**HYDRODYNAMICS AND HEAT EXCHANGE IN A FLUIDISED BED**

1. 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 of order |
| 13.06.01 | Electrical- and Thermal Engineering | 30 July 2014 | 878 |

* 1. Abstract of the discipline content

The discipline studies hydrodynamics and heat exchange in a fluidised bed as well as the equipment for transferring heat and mass in fluidised bed units.

* 1. Discipline mastering outcome requirements

As a result of mastering the discipline, a postgraduate student should obtain the competences as follows:

* ability and readiness to apply up-to-date research methods, carry out technical tests and scientific experiments, evaluate the results of the work performed (Professional Competence-1);
* readiness to use the latest achievements of the contemporary science and advanced technology in research (Professional Competence-3);
* readiness to use in the practical activities the theoretical foundations of working processes in power machines, units and installations, the methods for the calculating analysis of professional activity items (Professional Competence-5);
* readiness on the basis of a systematic approach to build and use models to describe and predict various phenomena, to carry out a qualitative and quantitative analysis of them (Professional Competence-6);

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

Know:

* the features of bubbling fluidisation;
* the construction of furnaces with a fluidised bed;
* the environmental benefits of fluidised bed furnaces.

Be able:

* to calculate the fluidisation onset rate, the terminal velocity;
* to calculate the heat exchange in the fluidised bed.
* to demonstrate skills and experience:
* to carry out the design calculation of a hot-water boiler with a fluidised bed.

1.3. Scope of the discipline

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| Types of the educational work, forms of control | Total, hours | Number of the academic semester |
| 5 |
| In-class learning, hours | 4 | 4 |
| Lectures | 4 | 4 |
| Practical exercises | - | - |
| Laboratory-based work | - | - |
| Self-guided work including all types of the current attestation | 104 | 104 |
| Interim assessment | - | test |
| Total scope according to the curriculum, hours | 108 |
| Total scope according to the curriculum, credits | 3 |

**2. CONTENTS OF THE DISCIPLINE**

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| Section and topic code | Discipline section, topic | Contents |
| 1 | Topic 1. Fluidisation modes  | The fluidisation onset rate. Terminal velocity. Fluidisation of polydisperse particles. Bubble fluidisation mode. Features of bubbling fluidisation. Fluidisation in a layer with pipe bundles. |
| 2 | Topic 2. Transfer of particles in the fluidised bed | Circulation and mixing of particles along the height of the layer. Stirring particles in the horizontal direction. The release of particles into the superlayer space and the entrainment from the layer. Particle sintering in the fluidised bed. Analysis of the conditions ensuring minimum wear of surfaces washed by a layer. |
| 3 | Topic 3. Heat transfer in the fluidised bed | Heat and mass transfer between the particles and the fluidising agent or the layer as a whole. The mechanism of heat exchange between the fluidised bed and the immersed surface. Factors affecting the maximum heat transfer coefficient. Local heat transfer. The maximum (average over the surface) heat transfer coefficient to the pipes immersed in the pipes and pipe bundles. |
| 4 | Topic 4. Burning in the fluidised bed | Burning of natural solid fuel particles. The model of coke particles combustion in a layer. Calculation of gas formation in a layer. Calculation of the temperature of the particles burning in the layer. Binding of sulphur oxides. |
| 5 | Topic 5. Design options of boilers with the fluidised bed | Furnaces with a stationary low-temperature fluidised bed. Furnaces with a circulating fluidised bed. A furnace according to the Alstrom technology. The Lurgi furnace setup. The Compact-Intrex furnace setup. |
| 6 | Topic 6. The use of fluidised bed combustors for the incineration of solid domestic waste and waste-based fuel | The top device with a swirl fluidized bed. A boiler plant with a circulating fluidised bed (CFB) for the waste incineration. |

**3.** **CURRICULAR AND INFORMATION SUPPORT TO THE DISCIPLINE**

**Key references**

1. Tugov A.N., Ryabov G.A., Dik E.R., Litoun D.S., Folomeev O.M., Shatlman S.G., Smimov O.N. Operating experience of fluidized bed furnaces of municipal wastes incineration at Rudnevo plant in Russia. In the collection *Circulating Fluidized Bed Technology 9* (Proceedings of the international conference on the circulating fluidised bed). 2008. Hamburg. FRG.
2. Gerdes R. Two-and-a-half years of operating experience with the RDF fired power plant Neumun ster // In the collection *Circulating Fluidized Bed Technology 9* (Proceedings of the international conference on the circulating fluidized bed). 2008. Hamburg. FRG.

**Additional references**

1. Sneyd Robert J. Energy recovery from fluidized bed combustion // Chemical Engng Progr. 1984. V.80. №1. P.48-54.
2. Werther J. Sewage sludge combustion J. Werther, T. Ogada // Progress in energy and combustion science. Pergamon Press. 1999. V.25. P.55-116.
3. Werther Joachim. Fluidization technology development - the industry / academia collaboration is¬sue / Joachim Werther // Powder Technology. 2000. V.l 13. P.230-241.
4. Goidich S.J. Foster Wheeler compact CFB for utility scale / S.J. Goidich, T. Hyppanen // Proceedings of the 16th International Conference on fluidized bed combustion. USA, 2001.
5. Nowak W. Ten years of experience of WOT Turow Power plant S.A. in the operation of high-power fluidized-bed boilers / W. Nowak, R. Walkowiak, T. Ozimowski, J. Jablonski, J. Wyszynski // In the collection *Circulating Fluidized Bed Technology 9* (Proceedings of an international conference on the circulation boiling layer). 2008. Hamburg. FRG.

**Databases & information, reference and search systems**

1. Zonal Scientific Library of UrFU http://lib.urfu.ru/
2. The Russian State Library http://www.rsl.ru/
3. The Russian National Library http://www.nlr.ru/
4. The Russian National Public Library for Science and Technology http://www.gpntb.ru/
5. Public Internet Library http://www.public.ru/
6. Students Library http://www.lib.students.ru/
7. Scientific Library of the St. Petersburg State University http://www.lib.pu.ru/
8. Scientific electronic library http://www.eLIBRARY.ru/

**4. SET OF EVALUATION TOOLS FOR CONDUCTING INTERMEDIATE ATTESTATION**

**List of sample questions for the test**

1. What is called a fluidized bed? What can explain its name? (Professional Competence-5)
2. What is meant by the fluidisation onset rate? How does it differ from the rate of free particle spinning? (Professional Competence-5)
3. What is the aerodynamic resistance of the fluidised bed? (Professional Competence-5)
4. How to correctly choose the fluidisation onset rate in respect of a polydisperse particle layer? (Professional Competence-5)
5. List the main features of bubbling fluidisation. (Professional Competence-5)
6. Why are the temperatures of the particles and the fluidisation agent equal to each other almost over the entire height of the fluidised bed? (Professional Competence-5)
7. How does the heat transfer coefficient change from the fluidised bed to the surface washed by it with an increase in fluidisation velocity? Why? (Professional Competence-6)
8. What is the structure of a furnace with a stationary low-temperature fluidised bed? (Professional Competence-5)
9. What is the heat transfer coefficient to the surface of the coil arranged in a furnace with a stationary low-temperature fluidised bed? (Professional Competence-5)
10. What is the optimum temperature in a fluidised-bed furnace? What determines its value? (Professional Competence-5)
11. Why can an optimum temperature be maintained in the furnace with a stationary fluidised bed? (Professional Competence-5)
12. In a furnace with a fluidised bed, a mixture of combustible particles and inert gases (ash, sand) is fluidised. What is the proportion of combustible particles in the mixture? (Professional Competence-5)
13. What is the lattice thermal stress? How is it related to the fluidisation rate? (Professional Competence-5)
14. How can the sulphur contained in fuel be bound in furnaces with a fluidised bed? (Professional Competence-5)
15. Why can the concentration of nitrogen oxides in the combustion products be sharply reduced by redistributing the air supplied to the combustion for primary and secondary ones? (Professional Competence-5)
16. What determines the limit content of ballast (water plus ash) in waste or sludge acceptable for combustion in a fluidised bed? What is it approximately equal to? (Professional Competence-5)
17. What are the differences between the furnaces with the stationary and circulating fluidised bed? Name the advantages of a furnace with a circulating fluidised bed. (Professional Competence-5)
18. What is the difference between the furnaces with the circulating fluidised bed made according to the scheme Alstrom, Lurgi and Foster-Wheeler (Compact-Intrex)? (Professional Competence-3)
19. Is it possible to burn unsorted solid domestic waste in combustion chambers with a circulating fluidized bed or are they suitable for burning only the fuel made of waste smaller than 10 mm? (Professional Competence-5)
20. How to arrange the holes in the caps for the fluidising air to release, so that the jets of one cap do not ‘cut off’ any adjacent caps? (Professional Competence-1)