Technical sciences

UDC 621.036.7

Fialko Nataliia
Doctor of Technical Sciences, Professor,
Corresponding Member of the NAS of Ukraine, Head of Department
Institute of Engineering Thermophysics of the NAS of Ukraine

Stepanova Alla
Candidate of Technical Sciences (PhD),
Senior Scientific Researcher, Leading Researcher
Institute of Engineering Thermophysics of the NAS of Ukraine

Navrodska Raisa
Candidate of Technical Sciences (PhD),
Senior Scientific Researcher, Leading Researcher
Institute of Engineering Thermophysics of the NAS of Ukraine

Meranova Nataliia
Candidate of Technical Sciences (PhD),
Senior Scientific Researcher, Leading Researcher
Institute of Engineering Thermophysics of the NAS of Ukraine

Shevchuk Svitlana
Candidate of Technical Sciences (PhD), Senior Researcher
Institute of Engineering Thermophysics of the NAS of Ukraine

DEVELOPMENT OF THE MAIN STAGES OF COMPLEX METHODS FOR STUDYING THE EFFICIENCY OF HEAT RECOVERY SYSTEMS BASED ON THE EXERGY APPROACH

Summary. *The results of the development of the main stages of complex methods for studying the efficiency of heat recovery systems based on the exergy approach are presented. The choice of multiplicative criteria for evaluating the efficiency of heat recovery systems is included as a stage common to all methodologies. Criteria for evaluating the efficiency of systems that are highly sensitive to changes in the regime and design parameters of heat recovery systems and can serve as target optimization functions are proposed. The main stages of complex methods based on the exergy approach for heat recovery systems of various types have been developed. Methods are considered in which the methods of exergy analysis, statistical methods of planning an experiment, structurally variant methods and methods based on the calculation of exergy dissipators are used.*

Key words: *heat recovery systems; complex methods; exergy approach; exergy dissipators.*

Introduction. The problem of development and implementation of efficient energy-saving technologies for the utilization of heat from power plants is currently relevant for the country's energy sector. The solution to this problem is connected with the need for systematic research from the standpoint of modern methodological approaches.

Statement of the problem. The effectiveness of research into the efficiency of power plants is significantly increased when using the exergy approach, which is increasingly used in the world [1-9]. This is due to the fact that the exergy characteristics are quite sensitive to changes in the design and operating parameters of power plants and can be used as a measure of their thermodynamic efficiency. A reasonable choice of methodology for each specific case allows, when developing the design of heat recovery systems, to use parameters that are as close as possible to optimal ones, which, in turn, increases the efficiency of the systems.

The purpose of the work is to develop the main stages of complex methods for studying the systems for utilizing the heat of waste gases from power plants based on the exergy approach. To achieve the goal, you must complete the following tasks:

- to determine the criteria for evaluating the efficiency of heat recovery systems based on the exergy approach;
- to develop the main stages of complex methods based on the exergy approach for heat recovery systems that include several elements, or for individual elements of the heat recovery system;
- to develop the main stages of complex methods for complex heat recovery systems, including a large number of structural elements.

Materials and research methods. To analyze the efficiency and optimize heat recovery systems, the main stages of complex methods based on the exergy approach have been developed. The methods considered in the work include statistical methods of experiment planning, balance methods of exergy analysis, and methods based on the calculation of exergy dissipators.

Research results. The choice of multiplicative criteria for evaluating the efficiency of heat recovery systems is included as a necessary stage common to all complex methods. Thermal-exergy and exergy-technological efficiency criteria are proposed, which are highly sensitive to changes in the regime and design parameters of systems. This is due to the fact that the criteria include exergy, thermal and technological characteristics. Further, the developed main stages of complex methods are outlined. For heat recovery systems consisting of several elements, or for individual elements of the heat recovery system, the main steps of the methodology are as follows:

- drawing up with the help of balance methods of exergy analysis of a system of exergy, thermal and material balance equations;
- determination of the exergy characteristics from the system of balance equations included in the criteria for evaluating the effectiveness and calculation

of the corresponding criteria;

- obtaining with the help of statistical methods of planning the experiment of the functional dependencies of the efficiency criteria on the optimization parameters;
- determination of optimal values of optimization parameters.

For complex heat recovery systems that include a large number of elements, it is not possible to establish the functional dependencies of the optimization target functions on the optimization parameters. In these cases, it is expedient to develop complex methods for such systems based on a combination of exergy, structurally variant methods, methods of multilevel optimization, the theory of linear systems, and thermodynamics of irreversible processes. The paper considers two complex methods that are most often used to analyze the efficiency of heat recovery systems.

1. The main stages of a comprehensive methodology based on the principles of exergy analysis and the structural-variant method:

- development of a block diagram of the installation, consisting of a number of discrete elements of a simple structure, interconnected by exergy flows;
- carrying out thermal and exergy calculations to identify elements, the change in exergy losses in which most significantly affects the exergy losses of the installation as a whole;
- optimization of these elements using exergy balance methods and statistical methods of experiment planning

2. The main stages of a complex methodology that combines exergy methods with methods based on the calculation of exergy dissipators:

- development of a mathematical model of the processes under study, which includes the exergy and entropy balance equations, the continuity equation, the phase motion equations, the energy equation, the enthalpy balance equations and the Gibbs equation;

- obtaining formulas for calculating exergy dissipators and calculating dissipators associated with non-equilibrium heat transfer between heat carriers and dissipators associated with the movement of heat carriers.

As an example, the results of the calculation of exergy dissipators in the air heater of the heat recovery system of the boiler plant are given for various values of the heat output N of the air heater (Table 1).

Table 1

The results of calculations of exergy dissipators in the air heater of the heat recovery system of the boiler plant

N, кВт	71,5	59,1	46,3	35,4	52,9	39,5	23,8
D_1, кВт	4,96	3,80	2,69	1,86	2,85	1,88	0,91
D_2, кВт	7,66	5,61	4,05	2,70	4,17	2,66	1,26
D_3, кВт	0,88	0,61	0,38	0,23	0,49	0,28	0,11
D_4, кВт	0,52	0,37	0,24	0,15	0,49	0,31	0,13
D_5, кВт	0,28	0,20	0,14	0,09	0,30	0,20	0,08

Here D_1, D_2 are exergy dissipators that determine heat transfer from flue gases and water; D_3 is the exergy dissipator associated with thermal conductivity; D_4, D_5 are exergy dissipators associated with the movement of coolants.

The results obtained can be used to calculate exergy losses in heat recovery systems and their individual elements in the development of optimal heat recovery schemes.

Conclusions.

1. Complex multiplicative criteria for evaluating the efficiency of heat recovery systems based on the exergy approach are determined: heat-exergy and exergy-technological criteria.

2. The main stages of complex methods based on the exergy approach for heat recovery systems that include several elements, or for individual elements of the heat recovery system, have been developed;

3. The main stages of complex methods for complex heat recovery systems, including a large number of structural elements, have been developed**.**

References

1. Dorosz P., Wojcieszak P., Malecha Z. Exergetic Analysis, Optimization and Comparison of LNG Cold Exergy Recovery Systems for Transportation, Entropy. 2018. 20(1). 59. doi: 10.3390/e20010059
2. Mitrović D., Zivkovic D., Laković M.S. Energy and Exergy Analysis of a 348.5 MW Steam Power Plant Energy Sources, Part A: Recovery, Utilization, and Environmental Effects. 2010. V. 32. P. 1016-1027. https://doi.org/10.1080/15567030903097012
3. Poljak I., Orović J., Mrzljak V. Energy and Exergy Analysis of the Condensate Pump During Internal Leakage from the Marine Steam Propulsion System Scientific Journal of Maritime Research. 2018. 32. P. 268-280. doi: https://doi.org/10.31217/p.32.2.12
4. Fialko N., Stepanova A., Navrodska R., Meranova N., Sherenkovskii J. Efficiency of the air heater in a heat recovery system at different thermophysical parameters and operational modes of the boiler. Eastern-European Journal of Enterprise Technologies. 2018. 6/8 (96). P. 43-48. doi: 10.15587/1729-4061.2018.147526
5. Fialko N., Stepanova A., Navrodskaya R. Study of the efficiency of a combined heat utilization system using the graph theory methods. International scientific journal "Internauka". 2019. № 15(1). C. 61-63.
6. Fialko N., Stepanova A., Navrodska R., Presich G. Localization of exergy losses in the air heater of the heat-recovery system under different boiler operating modes. "International scientific journal "Internauka". 2019. № 12(74). P. 30-33.
7. Stepanova, A. Analysis of the application combined heat recovery systems for water heating and blast air of the boiler unit. Industrial Heat Engineering. 2016. 38(4). P. 38-46. doi: https://doi.org/10.31472/ihe.4.2016.06
8. Fialko N., Stepanova A., Navrodska R., Shevchuk S. Comparative analysis of exergetic efficiency of methods of protection of gas exhaust tracks of

boiler installations Eastern-European Journal of Enterprise Technologies. 2021. 3/8 (111). P. 42-49. doi: 1015587/1729. 4061.2021/234026

9. Fialko N., Stepanova A., Navrodska R., Gnedash G., Shevchuk S. Complex metods for analysis of efficiency and optimization of heat-recovery system. Scientific and innovation. 2021. 17(4). P. 11-18. doi: 10.15407/scine17.04.011. ISSN 1815-2066