Технічні науки

UDC 621.036

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

Stepanova Alla
Candidate of Technical Sciences (PhD), Senior Researcher
Institute of Engineering Thermophysics of
National Academy of Sciences of Ukraine

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

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

Shevchuk Svetlana
Candidate of Technical Sciences (PhD), Senior Researcher
Institute of Engineering Thermophysics of
National Academy of Sciences of Ukraine

DISCRETE-MODULAR PRINCIPLE OF STUDY OF EFFICIENCY OF HEAT RECOVERY SYSTEMS ON THE BASIS OF THE EXERGY APPROACH

Summary. *The results of the development of the discrete-modular principle of studying the efficiency of heat recovery systems based on the exergy approach are presented. The principle under consideration is focused on the development of energy-efficient technological systems that meet the conditions of thermodynamic reversibility of processes in the system. Three types of representation of a heat recovery system in the form of a system of discrete modules are considered:*

- *discrete structuring of individual elements of the heat recovery system, which allows you to highlight the individual modules of such elements in which the largest loss of energy.*
- *structuring of the heat recovery system, i.e. its presentation in the form of a system of individual elements (modules), in which the properties of the module, which determine its material and energy interaction with other elements of the system, are taken into account.*
- *multilevel structuring of the heat recovery system, i.e. its representation in the form of a system of separate modules (levels), as if embedded in one another and interconnected by the initial parameters of the modules.*

The possibilities of using the discrete-modular principle in complex techniques for analyzing the efficiency of heat recovery systems are analyzed. An example of the implementation of the first type of discrete-modular representation for surface hot-water and hot-air heat recoveries that are part of the heat recovery system of a glass melting furnace is given. The second type of discrete-modular presentation, which can be the basis for a comprehensive technique combining exergy analysis methods with structural-variant methods are considered. The essence of the method consists in establishing, using exergy calculations, and those elements in which the change in exergy most significantly *affects the change in exergy of the entire heat recovery system. The third type of discrete-modular representation can be the basis for a comprehensive technique combining exergy analysis methods and multilevel optimization methods. The essence of the method is to use the optimal parameters of the internal module as the initial parameters of the external module.*

Key words: *exergy method, discrete-modular principle, heat recovery system, exergy efficiency.*

Introduction. The discrete-modular principle of the study of the efficiency of heat recovery systems based on the exergy approach considered in this paper is focused on the development of energy-efficient technological systems. Such a system must meet the conditions of thermodynamic reversibility of the processes occurring in all its constituent elements. Currently, an important aspect of studies of the exergy efficiency of various power plants is the study of the effectiveness of their individual elements and the identification of elements that have high exergy losses [1-4]. New studies in this area are aimed at increasing the efficiency of power plants and significantly expand the possibilities of applying methods of energy analysis in different fields of knowledge.

Statement of the problem, research method and aim of work. Exergy research methods are widely used due to the main features of the concept of exergy: universality and additivity. These features make it possible to implement the discrete-modular principle of exergy research of energy systems. Such modeling of a heat recovery system involves one or another of its representation in the form of a system of discrete modules. Clarification of the fundamental possibility of such modeling within the framework of complex methods for analyzing the efficiency of heat recovery systems is the task of this study.

The aim of the work is to develop a discrete-modular principle for studying the efficiency of heat recovery systems based on the exergy approach and its application in appropriate complex techniques.

To achieve this aim it is necessary to solve the following tasks:

- to develop, on the basis of the exergy approach, a discrete-modular principle for studying the efficiency of heat recovery systems;
- to analyze the possibilities of using the discrete-modular principle in complex methods for analyzing the efficiency of heat recovery systems;
- consider individual examples of the use of the discrete-modular principle.

Research results and their analysis. The discrete-modular principle of the exergy study of energy systems involves the representation of a heat recovery system in the form of a system of separate interacting discrete modules of a simpler structure. Such modeling of internal relations is often associated with the balance method of exergy analysis. However, the variety of exergy methods currently used for thermodynamic analysis of power plants allows us to develop integrated methods for analyzing the efficiency of heat recovery systems based on the use of the discrete-modular principle. There are three possible types of representations of a heat recovery system as a system of discrete modules:

- discrete structuring of individual elements of the heat recovery system, which allows you to highlight the individual modules of such elements in which the largest loss of energy.
- structuring of the heat recovery system, i.e. its presentation in the form of a system of individual elements (modules), in which the properties of the module, which determine its material and energy interaction with other elements of the system, are taken into account.
- multilevel structuring of the heat recovery system, i.e. its representation in the form of a system of separate modules (levels) nested one into another and interconnected by the initial parameters of the modules.

As an example of the implementation of the first type of discrete-modular representation, surface water-heating and air-heating heat recoveries that are part of the heat recovery system of a glass melting furnace are considered. The hot water heat recovery consists of three panel-type modules placed vertically and interconnected by gas and water paths. The air-heating heat recovery is a two-module design using panels formed by pipes with external membranes and ring turbulators of air flow inside the pipes. The calculation of exergy losses for individual heat recovery modules was carried out using the integrated balance method and exergy efficiency criteria ε: which represents the loss of exergy power per unit of heat power, and *k*, which also takes into account the mass of discrete modules (Table 1).

Table 1

Exergy losses in individual modules of the hot water and hot-air heat recoveries

Parameter	Flue gas module number				
	Water heating heat recovery			Air heating heat recovery	
	1	2	3	1	2
E_{los},kW	66,8	49,7	32,0	88,6	68,9
ε	0,37	0,35	0,30	0,46	0,34
k,kg/kW	1,60	1,98	2,05	2,10	1,60

A decrease in the magnitude of the exergy losses $E_и$ and the heat-energetic criterion ε in both heat exchangers during the transition to modules located along the flue gas is associated with a decrease in the thermodynamic irreversibility of transfer processes. Taking into account the mass of modules leads to an increase in the value of *k*. Modules in which the largest exergy losses are recorded need constructive refinement.

The second type of discrete-modular presentation can be the basis for a comprehensive technique combining exergy analysis methods with structurally variant methods. The essence of the method consists in establishing, using exergy calculations, those elements in which the change in exergy most significantly affects the change in exergy of the entire heat recovery system. Such elements need constructive refinement in order to optimize parameters. So, most often the maximum exergy loss in heat recovery systems occurs in a hot water heat recovery. They exceed the exergy loss in the remaining elements by 5-10%.

The third type of discrete-modular representation can be the basis for a comprehensive technique combining exergy analysis methods and multilevel optimization methods. The essence of the method is to use the optimal parameters of the internal module as the initial parameters of the external module. The technique can be used to optimize operational and structural parameters of both individual modules and the entire heat recovery system.

Conclusions

1. Based on the exergy approach, a discrete-modular principle for studying the efficiency of heat recovery systems has been developed.
2. The possibilities of using the discrete-modular principle in complex methods for analyzing the efficiency of heat recovery systems has been analyzed.
3. An example of the use of this principle for calculating exergy losses in surface hot-water and hot-air heat recoveries has been considered.

References

1. Libertini L., Vicidomin M. Exergetic Analysis of a Novel Solar Cooling System for Combined Cycle Power Plants Francesco Calise. Entropy. 2016. (18).356.doi:10.3390/e18100356.
2. Cavalcanti E. JC. Exergo-economic and exergue-nvironmental analyses of an integrated solar combined cycle system. Renewable and Sustainable Energy Reviews. 2017. 67. P. 507-519.
3. Fialko N., Stepanova A., Navrodska R., Meranova N., Sherenkovskii Ju. 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. [in Russian].
4. Fialko N., Navrodska R., Presich G., Gnedash G., Shevchuk S., Stepanova A.

Combined heat recovery systems for gas- consuming boilers of communal power engineering. Kyiv: Printing house "Pro format". 2019. 192 p. [in Ukraine].