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APPLICATION AND DEVELOPMENT PROSPECTS OF DYNAMIC PUMPS IN MODERN INDUSTRY

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Abstract. Dynamic pumps play a crucial role in modern industrial systems, ensuring efficient transportation of liquids across various sectors such as chemical processing, energy production, water supply, and manufacturing. This article explores the application of dynamic pumps, including centrifugal, axial, and mixed-flow types, emphasizing their operational principles and performance characteristics. Special attention is given to energy efficiency, hydraulic losses, and the impact of design parameters on pump performance. Furthermore, the study highlights recent advancements in pump technology, such as the integration of Computational Fluid Dynamics (CFD) for flow optimization and the use of smart monitoring systems for predictive maintenance. The issue of cavitation and its mitigation techniques are also discussed as a key factor affecting pump reliability and lifespan. In addition, the article outlines future development prospects, including the implementation of artificial intelligence, energy-saving technologies, and the use of advanced materials to improve durability and corrosion resistance. The findings demonstrate that dynamic pumps will continue to evolve as a vital component of industrial infrastructure, contributing

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significantly to energy efficiency and sustainable development in modern industry.

Keywords: dynamic pumps, centrifugal pump, axial pump, energy efficiency, cavitation, CFD analysis, industrial systems, hydraulic losses, smart monitoring, pump optimization

Annotatsiya. Dinamik nasoslar zamonaviy sanoat tizimlarida muhim o‘rin egallab, turli sohalarda jumladan kimyo sanoati, energetika, suv ta’minoti va ishlab chiqarishda suyuqliklarni samarali uzatishni ta’minlaydi. Ushbu maqolada dinamik nasoslarning, xususan markazdan qochma, aksial va aralash oqimli turlarining qo‘llanilishi, ishlash prinsiplari va asosiy texnik ko‘rsatkichlari tahlil qilinadi. Nasoslarning samaradorligiga ta’sir etuvchi omillar, jumladan gidravlik yo‘qotishlar va konstruktiv parametrlarning roli alohida yoritilgan. Shuningdek, maqolada zamonaviy texnologiyalar, xususan CFD (hisoblash suyuqliklar dinamikasi) yordamida oqimni modellashtirish va optimallashtirish, hamda aqlli monitoring tizimlari orqali nosozliklarni oldindan aniqlash masalalari ko‘rib chiqiladi. Kavitatsiya hodisasi va uni kamaytirish usullari ham muhim muammo sifatida tahlil etilgan. Bundan tashqari, dinamik nasoslarning rivojlanish istiqbollari, jumladan sun’iy intellektni joriy etish, energiya tejamkor texnologiyalar va yangi materiallardan foydalanish yo‘nalishlari bayon qilingan. Tadqiqot natijalari dinamik nasoslarning sanoatdagi ahamiyati yanada ortib borishini ko‘rsatadi.

Kalit so‘zlar: dinamik nasoslar, markazdan qochma nasos, aksial nasos, energiya samaradorligi, kavitatsiya, CFD, sanoat tizimlari, gidravlik yo‘qotishlar, monitoring, optimallashtirish

Аннотация. Динамические насосы играют важную роль в современных промышленных системах, обеспечивая эффективную транспортировку жидкостей в таких отраслях, как химическая промышленность, энергетика, водоснабжение и производство. В данной статье рассматриваются области применения динамических насосов, включая центробежные, осевые и смешанные типы, а также их принципы работы и эксплуатационные характеристики. Особое внимание уделено вопросам энергоэффективности, гидравлическим потерям и влиянию конструктивных параметров на работу насосов. Также рассматриваются современные методы анализа, включая использование CFD (вычислительной гидродинамики) для оптимизации потоков и внедрение интеллектуальных систем мониторинга для прогнозирования неисправностей. Отдельно анализируется явление кавитации и способы её снижения как важный фактор, влияющий на надежность и срок службы оборудования. В статье также представлены перспективы развития динамических насосов, включая применение

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искусственного интеллекта, энергосберегающих технологий и новых материалов с высокой устойчивостью к коррозии. Полученные результаты подтверждают, что динамические насосы остаются ключевым элементом промышленной инфраструктуры.

Ключевые слова: динамические насосы, центробежный насос, осевой насос, энергоэффективность, кавитация, CFD анализ, промышленные системы, гидравлические потери, мониторинг, оптимизация

INTRODUCTION.

In modern industry, the efficient transportation of liquids is a fundamental requirement for ensuring continuous and reliable operation across a wide range of sectors, including chemical processing, energy production, water supply, oil and gas, and manufacturing. Among the various types of fluid machinery, dynamic pumps occupy a central position due to their ability to handle large volumes of fluids with relatively high efficiency and operational stability. These pumps, which primarily include centrifugal, axial, and mixed-flow types, operate based on the principle of imparting kinetic energy to the fluid and converting it into pressure energy, enabling effective fluid movement in complex industrial systems. The increasing demand for energy efficiency and sustainability has significantly influenced the design and operation of dynamic pumps in recent years. Industrial facilities are continuously seeking ways to reduce energy consumption and operational costs while maintaining high performance. Since pumping systems can account for a substantial portion of total energy usage in many industries, improving the efficiency of dynamic pumps has become a critical research and engineering objective. Factors such as hydraulic losses, flow turbulence, and mechanical inefficiencies directly affect the overall performance of these systems and require detailed analysis and optimization. Furthermore, the rapid development of advanced engineering tools and digital technologies has opened new opportunities for enhancing the performance of dynamic pumps. Computational Fluid Dynamics (CFD) has become an essential method for analyzing fluid flow within pump components, allowing engineers to model complex flow patterns, identify inefficiencies, and optimize design parameters without extensive experimental testing. In addition, the integration of smart monitoring systems and sensors enables real-time performance tracking and predictive maintenance, reducing downtime and extending equipment lifespan. Another important challenge associated with dynamic pumps is the phenomenon of cavitation, which occurs when local pressure drops below the vapor pressure of the fluid, leading to the formation and collapse of vapor bubbles. Cavitation can cause significant damage to pump components, reduce efficiency, and increase maintenance costs. Therefore, understanding the mechanisms of

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cavitation and developing effective mitigation strategies are essential for ensuring the reliability and durability of pumping systems. In parallel with technological advancements, material science has also contributed to the development of more robust and corrosion-resistant pump components, particularly for applications involving aggressive or high-temperature fluids. The use of advanced alloys, composites, and coatings enhances the durability and operational reliability of pumps under challenging industrial conditions. Looking ahead, the future development of dynamic pumps is closely linked to the adoption of innovative technologies such as artificial intelligence, machine learning, and energy-efficient design approaches. These technologies have the potential to revolutionize pump operation by enabling intelligent control systems, automated optimization, and improved decision-making processes. Thus, dynamic pumps remain a vital component of modern industrial infrastructure, and their continuous improvement plays a key role in achieving higher efficiency, reduced environmental impact, and sustainable industrial development.

LITERATURE REVIEW.

The study of dynamic pumps has been widely addressed in scientific and engineering literature, focusing on improving efficiency, reliability, and performance under various operating conditions. Early foundational research by Stepanoff A. J. [1] established the fundamental principles of centrifugal pump design and performance characteristics, which remain relevant in modern engineering practices. Similarly, Karassik I. J. et al. [2] provided a comprehensive overview of pump types, operational theory, and industrial applications, forming the basis for many contemporary studies. Recent research has increasingly focused on energy efficiency and hydraulic optimization. For instance, Gülich J. F. [3] analyzed the influence of hydraulic losses on pump performance, highlighting the importance of internal flow optimization. Studies by Brennen C. E. [4] explored cavitation phenomena, identifying its causes and negative effects on pump lifespan and efficiency. These findings have been further supported by experimental and numerical investigations into cavitation suppression techniques [5]. The application of Computational Fluid Dynamics (CFD) has significantly advanced the understanding of internal flow behavior in dynamic pumps. Research by Versteeg H. K. and Malalasekera W. [6] introduced numerical methods for simulating fluid flow, which have since been applied extensively in pump design optimization. More recent studies [7][8] demonstrate how CFD tools can predict flow separation, turbulence, and efficiency losses, enabling engineers to improve impeller and casing geometries. In addition, the integration of intelligent monitoring systems has become a growing area of interest. According to recent works [9], sensor-based diagnostics and real-time data analysis allow

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early detection of faults and reduce maintenance costs. The use of artificial intelligence and machine learning algorithms in pump systems has also been explored to enhance predictive maintenance and operational efficiency [10]. Material selection and durability have also been discussed in the literature, particularly for pumps operating in aggressive environments. Studies [11] indicate that corrosion-resistant alloys and composite materials significantly improve pump lifespan. Furthermore, research on high-temperature and chemically active fluids [12] emphasizes the need for advanced coatings and structural optimization. Comparative analyses of different pump types, including centrifugal, axial, and mixed-flow pumps, have been conducted to determine their suitability for specific industrial applications [13]. These studies highlight the importance of selecting appropriate pump types based on flow rate, head, and operating conditions. Finally, recent publications [14][15] focus on sustainable development and energy-saving technologies in pumping systems, demonstrating that optimized pump operation can significantly reduce industrial energy consumption and environmental impact. Overall, the reviewed literature indicates that while significant progress has been made in the field of dynamic pumps, ongoing research is still required to address challenges related to efficiency, reliability, and integration with modern digital technologies.

RESULTS AND DISCUSSION.

The analysis of dynamic pumps in modern industrial applications demonstrates that their performance is strongly influenced by design parameters, operating conditions, and technological integration. Based on theoretical evaluation and recent research findings, several important results can be highlighted regarding efficiency, reliability, and future development potential. First, it was determined that the efficiency of dynamic pumps, particularly centrifugal types, largely depends on the optimization of internal flow structures. By applying modern simulation tools such as Computational Fluid Dynamics (CFD), it is possible to significantly reduce hydraulic losses caused by turbulence, flow separation, and vortex formation inside the impeller and volute casing. Studies show that optimized blade geometry can increase overall pump efficiency by 5–15%, which is a substantial improvement for large-scale industrial systems. This directly contributes to reduced energy consumption and operational costs. Second, the issue of cavitation remains one of the most critical factors affecting pump performance and durability. The results indicate that maintaining appropriate inlet pressure conditions and optimizing the Net Positive Suction Head (NPSH) are essential to minimizing cavitation risks. Advanced design modifications, including smoother flow passages and improved suction geometry, have proven effective in reducing vapor bubble formation. Consequently, these

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improvements lead to longer service life and lower maintenance requirements. Another important result concerns the implementation of smart monitoring and diagnostic systems. The integration of sensors and data acquisition technologies allows continuous tracking of parameters such as vibration, temperature, and flow rate. With the application of artificial intelligence algorithms, these data can be analyzed to predict potential failures before they occur. This predictive maintenance approach reduces unexpected downtime and enhances the overall reliability of pumping systems. Material advancements also play a significant role in improving pump performance under harsh operating conditions. The use of corrosion-resistant alloys, composite materials, and protective coatings has been shown to increase resistance to chemical and thermal degradation. As a result, pumps used in aggressive environments, such as chemical processing industries, demonstrate higher durability and operational stability. Furthermore, comparative analysis of centrifugal, axial, and mixed-flow pumps reveals that each type has distinct advantages depending on application requirements. Centrifugal pumps are more suitable for high-pressure, moderate-flow systems, while axial pumps are effective for high-flow, low-head applications. Mixed-flow pumps provide a balanced solution where both pressure and flow rate are important. Proper selection based on system requirements significantly enhances overall efficiency. Finally, the results highlight that future developments in dynamic pump technology will be closely linked to digitalization and energy-saving strategies. The adoption of intelligent control systems, automated optimization, and advanced manufacturing techniques will further improve pump performance. In particular, the integration of AI-based control and real-time optimization is expected to revolutionize industrial pumping systems. In conclusion, the obtained results confirm that dynamic pumps remain a key component of modern industry, and their continuous improvement through advanced technologies will play a crucial role in achieving higher efficiency, reliability, and sustainability.

CONCLUSION.

In conclusion, dynamic pumps play a vital role in modern industrial systems by ensuring efficient fluid transportation across various sectors. Their performance is significantly influenced by design optimization, operating conditions, and technological advancements. The application of Computational Fluid Dynamics and intelligent monitoring systems has improved efficiency, reduced energy consumption, and enhanced reliability. Addressing challenges such as cavitation and material degradation remains essential for long-term operation. Future developments, particularly the integration of artificial intelligence and energy-efficient technologies, will further enhance pump

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performance, making dynamic pumps indispensable for sustainable and high-performance industrial processes.

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