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COMPARATIVE ANALYSIS OF COMPLEX METHODS OF STADY OF THE HEAT RECOVERY SYSTEMS EFFICIENCY

СРАВНИТЕЛЬНЫЙ АНАЛИЗ КОМПЛЕКСНЫХ МЕТОДИК ИССЛЕДОВАНИЯ ЭФФЕКТИВНОСТИ ТЕПЛОУТИЛИЗАЦИОННЫХ СИСТЕМ

Summary. *The paper presents the results of a study of the efficiency of a heat recovery included in the recovery system of exhaust gas heat of a heat engine of a cogeneration unit. The studies were carried out using complex methods based on the following methods: a method using dissipative functions and a balance method of exergy analysis. The results of the calculation of dissipative functions, exergy* *losses and exergy criteria performed within the framework of the indicated methods for each of the eight heat recovery unit modules are presented. The analysis allows us to identify the heat recovery modules that need optimization or structural development. Particular attention is paid to a comparative analysis of the selected methods and consideration of the advantages and disadvantages of their use in various cases. It is noted that the methodology based on the integrated balance method of exergy analysis can be considered effective due to the small number of initial parameters necessary for calculation, as well as the simplicity of calculation and analytical methods to obtain exergy characteristics. The advantage of a technique that uses the concept of dissipative functions can be considered that it allows us to separate the exergy losses in the heat recovery associated with nonequilibrium heat transfer and the movement of coolants.*

Key words: *heat recovery unit, exergy loss, complex technique, exergy efficiency.*

Аннотация. *В работе приводятся результаты исследования эффективности теплоутилизатора, входящего в систему утилизации теплоты отходящих газов теплового двигателя когенерационной установки. Исследования проведены с помощью комплексных методик, в основе которых лежат следующие методы: метод, использующий диссипативные функции, балансовый метод эксергетического анализа. Приводятся результаты расчета диссипативных функций, эксергетических потерь и эксергетических критериев, выполненные в рамках указанных методик для каждого из восьми модулей теплоутилизатора. Проведенный анализ позволяет выделить модули теплоутилизатора, нуждающиеся в оптимизации либо в конструктивной доработке. Особое внимание уделяется сравнительному анализу выбранных методик и рассмотрению преимуществ и недостатков их использования в различных случаях. Отмечается, что методику, основанную на интегральном балансовом методе эксергетического анализа, можно считать эффективной в силу* *незначительного количества исходных параметров, необходимых для расчета, а также простоты расчетно-аналитических методов для получения эксергетических характеристик. Достоинством методики, использующей понятие диссипативные функции, можно считать то, что она позволяет разделить эксергетические потери в теплоутилизаторе, связанные с неравновесным теплообменом и движением теплоносителей.*

Ключевые слова: *теплоутилизатор, потери эксергии, комплексная методика, эксергетическая эффективность.*

Introduction. Given the limited primary energy resources in Ukraine, the problem of increasing the efficiency of power plants, including heat recovery systems, are becoming increasingly important. A detailed analysis of the efficiency of the elements of the heat recovery system using complex methods based on the methods of exergy analysis allows us to identify individual modules of elements that need optimization or structural refinement. Their further improvement increases the efficiency of the heat recovery system.

Problem statement and research method. A fairly widespread use of exergy research methods in world practice is due to the fact that complex methods based on them allow not only to determine exergy losses in power plants, but also to establish the causes and areas of their localization [1-6]. The objective of this study is to analyze the exergy efficiency of individual modules of the heat recovery unit included in the system of exhaust gas heat of the heat engine of a cogeneration unit. This heat recovery system is designed to heat water of heating systems. The studies were carried out using the discrete-modular principle and complex techniques, which are based on the methods of dissipative functions and exergy balances.

Research results and their analysis. In the framework of the first technique, the local differential exergy equation was used. Based on this equation, for each of the eight heat recovery modules, dissipative functions were obtained that determine the exergy losses in the processes of heat transfer from flue gases to the wall D_1, from the wall to water D_2, in the processes of heat conduction D_3; the exergy losses associated with the motion of the coolants D_4, and the total dissipative function D. In the framework of the second technique, using the balance method of exergy analysis, the exergy losses E, the exergy criteria ε and k (table 1). The heat-exergy criterion ε determines the loss of exergy power in the heat recovery unit per heat power unit. Exergo-technological criterion k includes the mass of the module. As can be seen from the table, the main exergy losses in all modules of the heat recovery are associated with losses due to heat transfer from flue gases to the wall. The corresponding dissipative functions make up, on average, 92% of the total dissipative functions. A logical decrease in exergy losses and the heat-exergy criterion of efficiency ε during the transition from the first to the eighth module of the heat recovery is associated with a decrease in the thermodynamic irreversibility of processes, which is determined by the finite temperature difference ΔT during heat transfer between the heat coolants.

Table 1

The results of the calculation of exergy characteristics

Parameter	**Flue gas module number**							
	1	2	3	4	5	6	7	8
D_1, kW	39,40	38,60	42,90	39,80	36,21	32,52	28,89	25,50
D_2, kW	2,53	2,14	2,17	2,15	1,86	1,65	1,45	1,25
D_3, kW	0,37	0,35	0,39	0,36	0,32	0,28	0,24	0,21
D_4, kW	0,30	0,28	0,30	0,28	0,22	0,20	0,18	0,17
D, kW	42,60	41,37	45,76	42,59	38,61	34,65	30,76	27,13
ΔT, K	355,3	334,1	311,0	288,1	266,1	245,2	225,5	207,1
E, kW	41,8	40,2	46,0	43,0	39,3	35,2	30,6	27,3
ε	0,417	0,404	0,408	0,410	0,385	0,371	0,350	0,340
k, kg/ kW	0,416	0,346	0,354	0,358	0,376	0,391	0,400	0,424

However, the indicated exergy characteristics for the third and fourth modules of the heat recovery are slightly higher than the dependence on ΔT of the exergy characteristics suggests. This fact indicates the thermodynamic imperfection of these modules. An increase in the exergo-technological efficiency criterion *k* for the first, seventh, and eighth modules indicates their structural imperfection. Thus, the assessment of the exergy efficiency of individual heat recovery unit modules using the indicated methods makes it possible to identify the modules that need optimization or structural development. The discrepancy between the values of the total exergy losses *D* and *E* calculated in the framework of the methods used is insignificant and averages 1.6%. This suggests that both methods can be used in various heat recovery schemes. A technique based on the integrated balance method of exergy analysis can be considered effective due to the small number of initial parameters needed for calculation, and the simplicity of calculation and analytical methods to obtain exergy characteristics. However, having certain advantages, this technique does not allow to separate the causes of the loss of exergy in individual elements or in individual modules of elements of a heat recovery system. An advantage of the technique that uses the concept of dissipative functions is that it allows one to separate the exergy losses in the individual modules of the heat recovery associated with nonequilibrium heat transfer between the heat transfer medium and the wall, heat conductivity and the movement of heat transfer media. However, when implementing this method, a larger number of initial parameters are used that are necessary for the calculation.

Conclusions

1. Using complex methods based on the methods of dissipative functions and exergy balances, the exergy characteristics for individual modules of the heat recovery included in the heat recovery system of exhaust gas of the cogeneration unit heat engine have been calculated.
2. The analysis of exergy characteristics using the indicated methods made it possible to isolate the heat recovery modules that need optimization or structural development.
3. A comparative analysis of the methods used is carried out and their advantages and disadvantages are determined.

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