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Improving Pump Flow Section for Technical and Economic Efficiency

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Abstract

This research work focuses on enhancing the economic efficiency of vane pumps by improving the flow section and the impeller. The study employs a systematic approach to calculate the expected economic efficiency, which is achieved through a series of modifications in the pump design. These modifications primarily target the flow section of the vane pump and the impeller, two critical components that significantly influence the pump's performance and efficiency. A series of parametric tests were conducted to assess the impact of these improvements. The results were then compiled into a comparison table that provided a clear and comprehensive overview of the energy savings achieved through these improvements. The table facilitated a thorough analysis, enabling the determination of the annual economic efficiency. The findings of this research underscore the potential of design improvements in enhancing the economic efficiency of vane pumps. They provide valuable insights that could guide future efforts aimed at optimizing the performance and efficiency of these pumps. This study thus makes a significant contribution to the field of pump design and optimization.

INTRODUCTION

Saving water and energy resources in the world, using them correctly and rationally, creating innovative energy-saving technologies in the water industry, improving the performance of pumps in use, and increasing energy efficiency and modernization using modern computer programs is one of the most important issues of today[1,2]. In this regard, it is important to develop cost-effective, energy-efficient methods of modernizing hydraulic machines in developed countries[3,4].

In order to improve the energy efficiency of pumping stations in the world, to improve the impellers and pump flow sections, to justify the indicators related to the construction of pumps, to develop methods of managing energy consumption using special programs and solutions, to eliminate the phenomenon of cavitation and hydro-abrasive erosion in pump units[5,6]. Scientific and research work aimed at the development of technical solutions is being carried out[10,11]. In this regard, special attention is being paid to the development of new constructions based on the structural parameters of the pump units, rotational speeds at the input and output of the impeller vanes, absolute flow velocities, the number of vanes, and the angles between the vectors[7,8,9].

INTRODUCTION

Extensive measures are being taken to modernize and reconstruct pumping stations in the irrigation system of our country, to determine the optimal design parameters of flow section elements and equipment, to use modern advanced methods of their use, to use innovative materials and energy-saving technologies, and certain results are being achieved[12,13,14].

MATERIALS AND METHODS

Optimization of the pump flow area. The design of the pump, especially the flow field, has a significant effect on its efficiency. Design optimization has led to improved performance and reduced energy consumption. The materials used in the construction of the pump, in particular the flow section, can affect its efficiency[19,20]. Materials that reduce friction and resist wear serve to increase the service life of the pump. Taking into account the erosion, cavitation, noisy operation, vibration process, as well as structural defects occurring in the pumps, the flow section and the blades of the impeller were prepared in a new way, ensuring the proportionality of the blades to the flow area. In fluid dynamics, the flow field is an important aspect that determines the behavior and properties of fluid flow[17,18]. However, when dealing with complex processes such as the motion of particles in the flow field, a significant gap in the literature is the lack of provision for fractionation of particles[21,22]. These shortcomings are particularly noticeable in advanced studies and have been found to seriously affect the accuracy and reliability of the results (Figure 1).

MATERIALS AND METHODS

Disruption of the flow of water in the flow area of the pump can be caused by several factors:

elbows in pipes, partially closed valves, grates, when working with an open system, air can be introduced into the system during liquid intake. Air or impurities mixed into the liquid cause bubbles to form[24]. Due to bends in pipes or changes in pipe diameter, the flow rate distribution becomes irregular. Under the influence of abrasive turbidities, each of these factors can significantly affect flow characteristics, including velocity, pressure, and turbulence, leading to distortions in the flow field of the pump (Figure 1)[23,26]. Also, a violation of the ratio of the flow section to the impeller (Fig. 2). The flow section was prepared according to the diameter of the impeller (Fig. 3).

MATERIALS AND METHODS

Figure 1. "D" type pump impeller collapse occurred as a result of cavitation and disruption of water flow dynamics

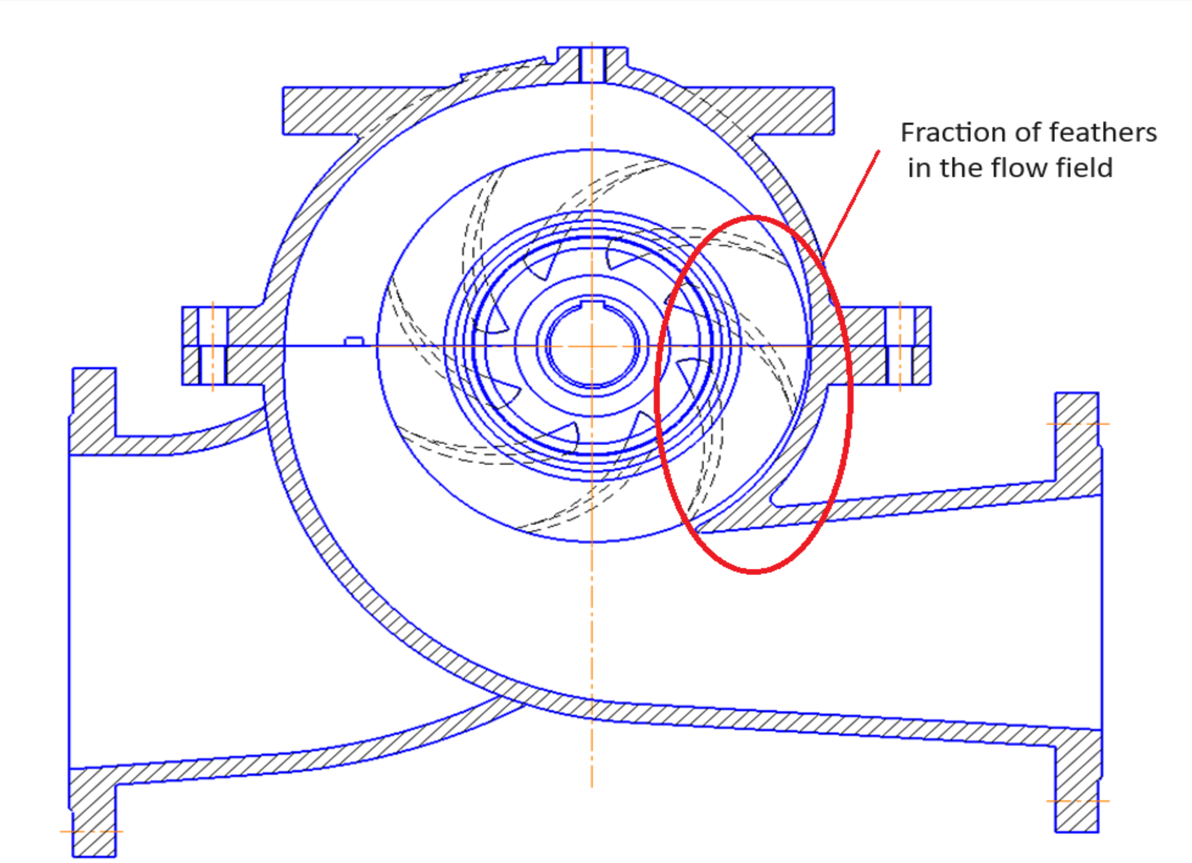

Figure 2. Condition that the pump flow area is not adapted to the number of impellers

MATERIALS AND METHODS

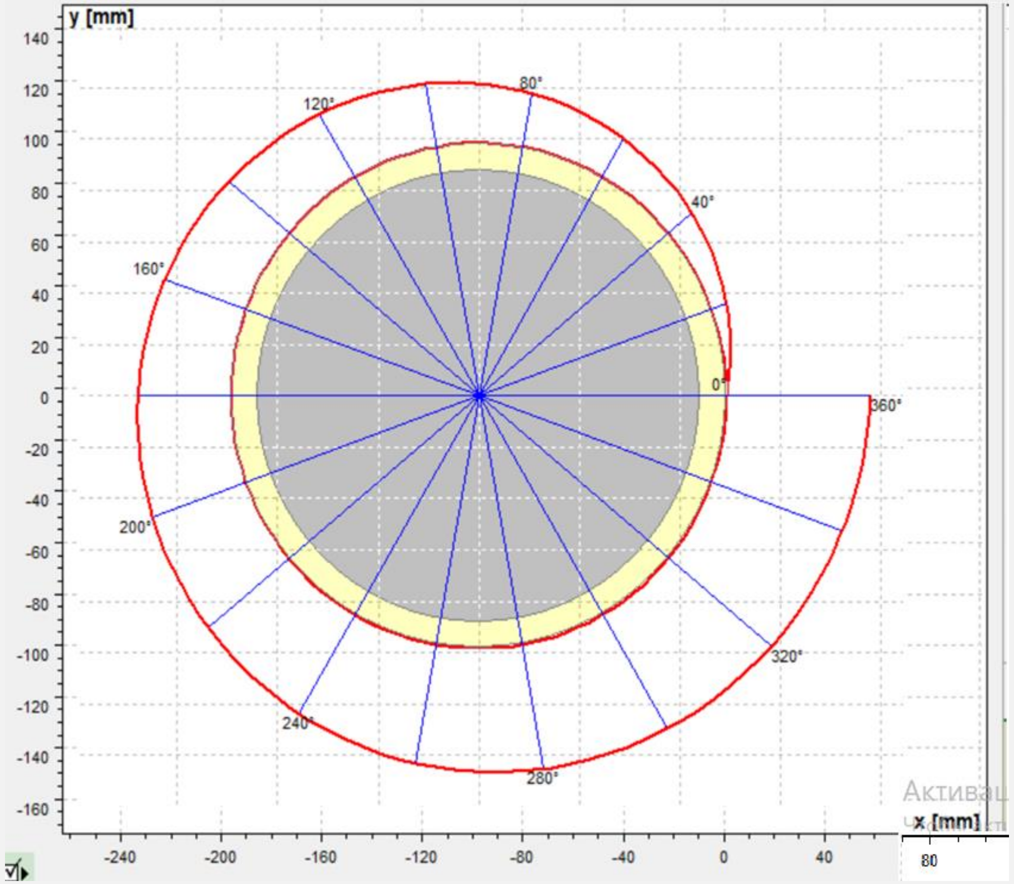

Figure 3. Flow field drawn by the program

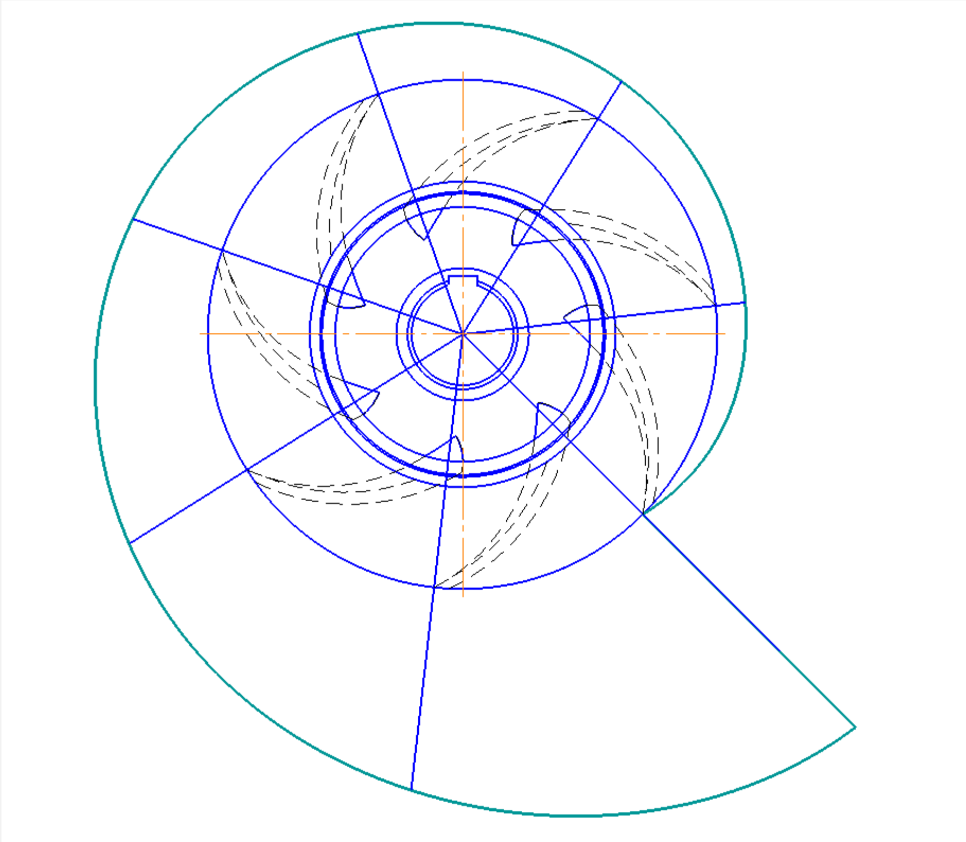

Figure 4. The pump flow field used in the manufacture of the pump

MATERIALS AND METHODS

Using spiral coils and Archimedean spirals in the Cartesian and polar coordinate systems, constructional drawings were prepared to ensure the proportionality of the pump flow field and impeller (Fig. 4). it was brought and assembled, the test was carried out, the curve graphs of the working indicators in Figure 5 were created using the test results, the tested pump was painted and ready for sale to consumers. From the Useful work coefficient curve, we can see that compared to the D320-50 pump, the Useful work coefficient of the D315-71SM pump increased by 3÷5%, i.e. from 78% to 81-83%, in the working range of 315÷320m^3/c water consumption. Recommendations on scientific practical work on ensuring the proportionality of pump flow area and impeller were developed and structural drawings were introduced for permanent use in the department of designers and technologists.

RESULTS AND DISCUSSION

To overcome these flow field problems, it is essential to develop methodologies that can accurately measure and incorporate the flow field. Advanced imaging techniques, combined with computational fluid dynamics simulations, can be used to quantify and visualize the fraction of feathers.

Based on the improved structural drawings of the prepared D315-71SM pump, a model of the pump was prepared, it was cast in the foundry based on the model, and the cast pump was processed. After finishing the work, painting of the pump was carried out. The finished pump was tested in the test laboratory, i.e., on test bench 4. Tests were carried out in the pump at different water consumptions, using ultrasonic flowmeter, mechanical flowmeter, manometer, vacuum meter, and the results were recorded. Based on the obtained results, graphs of dependence of the working parameters of the pump were constructed (Fig. 5).

RESULTS AND DISCUSSION

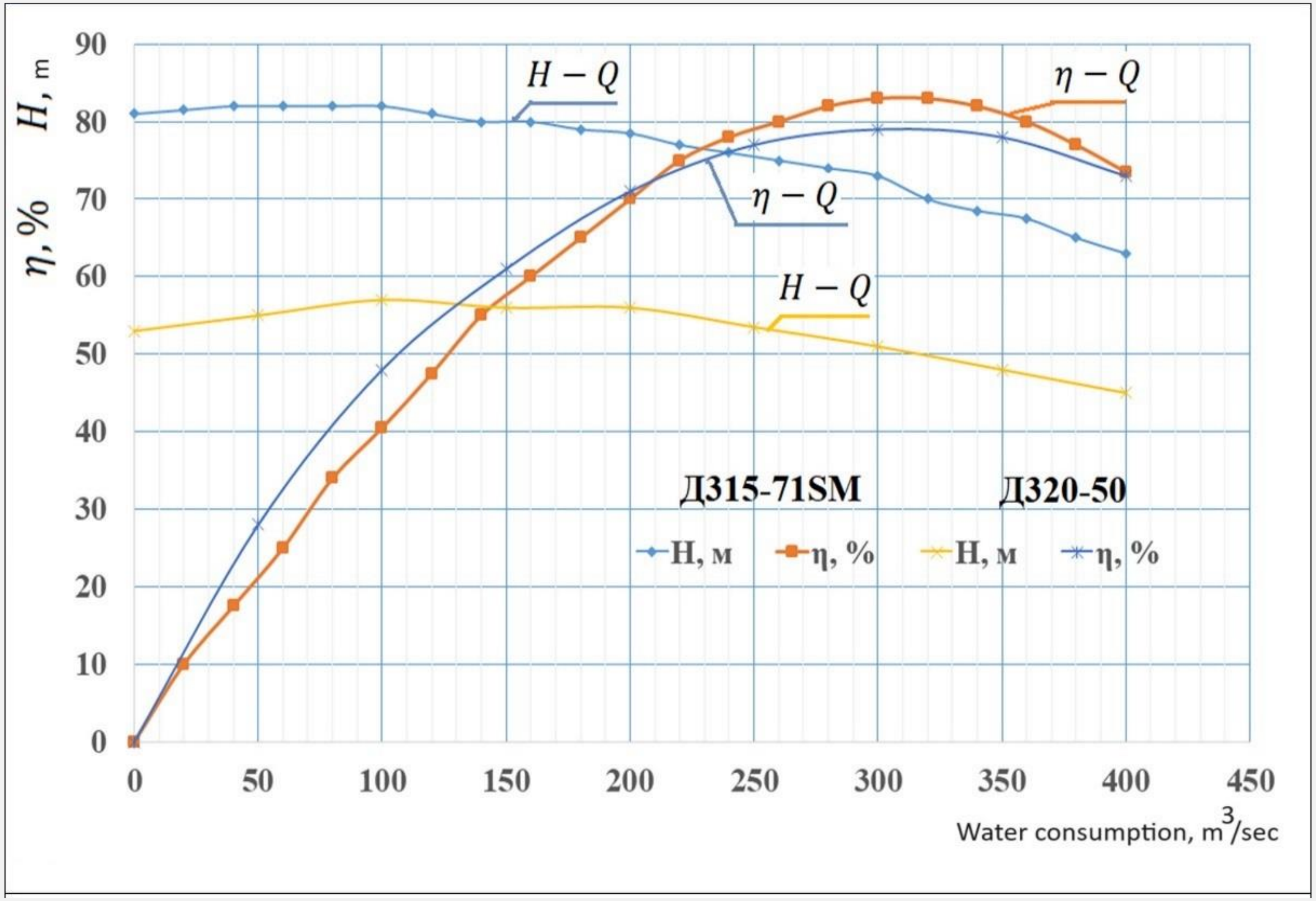

Figure 5. Performance characteristics of newly manufactured D315-71SM pump and D320-50 pump were compared

RESULTS AND DISCUSSION

In addition, the development of theoretical models that take into account the fraction of feathers can increase the predictive power of simulations. These models should take into account the specific characteristics of the wings, for example, their parameters and complex geometry.

In order to calculate the expected economic efficiency in the research work, the newly improved D315-71SM ("SUVMASH" modernization) was carried out by introducing an updated flow section and impeller to the two-way centrifugal pump.

In the process of conducting research at "SUVMASH" JSC, the parameters of the 1D315-71 and D320-50 pumps were analyzed, and the Russian-made AIR280S2 electric motor was used to obtain the experimental results. Power N=110 kW, 3000 rpm. As a result of the parametric tests conducted in the testing laboratory of "SUVMASH" JSC, the power consumption was 87 kW.

Based on research and design development, different angles of action of impellers and vanes were calculated and 3 design options were calculated to reduce cavitation and abrasive wear, and the flow field was recalculated and improved. The most optimal design of the impeller is the back-curved blades, that is, the blades are turned against the direction of flow. This type of impeller blades significantly increases the efficiency of the pump, the conversion of kinetic energy into potential energy in the flow section is accelerated, and the phenomenon of cavitation is reduced.

Before improving the structural parameters of the pump flow section, the power of the 1D315-71 pump:

RESULTS AND DISCUSSION

$$N_n = \frac{gQH}{\eta} = \frac{9,81 \cdot 0,10 \cdot 71}{0,82} = \frac{71,58}{0,82} = 87 \text{ kWh}$$

The power of the improved D315-71SM pump was determined as follows:

$$N_{\text{n}} = \frac{gQH}{\eta} = \frac{9,81 \cdot 0,098 \cdot 71}{0,83} = \frac{68,7}{0,83} = 82,7 \text{ kWh}$$

As a result of research, a new impeller and flow section in the D315-71SM pump were created based on the improvement of the nominal characteristics of the 1D315-71 pump. As a result of tests, it required 82.7 kW power consumption, the difference was 4.3 kW. The average annual operation of this pump, taking into account repairs and other types of work, is 7008 hours with a utilization factor of k = 0.8. 365 days/year x 24 hours x 0.8 = 7008 moto/hours in a year[25].

The calculation includes costs 1 kWh = 800.0 sum (as of 01.04.2023).
As such:
87 kW x 7008 moto hours.year x 800.0 sum = 487 756 800 sum/year.
82.7 kW x 7008 moto/h.year x 800.0 sum = 463 649 280 sum/year.

RESULTS AND DISCUSSION

The cost of energy saved in one year is 24,107,520 sums/year (Table 1).

Table 1. Comparison table of annual energy savings

№	Pump names	Brand electric engine	Power consumption, kW	Time utilization ratio	Annual operating hours	Electricity tariff, soum	Electricity costs, soums
1	1Д315-71	АИР280S2	87	0,8	7008	800,0	487 756 800
2	Д315-71SM	АИР250М2	82,7	0,8	7008	800,0	463 649 280

RESULTS AND DISCUSSION

If 40 pumps are supplied to the operation process from this pump in one year:
4.3 kW x 40 pcs. x 7008 moto/h.year x 800.0 sum = 964 300 000 sum/year.
The expected annual economic benefit from electricity costs is ~ 964 million soums. The Russian-made 1D315-71 pump was purchased in the Republic of Uzbekistan for 48,800,000 soums. The cost of the D315-71SM pump manufactured by "SUVMASH" JSC
34,947,979 soums were issued.
Thus, we reduce the cost by 28.4% - 13,852,021 soums.
48,800,000 x 40. = 1,952,000,000 sums
34,947,979 x 40. = 1 397 919 160 sums
The expected annual economic effect at the cost is 554,080,840 soums.
Annual expected total economic effect:
964 300 000 + 554 080 840 = 1 518 380 840 sums (~ 1518 million sums).

RESULTS AND DISCUSSION

Increasing the technical efficiency of the pump has reduced the energy required to operate it. This led to significant energy savings and reduced pump operating costs. Research and development, analytical analysis, experimental studies and construction drawings of the pump flow section have helped to increase the pressure and water consumption efficiency of the pumps, while reducing power consumption and ensuring long years of trouble-free operation[25]. Such activities help to identify and eliminate any design flaws or inefficiencies in the pump flow, optimize the flow and components, and ensure that the pump operates at peak performance with minimal energy consumption or wear. In addition, the use of advanced materials, manufacturing processes and quality control measures further increase the durability and reliability of the pumps, while reducing long-term maintenance and repair costs, which ensures a more economical and stable operation of the pumps.

CONCLUSIONS

1. Deficiencies in providing the fraction of particles in the flow field have been a significant limitation in advanced studies. Overcoming this problem has led to more accurate and reliable predictions of processes in the flow field.
2. It is very important to conduct a cost-benefit analysis when improving the flow section of the pump. Ensuring that the benefits in terms of increased efficiency and reduced operating costs outweigh the costs associated with implementing the improvements.
3. As a result of the conducted research, it was clear that the cost of energy saved per year from one pump was 24,107,520 soums/year. Improving the technical and economic efficiency of the pump has reduced the energy required to operate it. This led to significant energy savings and reduced pump operating costs.
4. Our republic has the capacity to produce some hydraulic machines and their parts. However, their sales system does not meet the requirements of the time. Therefore, it is important to expand support for the purchase of local hydromachines, to attract clusters and farmers, and to form orders in this regard.
5. The improvement of the flow field of the pump should be carried out in a sustainable manner. This means taking into account the environmental impact of the materials used and the energy consumed by the pump.

CONCLUSIONS

6. These seven aspects provide a comprehensive approach to improving the flow section of the pump, which leads to increased technical and economic efficiency. This is a multidimensional task that requires a balance of knowledge in fluid dynamics, materials science, and economic analysis. The benefits of such improvements are significant, resulting in energy savings, lower operating costs and more stable performance.
7. In order to reduce wear and tear in pumps and achieve energy savings, reducing the resistance to the flow moving inside the pump depends on the correct selection of the shape of the impeller and spiral chamber, as well as on the required level of preparation.
8. In order to determine the risk of the data obtained by software calculation, research studies were conducted to study the field of flow of "K and D" type centrifugal pumps used in production, software and structural drawings were compared and analyzed, and deficiencies were identified.
9. The above-mentioned aspects provide a comprehensive approach to the improvement of the flow section of the pump, which leads to an increase in technical and economic efficiency. This is a multidimensional task that requires a balance of knowledge in fluid dynamics, materials science, and economic analysis. The benefits of such improvements are significant, resulting in energy savings, lower operating costs and more stable performance.

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Questions?

Thank you for your attention!

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