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INNOVATIVE TECHNOLOGIES FOR IMPROVING THE OPERATIONAL AND TECHNICAL CHARACTERISTICS OF PROGRESSIVE CAVITY PUMP INSALLATION IN OIL WELLS

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Annotation. This article examines the main operational and technical issues encountered during the use of Progressive Cavity Pump (PCP) installations, which are widely employed in oil wells worldwide. The study analyzes the undesirable consequences arising from these issues, the key approaches to solving them, various factors influencing the operational reliability of PCP systems, as well as the essential performance characteristics of nanocoatings (titanium nitride, chromium nitride, Diamond-Like Carbon, titanium–aluminum nitride) that reduce friction and wear. The results of implementing these technologies and their advantages are also described. In addition, the article reviews modern innovative technologies for applying nanocoatings, including physical vapor deposition and condensation, chemical vapor deposition, and the introduction of nanoscale layers onto metal surfaces using high-energy plasma.

Changes in operational performance indicators of PCP installations with and without nanocoatings are compared. Field test results from foreign oil companies are presented, along with actual production performance data of the pumps in the form of tables and graphs demonstrating the effectiveness of nanocoatings. The study findings show that nanocoatings increase equipment service life by 1.5–3 times, enhance reliability, and significantly extend run time between overhauls. The article also proposes future technological development prospects for the innovative sector within the oil extraction industry.

Keywords: progressive cavity pump, nanocoating, nanostructured coating, innovation, friction, wear, corrosion.

Introduction. A progressing cavity pump (PCP) is a positive-displacement pump consisting of a rotor (metal screw) and a stator (elastomer-lined housing). As the rotor rotates, the fluid is moved from chamber to chamber and lifted from the bottom of the well to the surface.

- The key features of progressing cavity pump systems are as follows: adapted for producing high-viscosity oil;
- capable of operating even with high contents of sand, gas, and water;
- mechanically simple, yet sensitive to wear.

Progressing cavity pump systems are among the most efficient technologies in global oil production for lifting highly viscous, solids-laden, and high-gas-factor reservoir fluids. However, the primary factor limiting their service life is the intensive abrasive and corrosive wear of the rotor and stator.

The main issues encountered during the operation of PCP systems are as follows:

Mechanical wear – Oil and gas may contain various acids that damage the metallic parts of the pump. Such corrosive effects reduce the strength and durability of PCP components.

Gas-factor impact – The presence of gas lowers the density of the fluid, complicating PCP operation and reducing lifting capacity.

Impact of sand and solid particles – Abrasion caused by sand or hard particles rubbing against the screw surface negatively affects pump performance.

Thermal and chemical effects – Temperature fluctuations at the surface and at well depth cause expansion and contraction of metal parts, contributing to mechanical wear [1-7].

Figure 1 below shows worn elastomers and stators of progressing cavity pumps.

The issues listed above lead to several negative consequences.

Pump wear reduces operating efficiency, resulting in decreased oil-lifting performance. Pump efficiency may drop by 15–30%.

Increased energy consumption – Mechanical wear affects other pump components as well, leading to higher energy costs and longer repair times.

Shorter mean time between failures – Worn pumps require more frequent repair or replacement, increasing operational expenses.

Figure 1 – Worn PCP elastomers and stators

Unstable oil production – Some pump sections may lift only gas, reducing liquid-lifting efficiency. In such cases the pump operates "dry," significantly decreasing performance.

Below, Figure 2 shows worn PCP rotors.

Figure 2 – Worn PCP rotors

There are many solutions aimed at reducing or mitigating these negative effects. The main ones include: Material improvement (wear-resistant coatings, new elastomers) – use of high-strength, corrosion-resistant coatings; Gas-handling optimization – installation of separators to remove free gas from the wellstream; Sand and solids control (sand traps/filters) – prefilters to remove sand and solids during production; Drive system enhancements – proper selection and modification of pump components based on fluid properties; Monitoring and diagnostics – controlling pump load to avoid overload [7-12].

Research materials and methods. In recent years, friction-reducing nanostructured coatings have been proven to substantially increase the reliability of PCP systems by improving rotor surface properties. The use of nanocoatings to reduce friction and wear is among the most effective solutions. A nanocoating is a hard and durable protective layer typically 10–100 nanometers thick. On metal surfaces it:

- reduces friction;
- increases corrosion resistance;
- resists thermal and mechanical impacts.

The effectiveness of nanocoatings is directly related to their structure and physico-chemical properties. Studies show that hard carbon and nitride nanolayers applied to rotor surfaces reduce wear through well-defined scientific mechanisms.

Various chemical and physical methods are used to introduce nanostructured materials and additives into coatings. These additives modify the structure and provide the desired properties of coatings composed partly or fully of nanoparticles.

Different methods exist for forming nanocoatings:

Adding a hard amorphous phase to an alloy reduces crystallite size, producing nanostructured materials such as TiAlN+Si, TiMoN+Si, and TiCrN;

Use of multilayer coatings with alternating nanolayers;

Formation of nanostructures through high-speed sputtering of mosaic cathodes;

Formation of nanostructures using ion beams.

Table 1 below presents coating types and their main properties and advantages.

Table 1 – Types of nanocoatings and their main properties and advantages

Coating type	Main properties	Advantages
TiN (titanium nitride)	High hardness, wear resistance	Extends rotor surface life by 2–3 times
CrN (chromium nitride)	Corrosion resistance, stable at high temperature and friction	High anti-wear performance
DLC (Diamond-Like Carbon)	Low friction coefficient, energy-saving, diamond-like structure	Reduces energy consumption, lowers surface heating
TiAlN (titanium-aluminum nitride)	For heavy-duty loads, high-temperature resistance	Reduces heat generation and energy losses

One of the most widely used methods today is PVD (Physical Vapor Deposition) — a technology in which material is vaporized in a vacuum and condensed onto a substrate as a thin layer. This method applies thin films of metals, ceramics, glass, and polymers. Prior to coating, the substrate is degreased, cleaned, and sometimes heat-treated or polished. The material (e.g., chromium or titanium) is vaporized via sputtering, e-beam, or thermal evaporation, and vapor particles condense onto the substrate surface, forming a uniform thin layer 0.25–4 microns thick [13-15]. CVD (Chemical Vapor Deposition) is another common method that uses gaseous precursors to deposit thin solid films on substrates at elevated temperatures. CVD coatings are durable, chemically resistant, and ideal for wear protection. Another method is plasma-ion spraying, which uses high-energy plasma to deposit nanolayers onto metal surfaces. Vaporized ions accelerated by electric fields strike the substrate, forming strong chemical-metallurgical bonds and producing extremely hard, wear-resistant coatings. These technologies enable the formation of thin yet very hard protective layers on rotor steel surfaces.

Results and discussion. The described methods are applied depending on the required performance characteristics. Plasma-ion spraying is one of the most effective nanocoating technologies for improving PCP reliability. It strengthens rotor surfaces, reduces friction, and decreases corrosion and abrasive wear. CVD increases rotor durability, wear resistance, and corrosion resistance. PVD enhances coating strength, wear resistance, and appearance.

The use of these technologies is economically advantageous, as pump downtime and repair costs are significantly reduced. Nanocoated rotors reduce the friction coefficient by 40–60%, extend service life by 2–3 times, and increase mean time between failures by 25–30%.

Table 2 below shows comparative indicators of coated and uncoated rotors.

Table 2 – Comparative characteristics of coated and uncoated rotors

Indicator	Uncoated	Nanocoated
Friction coefficient	0.35–0.40	0.10–0.15
Wear rate	100%	30–40%
Heat resistance	Medium	High
Service life	1000 hours	2500–3000 hours

These results clearly demonstrate the effectiveness and advantages of nanocoated rotors, with performance improvements ranging from 2.5 to 3 times.

Table 3 below presents examples of global companies using nanocoatings and their reported results.

Table 3 – Global companies' experience with nanocoatings and their results

Country / Company	Nanocoating type	Result
Canada (Kudu Pumps)	DLC nanocoating	Rotor wear decreased 2.5× in high-sand wells
Russia (Tatneft, Lukoil)	TiN and CrN layers	Service life increased 1.7×
China (CNPC)	Nanoceramic coating	Corrosion reduced by 50% in hot, viscous media

Overall, the types of nanocoatings used worldwide continue to improve every year. Compared to conventional methods, nanocoatings remain a relatively new and rapidly developing technology.

Figure 3 below shows a comparative chart of wear rates for TiN- and DLC-coated and uncoated rotors. The key observation from the chart is the continuous decrease in wear rate over the years due to technological advances. This downward trend is expected to continue in the future.

Conclusion. This paper examines the use of nanocoatings as a solution to the major operational problems of progressing cavity pump systems. Applying nanocoatings to pump rotors and stators is a strategic direction fo r Kazakhstan's oil industry, contributing to resource efficiency and technological independence. The goal for the near future is the large-scale implementation of these solutions combined with strengthening local research capability.

Based on the obtained results, the following strategic priorities can be highlighted for improving PCP equipment in Kazakhstan:

1. Establishing local nanocoating centers – building production and laboratory bases in oil-producing regions;
2. Expanding coating material types – testing DLC, TiN, CrN, Al_2O_3, and multilayer hybrid systems;
3. Designing coating structures based on operating conditions – developing specialized solutions for paraffinic, saline, and high-solid wells;
4.

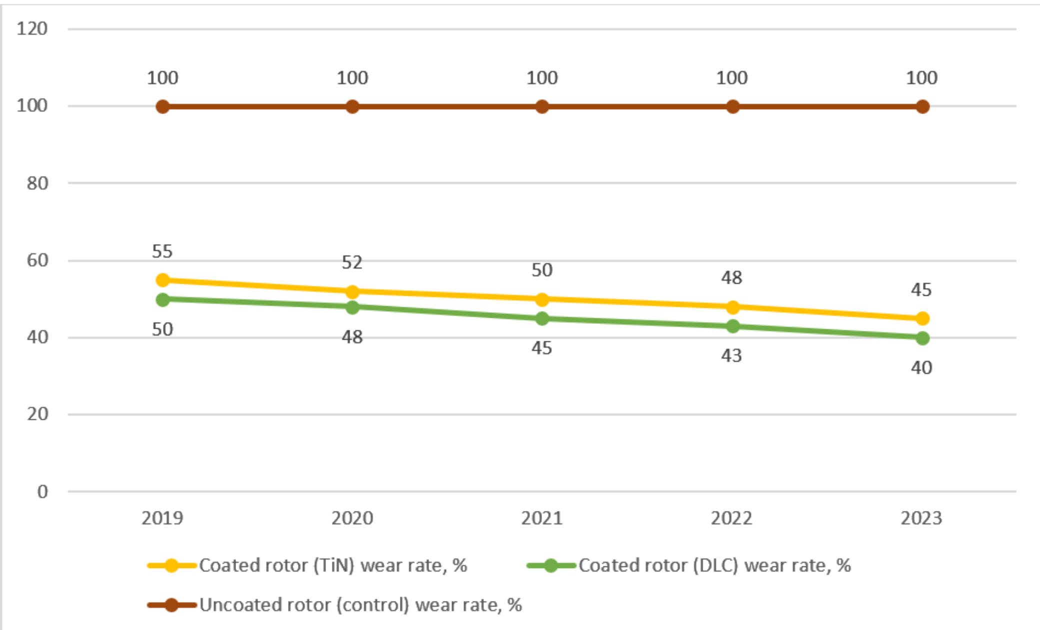

Figure 3 – Comparative wear rates of TiN-, DLC-coated and uncoated rotors

5. Introducing digital monitoring systems – real-time PCP performance tracking and wear-rate modeling;

6. Strengthening scientific-industrial cooperation – joint projects with national research universities and international engineering centers.

These measures will, in the long term, enhance technological independence, equipment reliability, and efficiency in Kazakhstan's oil and gas sector, while advancing the national scientific and technical base to a new qualitative level.

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МҰНАЙ ҰҢҒЫМАЛАРЫНДАҒЫ БҰРАНДАЛЫ СОРАП ҚОНДЫРҒЫЛАРЫНЫҢ ПАЙДАЛАНУ-ТЕХНИКАЛЫҚ СИПАТТАМАЛАРЫН ЖЕТІЛДІРУДЕГІ ИННОВАЦИЯЛЫҚ ТЕХНОЛОГИЯЛАР

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Аңдатпа. Бұл мақалада мұнай ұңғымаларында әлем бойынша кеңінен қолданысқа ие болған бұрандалы сорап қондырғыларының (PCP – Progressive Cavity Pump) пайдалану барысында кездесетін негізгі эксплуатациялық, техникалық мәселелер, олардан туындайтын жағымсыз салдар, проблемаларды шешудің негізгі жолдары, бұрандалы сорап қондырғыларының жұмыс сенімділігіне әсер етуші түрлі факторлар және үйкеліс пен тозуды азайтатын наноқаптамалардың (титан нитриді, хром нитриді, Diamond-Like Carbon, титан-алюминий нитриді) негізгі пайдалану қасиеттері, технологияны енгізу нәтижелері, артықшылықтары талданады. Сонымен қатар наноқаптамаларды жасаудың қазіргі таңдағы инновациялық технологиялары (физикалық буландыру және конденсация әдісі, химиялық буландыру арқылы шөгінді қабат алу, жоғары энергиялы плазма арқылы металл бетіне наноқабат енгізу) қарастырылған. Наноқаптамамен қапталған және қапталмаған бұрандалы сорап қондырғыларының пайдалану көрсетіштерінің өзгерісі салыстырылады. Шетелдік мұнай кәсіпорындарының кен орындағы тәжірибелер салыстырылып, наноқаптамалардың тиімділігіне қатысты сораптардың нақты өндірістік көрсеткіштері кесте және график түрінде келтірілген. Зерттеу нәтижелері наноқаптамалардың қызмет мерзімін 1,5–3 есеге арттыратынын, сенімділікті жоғарылататынын және жөндеу аралық жұмыс уақытын айтарлықтай ұзартатынын көрсетті. Сондай-ақ инновациялық саланың мұнай өндіру кешеніндегі болашақ технологиялық даму перспективалары ұсынылады.

Тірек сөздер: бұрандалы сорап қондырғысы, наноқаптама, наноқұрылымдық қаптама, инновациялық бағыт, үйкеліс, тозу, коррозия.

ИННОВАЦИОННЫЕ ТЕХНОЛОГИИ В СОВЕРШЕНСТВОВАНИИ ЭКСПЛУАТАЦИОННО-ТЕХНИЧЕСКИХ ХАРАКТЕРИСТИК ВИНТОВЫХ НАСОСНЫХ УСТАНОВОК В НЕФТЯНЫХ СКВАЖИНАХ

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Аннотация. В данной статье рассмотрены основные эксплуатационные и технические проблемы, возникающие при использовании винтовых насосных установок (PCP – Progressive Cavity Pump), которые получили широкое распространение в нефтяных скважинах по всему миру. Проанализированы возникающие вследствие этих проблем нежелательные последствия, основные пути их решения, различные факторы, влияющие на надежность работы винтовых насосов, а также ключевые эксплуатационные свойства нанопокрытий (нитрид титана, нитрид хрома, Diamond-Like Carbon, нитрид титана-алюминия), уменьшающих трение и износ. Описаны результаты внедрения этих технологий и их преимущества. Кроме того, рассмотрены современные инновационные технологии нанесения нанопокрытий (методы физического испарения и конденсации, получение осадочных слоев методом химического испарения, нанесение нанослоя на металлическую поверхность с использованием высокоэнергетической плазмы).

Сравнены изменения эксплуатационных показателей винтовых насосов с нанопокрытием и без него. Представлены результаты полевых испытаний зарубежных нефтяных компаний, а также реальные производственные показатели насосов в виде таблиц и графиков, подтверждающие эффективность нанопокрытий. Результаты исследования показывают, что применение нанопокрытий увеличивает срок службы оборудования в 1,5–3 раза, повышают надежность и значительно удлиняет межремонтный период работы. Также предложены перспективы дальнейшего технологического развития инновационного направления в нефтедобывающем комплексе.

Ключевые слова: винтовая насосная установка, нанопокрытие, наноструктурное покрытие, инновационное направление, трение, износ, коррозия.