on the pump shaft, as well as the absence of effective diagnostic and condition monitoring systems during equipment operation.

Table 3

Causes of failure of centrifugal pump components

Causes of shutdowns	Average failure rate of centrifugal pump components and assemblies, %							
	10	20	30	40	50	60	70	80
Wear of components								
Front cover		■						
Impeller								■
Casing							■	
Rear wear plate (back shroud)						■		
Bearings							■	
Design deficiencies of assemblies								
Insufficient strength of support assemblies			■					
Improper fastening of pump impellers		■						
Operational and monitoring deficiencies								
Bearing lubrication	■							
Vibration monitoring						■		

The above analysis indicates that the primary cause of failures in centrifugal pumping equipment—accounting for up to 75%—is hydroabrasive wear of the main components, namely the impellers, casings, and front covers [9].

It is well established that the service life of pump impellers is largely determined by the condition of their surface layer. This condition depends on the combination of physical and mechanical properties of the material forming the surface layer, as well as on the surface quality achieved during the formation of the working profile and its subsequent mechanical finishing.

One of the key quality parameters determining the wear resistance of a surface is its roughness level. Based on the above analysis, it can be concluded that the implementation of specific design and technological solutions makes it possible to significantly improve the resistance of impellers to hydroabrasive wear as well as to corrosion effects [10].

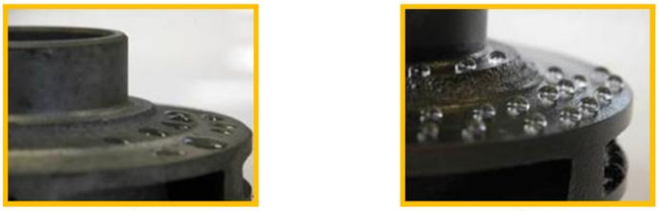
Results and Discussion. **Application of corrosion- and abrasion-resistant coatings.** The use of specialized protective coatings for pumping equipment operating in aggressive environments contributes to a reduction in the wear of impellers and casing components, thereby extending the service life of the pumping units.

One of the promising approaches is the improvement of the internal flow surfaces of centrifugal pumping equipment through

(E) ISSN: 3030-3214
Volume 4, № 1
2026

modification of the functional surfaces of the impellers.

In the work of B.S. Bekjapbarov, it is demonstrated that altering the surface properties of the flow passages of a pumping unit by applying hydrophobic coatings leads to improved operational performance of pump assemblies. Figure 3 illustrates the original and the modified impeller of the pump investigated in this study.



a) b)

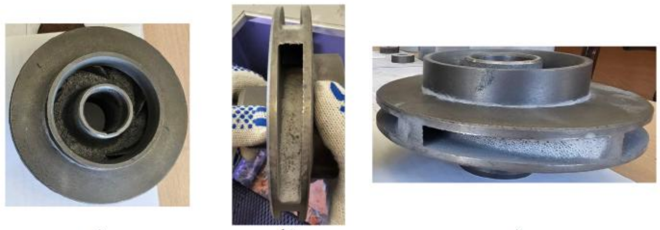
Fig.3. Impellers of a centrifugal pump:
(a) original condition; (b) after modification using a hydrophobic coating.

The long-term operational stability of hydrophobic coatings under the influence of abrasive particles, cavitation effects, and chemically aggressive environments remains insufficiently ensured. In addition, the high cost associated with the application of such coatings, as well as the need for their periodic maintenance and reapplication, significantly increases the overall operating expenses of pumping units.

At the same time, the use of hydrophobic coatings may adversely affect the hydraulic performance of the pump, leading to changes in the flow regime, an increase in turbulence intensity, and additional energy losses.

From this standpoint, one of the most efficient technological solutions is the application of metal-based coatings by means of cold gas-dynamic spraying. This method enables the densification of the surface layer through the elimination of porosity, as well as the removal of manufacturing defects manifested in the form of microcracks. None of the conventional coating techniques provides a comparable combination of functional properties and technological capabilities (see Figure 4).

As can be seen from the figure above, the cold gas-dynamic spraying method makes it possible to form multilayer coatings based on various metal–ceramic composites, including aluminum, copper, nickel, and other metal-based materials. This technology provides the required functional properties in the surface layer of impellers and other pump components, ensuring their high performance not only during initial manufacturing but also in repair and reconditioning processes.



a) b) c)

Fig.4. Formation of multilayer coatings using the cold gas-dynamic spraying technique:
(a) top view of the impeller after coating; (b) side view of the impeller after coating; (c) front view of the impeller after coating.

In addition, the application of this method improves the technological performance of pumping equipment, in particular by increasing the delivery head and overall efficiency, as illustrated in Figures 5 and 6.

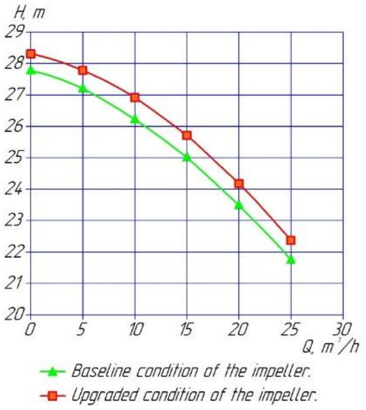


Fig.5. Original and improved configurations of the pump impeller based on the fluid discharge head performance indicator.

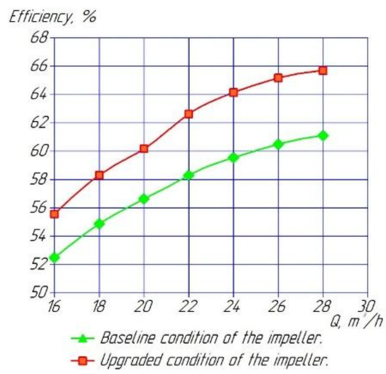


Fig.6. Original and modified configurations of the pump impeller based on the pump efficiency (performance efficiency) indicator.

(E) ISSN: 3030-3214
Volume 4, № 1
2026

As can be observed from the graphs presented in Figures 5 and 6, the pump head and efficiency are comparatively evaluated for the original and the improved impeller configurations as functions of the flow rate Q (m³/h).

The results of the conducted analysis indicate that, for the improved impeller configuration (red curve), the generated head values remain consistently higher across the entire operating flow range compared to those of the original design (green curve). A particularly noticeable increase in head is observed in the low- and medium-flow regions, which indicates a substantial improvement in the functional properties of the impeller surface layer and its operational performance. In addition, the modified impeller is characterized by higher efficiency values across all operating conditions. In particular, the increase in efficiency becomes more pronounced within the medium- and high-flow operating range, which confirms a reduction in hydraulic losses within the flow and an improvement in the efficiency of energy transfer.

A decrease in head with increasing flow rate is observed in both cases; however, the rate of head reduction is relatively lower for the improved impeller design. This behavior indicates a decrease in hydraulic losses within the flow passage and a more efficient transfer of energy to the working fluid. Furthermore, the observed improvement is directly associated with the enhanced resistance of the impeller surface layer to hydro-abrasive wear and cavitation effects.

Moreover, although an increase in efficiency with rising flow rate is observed for both configurations, the improved impeller demonstrates a higher growth rate of efficiency and a more stable approach to its maximum value. This behavior can be attributed to the significant enhancement of the surface quality of the impeller, the reduction of flow separation phenomena, and a decrease in the level of turbulence within the flow passage.

Conclusion. In summary, the graphical and experimental investigations demonstrate that the application of cold gas-dynamic spraying technology for the modification of pump impellers leads to a significant improvement in the hydraulic and energy performance of pumping units. The implementation of this technology enhances the stability of operating conditions, reduces hydraulic losses, and contributes to increased overall operational efficiency and reliability of the equipment.

REFERENCES

[1] Development, production and operation of turbo- and electric pump units and systems based on them. (2009). In Proceedings of the V International Conference. Voronezh: Nauchnaya Kniga.
[2] Efficiency and environmental performance of pumping equipment. (2009). In Proceedings of the International Scientific and Technical Conference. Moscow: RAPN Publishing House. Available at: http://www.ecopump.ru
[3] Ivanova, T. D. (1981). Investigation and improvement of slurry pumps for transportation of ore tailings (case study of the Magnitogorsk Metallurgical Plant) (PhD Thesis). Leningrad.
[4] Timokhin, Yu. V., Adam, O. V., Antonov, E. I., Koshkalda, L. I., & Palamarchuk, N. V. (1991). Reliability of high-speed pumps. In Mining Mechanics: Collected Scientific Papers (Issue 1, Part 2, pp. 81–87). Donetsk.
[5] Operational design project of the tailings storage facility of SOF and MOF for deposition of 0.1 million tons of tailings for 2006–2009. (2005). JSC Mekhanobr Engineering.
[6] Bekzhapbarov, B. S. (2019). Improvement of the PNV-2 sand pump design using composite (powder) materials. Kazakhstan.
[7] Istamov, M. F., Xamzayev, A. A., Kayumov, U. E., & Fayziyev, A. I. (2023). Elimination of shaft misalignment in pump units. Academic Research in Educational Sciences, 4(4), 134–139.
[8] Atakulov, L. N., Kayumov, U. E., & Pardayeva, S. S. (2023). Modeling of optimal blade angle parameters for pump impellers. Academic Research in Educational Sciences, 4(2), 274–284.
[9] Atakulov, L. N., & Kayumov, U. E. (2020). Investigation of optimal blade parameters of pump impellers. Problems of Science and Education, 26(110), 4–12.