**TURBOMACHINES AND COMBINED TURBINE** GENERAL DESCRIPTION OF THE DISCIPLINE

The work programme of the discipline is compiled according to the Federal State Higher Professional Education Standards

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| --- | --- | --- | --- |
| Code of the field of study and attainment level | Field of study | Details of the order of the Ministry of Education and Science of the Russian Federation on approval and commissioning of the Federal State Higher Educational Standard | |
| Date | Number o order |
| 13.06.01 | Power Engineering and Electrical Engineering | 30 July 2014 | 878 |

## Abstract of the discipline content

The discipline falls under the post-graduate programme. The main goal of studying the discipline is the creation of some basic knowledge and practical skills for postgraduates, which allow analysing the problems of science and production in the power engineering industry at the modern level (meeting the up-to-date requirements) with the aim of improving it.

The discipline programme is developed on the basis of qualifying examinations for the PhD degree in the specialty prepared by the expert council of the Higher Attestation Commission for Energy, Electrification and Power Engineering of the Ministry of Education of the Russian Federation with the participation of the All-Russia Thermal Engineering Institute (VTI JSC), the N.E. Bauman Moscow State Technical University and the Moscow Power Engineering Institute (Technical University). The programme is based on the disciplines of the Thermal Engineering and Electrical Engineering specialty *Gas Turbine, Steam Turbines and Motors* related to the features of analysis, synthesis and technical use of turbomachines and turbines, aggregates and auxiliary equipment used in power plants and transport.

## Discipline mastering outcome planned

The discipline results in generating the competencies by students as follows:

* the ability to critically analyse and evaluate current scientific achievements, generate new ideas for solving research and practical problems, also in inter-disciplinary areas (UC-1);
* the ability to design and carry out complex research, including that of the inter-disciplinary nature, based on an integral systematic scientific worldview by using the knowledge in the field of history and the philosophy of science (UC-2);
* the theoretical and experimental research methodology in the professional activities (GPC-1);
* the research culture, also by making use of the latest information and communication technologies (GPC-2);
* the ability to develop new research methods and use them in independent research activities in the professional activities (GPC-3);
* readiness to arrange for the work of a research team in the professional activities (GPC-4);
* the ability to demonstrate basic knowledge in the natural science disciplines and readiness to use the key professional activity laws, apply methods for the mathematical analysis and modelling, theoretical and experimental research (PC-1);
* the ability to conduct kinematic and dynamic analysis and synthesis of up-to-date machine tools, robotics, information, measurement and diagnostic systems, automation and process equipment control systems in heat power engineering (PC-2);
* the ability to develop technical terms of reference (ToR) and feasibility studies for the development of scientific products for the heat and power industry, the provision of production and engineering processes, and the development of quality indicators for products and processes in accordance with the existing national and international regulatory framework (PC-3)
* knowledge of the software of up-to-date production systems, knowledge of programming languages in the design and technology of production preparation, automated product design tools as well as production and engineering processes and systems (PC-4)
* the readiness to use most recent achievements in science and advanced technologies in the turbo machinery and units (PC-7)

As a result of mastering the discipline, a post-graduate student should:

Know:

- the principles of operation of the main and auxiliary equipment of power plants

- the prospects and trends in power engineering and turbine installations

- the contemporary trends in and methods for designing and improving the efficiency, reliability and safety of power plants

- the fundamentals of contemporary methods for the technical and economic analysis in relation to the power engineering challenges.

Be able:

- to analyse the information received from power engineering facilities and take reasonable technical decisions based on it;

- to identify possible solutions for improving turbo machinery and power plants at various stages of their life cycle

Demonstrate skills and experience:

- in the design and operation of turbo machinery.

## Scope of the discipline

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| --- | --- | --- |
| **Types of educational activity, forms of control** | **Total, hours** | **Term,**  **number** |
| **6** |
| **In-class learning, hours** | **4** | **4** |
| Lectures, hours | 4 | 4 |
| Practical exercises | - | - |
| Laboratory research | - | - |
| **Self-guided** **of graduate students including all the types of the current attestation** | **104** | **104** |
| **Interim attestation** | - | **Exam** |
| **Total work input by curriculum, hours** | 108 | |
| **Total work input by curriculum, credits** | 3 | |

# DISCIPLINE CONTENT

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| --- | --- | --- |
| Section and subject code | Section, subject of  the discipline | Content |
| P1 | **Thermal cycles of turbine units.** | Schematic diagrams and thermal cycles of steam and gas turbine plants for power plants operated with the organic and nuclear fuels. The combined cycles and schemes of combined-cycle plants. The thermal efficiency of plants and methods for improving it. The combined heat and electric power generation. The prospective cycles and schemes of turbine and combined plants for power plants operated with the organic and nuclear fuels. |
| P2 | **Fluid and gas mechanics** | Kinematics of the continuous medium. The motion of a small particle of a fluid and Helmholtz’s theorem on the motion of a liquid in the general case. Potential and vortex motions in a fluid. A current line and a vortex line. Methods for studying the motion of a liquid. Circulation of speed. The Bio-Savart law.  Basic equations of the fluid motion. Equation of continuity. Flow equation. Equations of motion in the form of Euler, Gromeko-Lamb and Navier-Stokes. Integral equations of motion for an ideal fluid. Equation of energy and its shape. One-dimensional flow diagram. Equations of the one-dimensional flow. Full braking parameters. Speed of sound and critical speed. Relationship between dimensionless flow parameters with dimensionless velocities and?. Critical parameters. Conditions for transition through the speed of sound. The reduced flow rate and the specific reduced flow rate. Gasdynamic functions. Averaging non-uniform flows and their reduction to a one-dimensional flow pattern.  Potential currents. Plane potential flows of an incompressible fluid. The complex potentials of elementary flows and their use for calculating potential currents. Equation for calculating velocity in a compressible flow. The equation of N.E. Zhukovsky on the lifting force. The postulate of Chaplygin-Zhukovsky.  Supersonic flows. The features of supersonic flows. The characteristics in the plane of flow and in the plane of the velocity hodograph. The diagram of characteristics and its use for supersonic flows. Occurrence of shock waves. Direct compression shock and its calculation. The shock polar diagram. Energy loss in shock waves.  Expiration from nozzles and non-profiled apertures. Variable modes of converging nozzles. The Laval nozzle and the diagram of the variable modes of Laval nozzles. The profiled nozzles of Laval. Expiration from unprofiled holes. Flow coefficients for flow out of slits with a sharp edge. The theory of similarity and dimensions. The problems of the theory of similarity. The coefficients of similarity and the number of similarity. π theorem. The condition of physical similarity of the flow. Similarity criteria. Complete and partial simulation.  The flow of a viscous fluid. Exact solutions of the Navier-Stokes equations. Laminar and turbulent flow types. Methods for averaging turbulent flows and their key characteristics. The Reynolds equation. The boundary layer. Ways of solving equations for the boundary layer. Turbulence models. Separation of the boundary layer and ways to prevent it. Numerical solutions of fluid mechanics problems.  The flow of two-phase and two-component media. The features of two-phase flows. The homogeneous flow with a constant concentration of the second phase. The homogeneous flow of liquid with gas bubbles. The flow of a two-phase medium with phase equilibrium or complete supercooling. Thermal jumps and condensation jumps. |
| P3 | **Stage of the turbomachine** | The energy conversion in the turbine and compressor stages. The computation of the turbine and compressor stages. Features of designing steps of great fan. Speed stages, radial, radial-axial and diagonal stages. Two-level stages. The efficiency of the turbine and compressor stage. The main types of losses in the stage. The influence of the basic geometric and regime parameters on the efficiency. The degree of reactivity and the rate of flow of the stage. Effect of humidity and cooling on the main characteristics of the steam and gas turbine stage. |
| P4 | **Turbomachine lattices** | Turbine and compressor lattices, their classification. The geometric and aerodynamic characteristics of the lattices of turbomachines. The methods of plane, axisymmetric and spatial calculation of lattices. The profile and terminal losses in lattices, methods of their calculation. The lattices of steam turbines for the wet steam. Processes of non-equilibrium moisture formation in lattices. The main features of the motion of supercooled and wet steam in the lattices of steam turbines. Non-stationary flows in lattices of turbomachines. Variables, aerodynamic forces. The forced and self-excited oscillations of the working blades of the turbine and compressor. Flutter and surging. Rotating gap in the grids of turbomachines. Pulsation of pressure in wet steam flows, unsteady condensation jumps. |
| P5 | **Multi-stage turbines** | The thermal process in a multi-stage turbine. The advantages and disadvantages of multi-stage turbines. The choice of design and repair of multi-stage turbines. The limiting power of a single-flow steam and gas turbine. Ways to increase the maximum power of a turbine.  Selection of the speed, number of shafts and cylinders of a steam turbine. The technical and economic basis for choosing a turbine design. Axial forces in turbines, their calculation and methods of balancing. Shaft-end seals. Regulating valves, inlet and exhaust pipes of turbines. Erosion of cover blades. Protection of the elements of the flowing part from erosion. The separation of moisture from the flowing part of a steam turbine. Remote separators-steam superheaters of turbines of nuclear power plants (NPP). |
| P6 | **Calculation and design of multi-stage compressors** | Multistage axial compressor. The effect of losses in the nozzles on the efficiency and pressure of a compressor. Unstable modes in compressor operation. The universal characteristic. Modelling of compressors. Multi-stage centrifugal compressors. The choice of the optimal geometric dimensions of the centrifugal compressor stages. Profiling impellers and blade diffusers. |
| P7 | **Variable mode of operation of turbines** | Gasdynamic similarity. Variable stage operation mode. The generalised characteristics of turbine stages. The distribution of pressures over the stages when the turbine operating mode changes. The effect of changing the operating mode on the turbine efficiency. The features of the last stages of the condensation turbine when changing the volume pass of steam. The steam distribution system. A change in the load of a steam turbine by the sliding pressure method. Methods for calculating turbines under variable operating conditions. Contamination of the flowing part.  Variable operation mode of a gas turbine unit (GTU). Ways to change the operating mode of GTU. Coordination of the operating modes of turbomachines. Representation of characteristics by similarity methods. Dependence of GTU indicators on the load and temperature of the outside air, its cycle and scheme. The diagram of GTU modes. The GTU starting mode, starting devices. |
| P8 | **Turbines for the combined heat and power generation** | Turbines with back pressure, with an intermediate adjustable steam sampling. Stage heating of water. Diagrams of turbine operation modes. The use of heat for heat and nuclear power plants for heat. |
| P9 | **Heat transfer in turbomachine elements** | Basic equations of heat conduction and convective heat transfer. Heat transfer during phase transformations. Heat transfer with penetrating cooling and gas curtains. Temperature distribution in cooled turbine blades, rotors and housings. Methods for solving heat conduction and heat transfer problems with reference to the main parts of turbines. The constructions of cooled blades of gas turbines. |
| P10 | **Dynamics and strength of the parts of steam and gas turbines** | Reliability of turbines as the main precondition for their manufacture, installation and operation. Materials used in turbine construction. The operating conditions of metals in steam and gas turbines. The properties of steels and alloys used in turbine construction, and the requirements for them. Processes that accompany the operation of metals at high temperatures, long-term operation and variable loads. Corrosion fatigue and stress corrosion cracking in turbine elements under the influence of aggressive impurities in the vapour. Corrosion of gas turbine blades, protective coatings. Working blades, their vibratory strength. Ensuring the vibratory reliability of the scapula. Disks, their strength and vibration. Vibration of rotors and foundation. Low-frequency vibrations of rotors. The technique of numerical analysis and calculation of the stressed state of turbine parts. Hydrodynamic forces in steps, seals and bearings. Maneuverability of turbines. Thermal stresses in turbine details, thermal fatigue. |
| P11 | **Regulation of turbines** | Principal schemes for regulating steam and gas turbines. The static control characteristics. The parallel operation of turbogenerators. Mathematical description of the turbine control system. The stability of the turbine control system. Transient processes in turbine control systems. The use of computer technology for the analysis of transient processes in the turbine control system and synthesis of the control system. The mechanism to control a steam condensing turbine. The features of turbine control for the combined heat and power generation. GTU regulation. Gas and power temperature regulators. The regulation of power units of thermal power plants and nuclear power plants. Protective devices of turbine installations. The use of digital and microprocessor-based systems for turbine plant control. Automation of the start-up of a turbine unit. Automatic control systems. |

**3. PROCEDURES FOR MONITORING AND EVALUATING THE RESULLEARNING OUTCOMES**

Based on the results of studying the discipline, an examination is conducted, which is of the PhD level in the specialty. The exam is taken by a commission consisting of teachers of the Chair providing the Principal Educational Programme in the area of focus approved by an order of the UrFU rector.

Questions for the exam are prepared according to the discipline content (see Section 2)

Databases, information and reference systems and search systems

1. http://www.google.com and others.

2. The official website of the Ministry of Energy of the Russian Federation: http://minenergo.gov.ru