MINISTRY OF EDUCATION AND SCIENCE OF THE RUSSIAN FEDERATION

Federal State Autonomous Education “Ural Federal University named after the first President of Russia B.N. Yeltsin”

Institute of New Materials and Technologies

Signed and Approved

Vice-rector for Research

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ V.V. Kruzhaev

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COURSE PROGRAM

**MODERN RESEARCH METHODS OF PROCESSES**

**IN PYROMETALLURGY**

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| **The list of information about the work program of the discipline** | **Credentials** |
| **Educational program**  Modern research methods of processes  in pyrometallurgy | **Code of EP** 22.06.01  **Curriculum** № 6513 (version 2) |
| **Direction**  Materials technology | **Code of direction and level of preparation** 22.06.01 |
| **Level of preparation**  Training of highly qualified personnel |
| **FSES** | **Details of the order of the Ministry of Education and Science of the Russian Federation on the approval of the FSES:** № 888 of July 30, 2014, as amended on April 30, 2015 |

**Ekaterinburg**

**2018**

**1. GENERAL CHARACTERISTICS OF THE DISCIPLINE**

**1.1. Annotation of the content of the discipline**

The purpose of studying the discipline is to uncover the scientific and methodological foundations and logical prerequisites on which modern research methods of processes in pyrometallurgy, methods of mathematical modeling, as well as the formulation of optimization and optimal management of processes as applied to high temperature metallurgy processes are based.

The main task: to acquaint graduate students with the main methods used in the study of high-temperature processes, in setting up and solving problems of modeling technological systems and complexes, optimizing and optimal management, and the problems of identification and assessment applied to metallurgical aggregates and processes.

The program provides a list of topics for the formation of graduate students of scientific knowledge in the field of methodology, scientific foundations and formalized methods of mathematical modeling and process control of metallurgy.

**1.2. The language of the implementation of the discipline is Russian.**

**1.3. Planned learning outcomes of the discipline**

The result of training in the framework of the discipline is the formation of the following competencies in a graduate student:

- the ability to critically analyze and evaluate modern scientific achievements, to generate new ideas in solving research and practical problems, including in interdisciplinary areas (UC-1);

- the ability and willingness to prove theoretically and optimize the technological processes of obtaining advanced materials and the production of new products from them, taking into account the consequences for society, the economy and the environment (GPC-1);

- the ability and willingness to develop and produce technological documentation for advanced materials, new products and measures of technical quality control of manufactured products (GPC-2);

- the ability and willingness to economically evaluate the production and non-production costs of creating new materials and products, to work to reduce their cost and improve quality (GPC-3);

- the ability and willingness to comply with regulatory requirements that ensure the safety of production and operational activities (GPC-4);

- the ability and willingness to use in practice the integrated knowledge of natural science, general vocational-oriented and special disciplines for understanding the problems of materials science development, the ability to put forward and put into practice new high-performance technologies (GPC-5);

- the ability and willingness to perform theoretical and experimental research as a leading performer using computer technology (GPC-6);

- the ability and willingness to develop technological process, technological tooling, working documentation, route and operational flow charts for the manufacture of new products from advanced materials (GPC-11);

- the ability and willingness to participate in carrying out technological experiments, to carry out technological control in the production of materials and products (GPC-12);

- the ability and willingness to participate in the certification of materials, semi-finished products, products and technological processes of their manufacture (GPC-13);

- the ability and willingness to assess investment risks in the implementation of innovative materials science and design and technology projects and the introduction of advanced materials and technologies (GPC-14);

- the ability and willingness to demonstrate a systematic understanding of the current state and problems of the chosen (professional) branch of scientific knowledge (PC-1);

- the ability and willingness to conduct research in the chosen (professional) branch of scientific knowledge using modern methods and technologies (PC-2);

- the readiness to identify, develop problems using the scientific approach, conduct and implement the results of research in the selected (professional) branch of scientific knowledge (PC-3);

- the ability to critically analyze, evaluate and synthesize new ideas in the chosen (professional) branch of scientific knowledge, related fields (PC-6).

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

**Know:**

- principles of mathematical description of thermal processes, the formulation of boundary conditions and boundary problems in general;

- current trends in the improvement and development of scientific and practical methods of machine design of thermal power units;

- methods for the numerical analysis of heat and mass transfer processes.

**Be able to:**

- use other (non-analytical) methods for solving boundary value problems, the capabilities of application software (Maple, Mathcad, ANSYS, Mathematica and MATLAB packages) for solving problems of the thermophysics of metallurgical processes;

- apply computer equipment and information technology in the educational process;

- use statistical methods for processing and summarizing the results of experiments or numerical modeling of heat and mass transfer processes.

**Acquire** (demonstrate skills and experience):

- technique of the use of the experimental base and laboratory equipment of the department, technical training tools;

- skills of construction and implementation of mathematical models of pyrometallurgical processes;

- methods of intensification of heat and mass transfer processes in metallurgical furnaces.

**2. CONTENT OF THE DISCIPLINE**

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| --- | --- | --- |
| **Code of**  **sections, topics** | **Section, topic of the discipline** | **Content** |
| **Р1** | **Methodology of system analysis in the simulation of technological processes** | Modern principles of system design. Stages of system development. The main approaches to the construction of mathematical models. Stages of mathematical modeling of systems. Decomposition of the model. The structure of the elements of the model systems. The composition of the model. Identification of parameters. System-wide models. Operators transition, exit. Parameters of state, inputs, outputs. Uniqueness properties of transition and exit parameters. The tasks of diagnostics, design, control and system behavior. The concept of system models. Types of system models, their features, applications. Stationary and non-stationary. Dynamic and static. Dynamic description of information systems. Linear and nonlinear models. Deterministic and stochastic. Unit as a random process. Continuous and discrete. One-dimensional and multidimensional. Distribution and concentration of parameters. Verification and identification of mathematical models. Computational experiment in the simulation of technological processes. System-structural modeling. Principles of building a model IDEF0. Software support for standard methodologies IDEF0 (functional modeling), DFD (data flow modeling) and IDEF3 (workflow modeling). |
| **Р2** | **Deterministic approach to the construction of mathematical models of pyrometallurgical processes** | The generalized thermodynamic approach in the construction of mathematical models. General view of the laws of conservation. Characteristic macroscopic velocity and diffusion flow. Mass balance. The law of conservation of momentum. Energy balance. Entropy balance. Phenomenological laws. The generalized equation of heat and mass transfer in metallurgical units. Simplified mathematical description of mass transfer in technological processes. The use of numerical methods for the analysis and calculation of processes occurring in the production and processing of metals and alloys; methods for solving adjoint problems. Theoretical foundations of numerical methods. Identification of mathematical models. Parametric identification. Adaptive and non-adaptive algorithms. Self-tuning models. The concept of the adequacy of mathematical models of real objects. Methods for assessing the adequacy of models. |
| **Р3** | **Experimental statistical methods for the mathematical description of pyrometallurgical processes** | Development of models by passive methods according to observations of the course of normal operation of an object. Experimental determination of static models. Possibilities and areas of application of the methods of regression, correlation, analysis of variance. Experimental determination of models of dynamics by statistical methods. Modeling by active methods. Methods of structural and parametric identification. Using the theory of planning experiments to build models of technological processes. Planning experiments when searching for optimal conditions. Identification of mathematical models using signal effects of the dynamic characteristics of objects (transient, impulse, frequency). Features of identification of objects in a closed control loop. |
| **Р4** | **Optimization and optimal management of technological units and their complexes** | Mathematical programming as a method for optimizing heat engineering processes. Statement of the problem of mathematical programming. Classification of problems of mathematical programming. Problem solving problems. Process optimization using linear programming. Integer math programming. Statement and problems and algorithms for solving problems. Methods for solving problems of nonlinear mathematical programming. Dynamic programming as an optimization method. General characteristics of the formulation of problems of dynamic programming. Algorithms for solving problems. Optimization of discrete systems. Optimization of continuous systems. The principle of maximum. Formulation of the problem. The characteristic of the solution algorithm. Optimal control of systems with distributed parameters. |
| **Р5** | **Methods for analyzing heat and mass transfer processes** | Radiation heat transfer in metallurgical units Zonal methods for calculating heat transfer by radiation. The classical zone method for a system of surfaces separated by an emitting and absorbing gas in a mixed statement of the problem. The limitations of the classical method. Two approaches to solving systems of zonal equations, methods for solving. Resolvent zonal method. The difficulties of calculating the generalized resolving angular coefficients, their overcoming. Accounting for the convective component of heat transfer.  Approximate methods for solving the radiation transfer equation. Approaching an optically thin layer. Optically thick layer approximation (Rosseland approximation or diffusion approximation). Calculation schemes for heat transfer by radiation in mathematical packages and media (ANSYS, Comsol Multiphysics, etc.).  Convective and complex heat transfer.  Mathematical description of convective heat transfer. Equations of thermal boundary layer. Integral equations of the thermal boundary layer.  Free convection complicated by other types of heat transfer. Heat transfer during free convection in closed cavities. Effect of radiation on heat transfer results. Examples of the numerical solution of heat transfer problems with free convection.  Convective heat transfer when the medium moves in the variable profile channels (numerical solutions). Engineering models of turbulence. Theory of turbulence L. f. Prandtl, its limitations. Modern engineering theories of turbulence: standard k - ε model, model of the zero equation, group of models normalized by Reynolds number, new k - Ши model of Shi, model of Dzhirimey, model of Shi, Zu and Limleylla. Computational aspects of using models. Construction of a numerical model of the conjugate heat transfer problem. Using the ANSYS system (FLOTRAN, CFX, Fluent packages) for calculating flow and heat exchange parameters in complex-shaped channels. Influence of flow regime and compressibility of the medium |

**4.3.2. Indicative list of essay topics (essay, creative works)**

1. The use of computational experiment in the study of pyrometallurgical processes.

2. Zonal methods for calculating heat transfer by radiation and using them to study pyrometallurgical processes.

3. Mathematical description of convective heat transfer and their use for the study of pyrometallurgical processes

4. Methods of parametric identification of mathematical models of pyrometallurgical processes.

5. The use of a generalized thermodynamic approach in the construction of mathematical models and the study of processes in pyrometallurgy.

6. Application of modern principles of process control in objects in pyrometallurgy.

7. Modern methods of optimal management of fuel and energy resources in pyrometallurgical technologies.

8. The use of the methods of mathematical planned experiment for the study and optimization of pyrometallurgical processes and objects.

9. Modern software and integrated systems for the study of processes of heat-mass transfer and gas dynamics in metallurgical technologies.

The topic of the essay is specified taking into account the content of the planned dissertation research and is consistent with the graduate student and his supervisor.

**6.3.4. List of indicative questions for the credit**

1. Mathematical model of heat and mass transfer processes in a dense moving layer and their use for the study of pyrometallurgical processes

2. Methods of solving multidimensional nonstationary problems of heat and mass transfer and using them to study pyrometallurgical processes.

3. Solving the problem of optimizing the distribution of fuel and energy resources in metallurgy using mathematical programming methods.

4. Methods of solving problems of optimal control of metal heating in metallurgical furnaces.

5. Zonal methods of calculating heat transfer by radiation and using them to study pyrometallurgical processes.

6. Mathematical description of convective heat exchange and their use for the study of pyrometallurgical processes

7. Methods of parametric identification of mathematical models of pyrometallurgical processes.

8. The use of a generalized thermodynamic approach in the construction of mathematical models and the study of processes in pyrometallurgy.

9. Application of modern principles of process control in objects in pyrometallurgy.

10. Mathematical planning of experiments. Planning first order. Full and fractional factorial experiment.

11. Using the methods of mathematical planned experiment for the study of pyrometallurgical processes and objects. Second order planning. Orthogonal and rotatable plans

12. Modern software and integrated systems for the study of processes of heat-mass transfer and gas dynamics in metallurgical technologies

13. Zonal methods of calculating heat transfer by radiation. The classical zone method for a system of surfaces separated by an emitting and absorbing gas in a mixed statement of the problem. The limitations of the classical method.

14. General information about convective heat transfer. Mathematical description of convective heat transfer.

15. Free convection complicated by other types of heat transfer. Heat transfer during free convection in closed cavities.

16. Effect of radiation on heat transfer results. Examples of the numerical solution of heat transfer problems with free convection.

17. Convective heat transfer when the medium moves in the variable profile channels (numerical solutions).

18. Engineering models of turbulence. L. F. Prandtl’s theory of turbulence, its limitations.

19. Modern engineering theories of turbulence: standard k-ε model, model of the zero equation, group of models normalized by the Reynolds number, new k-ε model of Shi, model of Jirimey, model of Shi, Zu and Limleylla.

**7. TRAINING-METHODOLOGICAL AND INFORMATION SUPPORT OF THE DISCIPLINE**

**7.4. Databases, information and reference and search engines**

1. Official site of legal information http://pravo.gov.ru
2. Web portal of information education resources of UrFU http://study.urfu.ru/info
3. Electronic database of normative documents ГОСТЭКСПЕРТ http://gostexpert.ru
4. Search systems: www.yandex.ru, google.ru www.rambler.ru.