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APPLICATION OF DIGITAL TECHNOLOGIES IN PROCESS RESEARCH AND DESIGN OF FLOW PARTS OF STEAM TURBINES

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Abstract. *The paper highlights the main application of digital technologies in the study of processes in the design of the flow parts of steam turbines. Reviews of studies in this area have been carried out. The use of digital technologies for design and production significantly reduces the time required to introduce new technical solutions when upgrading existing equipment with long service life, as well as to create promising competitive designs of new generation steam turbines.*

Key words: *digital technology, steam turbines, turbine unit, flow path, power, gas turbine.*

ПРИМЕНЕНИЕ ЦИФРОВЫХ ТЕХНОЛОГИЙ В ТЕХНОЛОГИЧЕСКИХ ИССЛЕДОВАНИЯХ И ПРОЕКТИРОВАНИИ ПРОТОЧНЫХ ЧАСТЕЙ ПАРОВЫХ ТУРБИН

Аннотация. *В работе освещены основные области применения цифровых технологий при исследовании процессов проектирования проточных частей паровых турбин. Проведены обзоры исследований в этой области. Использование цифровых технологий для проектирования и производства значительно сокращает сроки внедрения новых технических решений при модернизации существующего оборудования с длительным сроком службы, а также для создания перспективных конкурентоспособных конструкций паровых турбин нового поколения.*

Ключевые слова: *цифровая технология, паровые турбины, турбоагрегат, проточная часть, мощность, газовая турбина.*

The use of digital technologies for design and production significantly reduces the time required to introduce new technical solutions for the modernization of existing equipment with a long service life, and also creates promising competitive designs for the next generation of steam turbines [1- 6]. The results of calculation and experimental studies carried out at NRU MPEI show that it is possible to increase the power of the turbine unit by 8-10% due to the improvement of the aerodynamic properties of parts and aggregates of flow paths. in the initial state of the flow path. In addition, necessary work can be done at power plants during scheduled maintenance companies.

The maximum total increase in power can be obtained by upgrading the following elements of the flow path:

* scapular apparatus;
* over-shroud, diaphragm, end seals;
* systems for removal and destruction of coarse moisture;
* designs of valves, branch pipes, steam pipelines.

Figure 1 shows the interface of the program for automated profiling based on Bezier polynomials of turbomachine lattices, developed at the NRU MPEI at the Department of Steam and Gas Turbines.

The use of similar methods in the "manual mode" for the re-profiling of the first three stages of the medium-pressure cylinder of an 800 MW turbine made it possible to increase the efficiency of the compartment by 2.4%.

The increase in efficiency was achieved by changing and smoothing the values of the curvature of the contours of the profiles of the nozzle and working gratings, minimizing the length of sections flown around with a positive pressure gradient, and forming an optimal change in the velocity gradient along the streamlined surface.

A promising method for profiling nozzle arrays is the use of a variable angle of flow exit to redistribute the flow rate along the height of the array. By reducing the exit angle of the flow near the meridional contours, the flow rate through sections with maximum end losses is reduced, and, consequently, power losses are reduced. Increasing the outlet angle of the flow in the middle part of the profile - the core of the flow - leads to an increase in the flow rate in the part of the grid with minimal losses. As a result, at constant values of the total flow, the useful power of the stage increases. Calculations show that up to2.0% increase in the power of the stage is achieved due to the application of the profiling method under consideration.

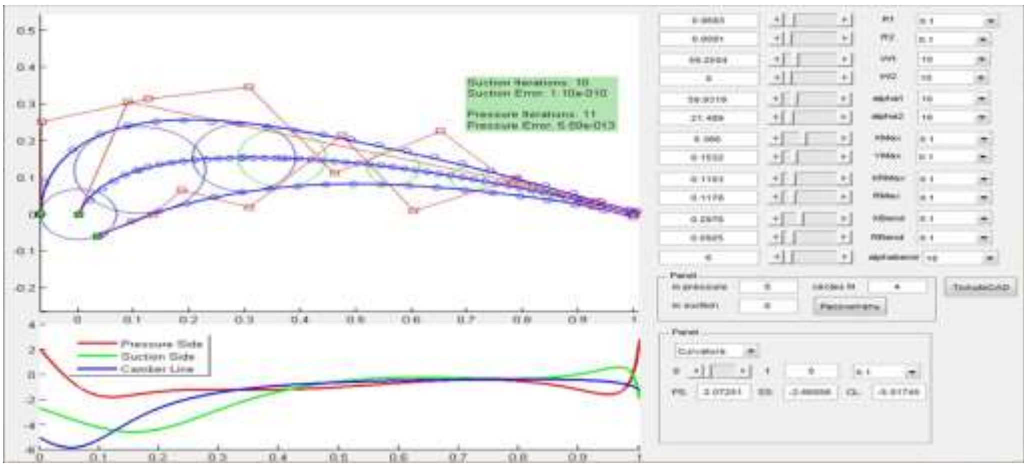

Figure 1. Interface of the automated profiling program

A significant reduction in stage losses is also possible by reducing steam leakage through the seals. The average calculated values of the increase in power due to the reduction of losses from leaks are:

– in the high pressure cylinder ~0.8%; – in the medium pressure cylinder ~ 0.6%; – in the low pressure cylinder ~ 1.4%.

At the MPEI pilot plant, together with the Department of Steam and Gas Turbines, models were developed and manufactured for testing seals of a new design - "cellular" seals (Fig. 2), an analogue of those widely used both for modernization and in new conditions structures of steam turbines with honeycomb seals.

The results of the tests performed showed good results, confirming the competitiveness of the proposed technical solution. Significantly reduced the cost of manufacturing seals; the values

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of leakage of the working fluid and the level of aerodynamic exciting forces do not exceed the values characteristic of honeycomb seals.

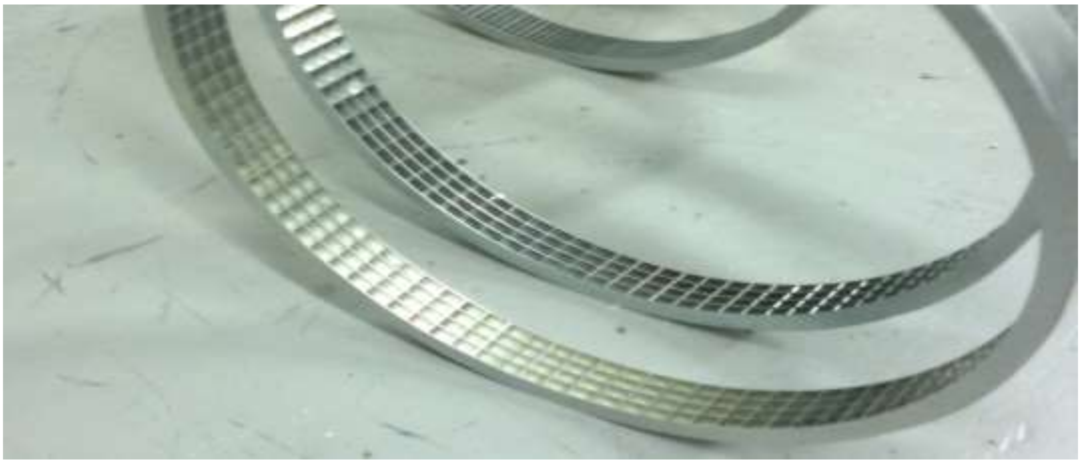

Figure 2. Models of "cellular" seals

The results of the experiments showed the possibility of using honeycomb, cellular seals for moisture separation in the last stages of the low-pressure cylinder of TPP turbines and in the flow parts of NPP steam turbines. To carry out comprehensive research, characteristics and improvement of seal designs, a special stand has been developed that allows testing different types of seal models both in air and in steam with different humidity values (Fig. 3)

Fig 3. Stand for testing models of seals

The use of digital technologies in testing elements of the flow parts of steam turbines significantly expands the possibilities of studying gas-dynamic, thermal thermodynamic processes, which creates a reliable basis for verifying the results of calculations and switching from using standard computer systems, for example, ANSYS to homemade codes.

By home code, we mean calculation programs debugged on the basis of experimental data and tests of elements of flow parts.

The development of such codes is fundamentally important for the application of calculation methods in the design of almost all elements of the flow path. Comparison of

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calculation results and experimental results shows that "standard" programs can have significant errors and unacceptably large discrepancies when compared with the results of full-scale tests and experiments.

As a rule, the maximum deviations were recorded in areas of the flow path that are significant for the occurrence of aerodynamic forces and losses, and, therefore, fundamentally important from the point of view of the reliability of the results obtained. The main problems in carrying out calculations arise in channels with limiting values of a positive pressure gradient for continuous flow, transonic flow velocities, developed zones of flow separation, and high values of humidity.

In the zone of phase transitions at transonic and supersonic flow velocities, there is an intense interaction of shock waves and condensation with non-stationary changes in flow parameters and the appearance of additional dynamic forces on the elements of the flow path.

Inadmissibly large errors in modeling processes in wet steam in some cases led to accidents on operating equipment. There is a case when, justified by calculations, changes in the angle of installation of the working blade of the last stage of a turbine with a power of 300 MW, operating in wet steam, by only three degrees, led to the occurrence of self-oscillations with the destruction of the blade apparatus.

Comparison of the results of calculations for "problem" options with the data obtained on model and full-scale experimental stands, followed by changes in the calculation programs, makes it possible to develop "home" codes necessary for the application of sound technical solutions in the design of equipment.

The use of digital technologies has significantly expanded the possibilities of studying thermophysical processes in the flow parts of turbomachines. The Moscow Power Engineering Institute (NRU MPEI) has an excellent base for testing and aerodynamic debugging of steam turbine equipment: the MPEI training and experimental CHPP.Figure 4 shows a thermal diagram of one of the stands for studying the elements of the flow parts of steam and gas turbines. A feature of the thermal scheme of the stand is the ability to control and select the parameters of the working fluid not only at the flow inlet, but also at the outlet of the model under study, which allows you to independently change the Mach numbers and Reynolds numbers during experiments.

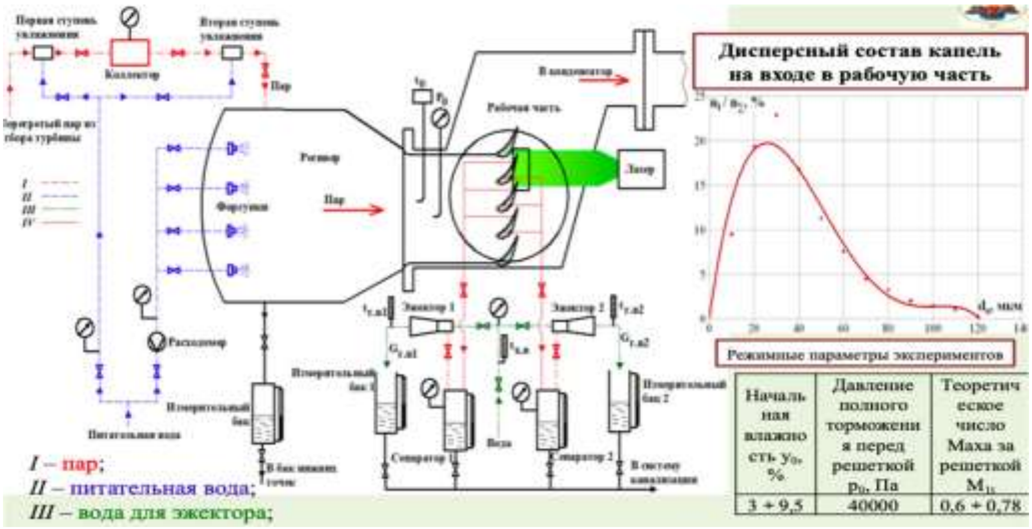

Fig. 4. Thermal scheme of the stand for studying the elements of the flow parts of steam and gas turbines

In the thermal scheme, a developed system for preparing the working fluid is made, which provides superheated, saturated or wet steam with specified parameters at the entrance to the model under study. Depending on the problem being solved, the flow velocity can vary over a wide range from subsonic to supersonic values. In conclusion, we formulate the main directions of promising developments using digital technologies in the aerodynamics of the flow parts of steam turbines.

Development of home codes for 3D design of the blade apparatus, taking into account the peculiarities of the movement of the liquid phase. Reducing aerodynamic energy losses and increasing the reliability of elements of the flow parts of turbines: steam intake systems, seals, transition and exhaust pipes.

Experimental study of new designs of the exhaust compartment with increased throughput. Development of standard designs of the exhaust compartment for powerful steam turbines with rotor blades limit length. The exhaust compartment consists of the last two stages and a diffuser exhaust pipe. The final stage of development is testing on a full-scale test bench of the plant. Development and application of effective methods for reducing the dispersion of the wet steam flow, as well as improving systems for separating moisture from the flow path of a steam turbine.

REFERENCES

1. Костюк, А.Г. Насущные проблемы отечественного паротур-бостроения // Теплоэнергетика. – 1997. – №1. – С. 2–8.
2. Дейч, М.Е. Исследование и расчет ступеней осевых турбин / М.Е. Дейч, Б.Н. Трояновский. – М.: Машиностроение, 1964.
3. Грибин, В.Г. Прямоугольно-ячеистые уплотнения для паровых турбин / В.Г. Грибин, С.С. Дмитриев, Б.Н. Петрунин и др. – Известия высших учебных заведений. – Машиностроение, 2017.
4. Грибин, В.Г. Влияние геометрических характеристик корпуса выхлопного патрубка конденсационной паровой турбины на экономичность выхлопа / В.Г. Грибин, А.Н. Парамонов, О.М. Митрохова // Thermal Engineering. – 2018.
5. V.G. Gribin., A.A. Tishchenko, I.Yu. Gavrilov, V.A. Experimental study of into channel separation in a flat nozzle turbine blade assembly in wet
6. steam flow // Power Technology and Engineering. – Vol. – 50. No. – 2. – 2016. P. 180–187.
7. Зарянкин, А.Е. Основы физического моделирования, элементы теории размерностей и примеры ее практического использования в задачах гидрогазодинамики / А.Е. Зарянкин. – М.: Издательский дом МЭИ, 2017. – 121 с.