

## ANNOTATION

for the dissertation for the degree of Doctor of Philosophy (PhD)  
8D07110 - "Digital engineering of machines and equipment"

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### IMPROVEMENT OF DESIGNS OF TURBOMACHINES WITH COAXIAL POSITION OF IMPELLER WHEELS

#### **Assessment of the current state of the scientific and technical problem being solved**

The improvement of modern designs of turbomachines follows the path of further increase in power density, while at the same time tightening the requirements for energy efficiency, reliability and service life. The solution of these problems is accompanied by the application of the principles of multi-cascade, modularity, complication of geometric shapes, etc.

The analysis of the operation of existing designs of turbomachines revealed the presence of a significant number of shortcomings in their operation. These shortcomings are expressed in the form of: a narrow range of effective operation, low energy efficiency of operation in off-design modes, imperfection of multi-stage structures, namely the presence of elements with a high value of hydraulic losses (transfer channels and guide devices), low efficiency of installations when they work together.

#### **Rationale for the need for this research work**

Currently, in order to eliminate the existing shortcomings in the design of turbomachines, many researchers are taking the path of improving structural elements (case, impellers, guides, control devices) or drive systems. However, it should be noted that the introduction of such technical solutions can only slightly increase the efficiency of this type of installations. To further expand the area of effective use of installations, in the conditions of a frequently changing technological process, it is necessary to search for new ways and methods for improving the designs of turbomachines.

One of these ways can be the application of the principle underlying the operation of coaxial turbomachines, namely in multistage structures, where the movement of the fluid flow (water, air, gas) is carried out directly from wheel to wheel without the use of intermediate transfer channels and guide devices.

**Scientific research on the topic of the dissertation** was carried out as part of experiments at the Magnitogorsk State Technical University named after G.I. Nosov (Protocol of the technical council dated 17.08.2022).

#### **Information about the planned scientific and technological level of development, about patent research and conclusions from them**

The scientific and technological level of developments in the dissertation corresponds to world trends, and the results surpass in many respects the existing level of known developments: on the research topic, an analysis was carried out based on research conducted in a depth of 10-15 years, which showed the absence of similar studies. According to the results of research on the topic of the dissertation, the following:

1) The research results were accepted for implementation in JSC "Kelet" for practical implementation in the development of terms of reference for the modernization of centrifugal pumping units with coaxial arrangement of workerswheels (Act of implementation).

2) The main provisions and recommendations are introduced into the lecture courses of the disciplines "Methodical principles and solutions in the design of mining machines and stationary installations", "Modeling of the working processes of mining machines and equipment", "Machines and equipment of continuous operation", included in the curriculum of the masters of

the direction of training 7M07111 - Digital engineering of machinery and equipment and students of the specialty 6B072400 - Technological machines and equipment KazNRTU named after K.I. Satbayev (Act of implementation dated 17.06.2022).

2) Methodology for designing turbomachines with a coaxial arrangement impellers are used in the educational process of the Magnitogorsk State Technical University (Act of implementation).

#### **The relevance of research**

The relevance of the topic of experiments lies in the fact that at the moment the lack of methods for calculating multi-stage turbomachines with coaxial arrangement of impellers and the experience of experimental studies does not allow us to qualitatively and quantitatively evaluate the energy efficiency of turbomachines with this design technological design.

The specificity of the use of turbomachines by industrial enterprises lies in the manifestation of non-stationary (freelance) operating modes, the operation in which leads the pump to increased loading of its design.

Thus, a complex of theoretical and experimental studies of the influence of non-stationary operating modes on the operational reliability of turbomachines and the development of scientifically based recommendations aimed at eliminating the negative impact of modes are an urgent scientific and practical task.

**The purpose of the work** is to increase the efficiency and energy efficiency of turbomachines by improving their design and technological schemes and operating modes with coaxially mounted impellers.

**Job idea** is that the increase in the performance and energy efficiency of turbomachines is achieved by substantiating rational technological and geometric parameters and operating modes of turbomachines with coaxial arrangement of impellers, excluding pressure losses and braking of the fluid in the stationary elements of the turbomachines.

#### **Research objectives:**

- Analysis of existing criteria for choosing the geometric parameters of turbomachines;
- Study of the energy exchange process in the interblade space of turbomachines based on well-known mathematical models and theories describing the movement of a fluid flow;
- Development of a methodology for designing the design parameters of a turbomachine with a coaxial arrangement of impellers;
- Development of an algorithm for selecting rational operating modes and values of the design geometric parameters of turbomachines for the conditions of mining and metallurgical and oil production;
- Manufacturing full-scale models to perform experimental studies to establish pressure-flow and mechanical characteristics, as well as to evaluate the efficiency of turbomachines with coaxial arrangement of impellers.

#### **Scientific provisions submitted for defense:**

1. The reduction of hydraulic energy losses due to the exclusion of systems of transfer channels, guide vanes and straighteners is achieved by establishing patterns of energy exchange of fluid in the interblade space of turbomachines with coaxially located impellers, which makes it possible to reduce hydraulic losses by up to 23%.

2. Expansion of the range of energy efficient operation of turbomachines with coaxial arrangement of impellers by 56% and maximum efficiency values is achieved by a rational ratio of operating modes and values of the geometric parameters of the impellers.

3. The magnitude of energy exchange and efficiency of turbomachines with coaxial arrangement of impellers is determined by the degree of reaction of the blades at the outer stage of the installation.

#### **Scientific novelty of research results** is as follows:

1. A mathematical model of the process of energy exchange in the interblade space of coaxially located impellers has been developed, taking into account the mutual influence of the

impellers on each other.

2. For the first time, analytical dependences of energy losses in impellers on the change in the speed of the fluid flow during its deceleration and acceleration in coaxially located impellers have been established.

3. Rational values of geometric parameters and modes of operation of coaxially located impellers of turbomachines have been established, which allow achieving a reduction in hydraulic losses by 23%, and also contribute to an increase in the output pressure-flow parameters of the supercharger - in terms of pressure up to 75%, - in terms of flow up to 60%, at constant overall dimensions of the installation.

#### **The practical significance of the work**

1) For the first time, a method for designing turbomachines with a coaxial arrangement of impellers has been proposed and scientifically substantiated, which makes it possible to select the geometric and regime parameters of their operation.

2) The relative discrepancy between the obtained experimental and theoretical data is no more than 10%.

3) The developed method for calculating the flow parts of turbomachines based on the optimization of algorithms for simulation-mathematical models of fluid hydrodynamics using the Ansys software package can be recommended to design organizations, research institutions and manufacturing enterprises for use in the design, operation and improvement of turbomachines at the stage of their design.

#### **Methodology and research methods**

The methodology of theoretical, mathematical analysis and methods of the theory of reliability and processing of statistical and experimental data of studies in laboratory conditions are used.

Modeling of oscillatory processes in turbomachines with coaxial arrangement of impellers was carried out using numerical three-dimensional hydrodynamic models. The work was carried out using the numerical method of finite volumes. The calculations were carried out using the Ansys CFXu Flow Vision HPC engineering analysis systems.

**Applicant's personal contribution** consists in analyzing and summarizing the results of the performed research, formulating the purpose and objectives of the research; development of a mathematical model to determine the rational geometric and operating parameters of turbomachines with coaxial arrangement of impellers; carrying out a full cycle of full-scale experimental studies.

#### **Processing of research results**

Experimental studies were carried out:

1) With the use of laboratory stands of the department "Mining machines and transport and technological complexes" of the Magnitogorsk State Technical University in his dissertation work, experimental work was carried out;

2) Processing of experimental data was carried out in accordance with the algorithm for processing deterministic and stochastic data, taking into account the limiting absolute error (Appendix 3).

3) Based on the processing and analysis of experimental data, the following results were obtained:

- The reliability of the performance of turbomachines with coaxial arrangement of impellers was determined;

- It is proved that the expansion of the range of energy-efficient operation of turbomachines with coaxial arrangement of impellers is achieved by establishing rational geometric parameters and modes of operation of the pump with coaxial arrangement of impellers (rotation of impellers in one and opposite directions).

**Approbation of work.** The main provisions and scientific results were discussed at international scientific and technical conferences:



1) At the technical seminars of the department "Technological machines and transport" KazNRTU named after K.I. Satpaev and the Department of Mining Machines and Transport and Technological Complexes of the Magnitogorsk State Technical University;

2) Ways to reduce hydraulic losses in pumps designed for pipeline transportation of liquids (conference) Electronic Proceedings of the International Scientific and Practical Conference "XIII International Scientific Conference "Transport problems". 2021. Pp. 1-14, ISBN 978-83-959742-1-2 A. Sładkowski, S. Podbolotov, A. Kolga, I. Stopovskikh;

3) Improvement of control systems for hydraulic drives of technological machines (conference, article) Electronic 4th International scientific and technical conference "Innovative development of resource-saving technologies and sustainable use of natural resources", Petroșani, Romania, Volume 4, 2021, pp . 194-196, ISSN 2734-6935, ISSN-L 2734-6935 AD Kolga, I.P. Golchak;

4) Increasing the energy efficiency of turbomachines based on the modification of the elements of their flow path (Conference) of the KazNRTU named after K.I. Satbayev, Almaty, 2022 Russian language; Volume 1;

**Publications.** Based on the materials of the dissertation, 2 articles were published in publications peer-reviewed by the international reference databases Scopus and Web of Science, 2 articles in journals included in the list of publications recommended by the Control Committee of the Ministry of Education and Science of the Republic of Kazakhstan, 4 reports at international conferences.

#### **Contribution of the dissertation student to the preparation of publications**

1. Ways to reduce hydraulic losses in multistage centrifugal pumping equipment for mining and oil-producing industries. Selection of materials for the review, writing a review and introduction, processing and description of the results of experiments, writing a conclusion.

2. "Choosing the flow part geometric shape of the dredge pumps for viscous fluid" Search for publications for a review and its writing, writing sections: research methodology, research results, design of graphs, responses to reviewers' comments.

3. Switching of hydraulic lines according to the method of electrohydraulic analogy. Section writing: introduction, research methodology, mathematical processing and discussion of experimental results, article design.

4. **Improving the design of turbomachines.** Drawing up an article plan, writing sections: discussion of research results and conclusions, article design

5. **Ways to reduce hydraulic losses in pumps designed for pipeline transportation of liquids**// "XIII International Scientific Conference "TRANSPORT PROBLEMS". – Katowice, Poland. Development of a report plan, selection and systematization of materials, writing two sections, presentation at a conference.

6. **Improvement of control systems for hydraulic drives of technological machines**4th International scientific and technical conference "Innovative development of resource-saving technologies and sustainable use of natural resources". Petroșani, Romania - 2021. Development of the report plan, selection and systematization of materials, writing two sections, presentation at the conference.

7. Improving the design of the valve assembly of sucker rod pumps // Proceedings of the Satpaev Readings. - Almaty, 2020. Development of a report plan, selection and systematization of materials, writing two sections, presentation at the conference.

8. **Increasing the energy efficiency of turbomachines based on the modification of the elements of their flow path** // Proceedings of the international scientific and practical conference "Satbayev conference - 2022. Trends in modern scientific research". – Almaty, 2022. Development of a report plan, selection and systematization of materials, writing two sections, presentation at the conference.

#### **The structure and scope of the dissertation**

The dissertation consists of an introduction, 4 sections and a conclusion, set out on 120 pages, contains 70 figures, 20 tables, a bibliography of 41 titles and 3 appendices.