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STUDY OF THE EFFICIENCY OF A COMBINED HEAT UTILIZATION SYSTEM USING THE GRAPH THEORY METHODS
ИССЛЕДОВАНИЕ ЭФФЕКТИВНОСТИ КОМБИНИРОВАННЫХ ТЕПЛОУТИЛИЗАЦИОННЫХ СИСТЕМ С ИСПОЛЬЗОВАНИЕМ ТЕОРИИ ГРАФОВ

Summary. *The data on the determination based on graph theory of the required number of heat exchangers in the combined heat recovery system of a boiler plant are presented. The results of studies of the magnitude of the exergy power loss in the installation as a whole and in its various elements are performed.*

Key words: *exergy analysis, energy efficiency, graph theory, heat recovery systems.*

Аннотация. *Представлены данные, касающиеся определения на основе теории графов необходимого количества теплообменников в комбинированной теплоутилизационной системе котельной установки. Приводятся результаты исследований величины потерь эксергетической мощности в установке в целом и в ее различных элементах.*

Ключевые слова: *эксергетический анализ, энергетическая эффективность, теория графов, теплоутилизационные системы*

For the decentralized power industry of Ukraine, the problem of developing and introducing efficient technologies for the deep utilization of heat from the exhaust gases of power plants is relevant both now and in the near future. Combined heat-recovery systems designed to heat several heat transfer fluids make it possible to carry out a mode of deep heat utilization throughout the heating season, which ensures an overall increase in boiler efficiency by 13-14%. Coolants in these systems can be reverse heat network water, additional water of a water treatment system, blast air, etc. [1; 2]. In the general case, in the combined heat-utilization systems, communication between individual heat exchangers exist in three types: with series, parallel, and mixed connections of elements. It is of interest using the methods of graph theory to find the optimal number and distribution of heat exchangers in such systems [3]. The number of heat exchangers in the heat recovery system and the choice of the type of connection between them is determined, first of all, by the need to reduce the temperature of flue gases passing through the heat exchangers to a predetermined value with the help of several heat carriers, and also to ensure minimal exergy losses in the system. Exergy losses can be controlled by various criteria, including exergy characteristics. These characteristics have all the necessary properties for evaluating the effectiveness of heat exchangers: additivity, high sensitivity to changes in regime and structural parameters of heat exchangers, etc. [4; 5]. As such criteria, both the exergy loss in the heat exchanger system and the criteria including this characteristic can be used directly. Such criteria are exergy-technological and heat-exergy criteria for evaluating efficiency, where m is the mass; Q - thermal power. When analyzing the operation of a system consisting of n heat exchangers, the construction and analysis of the exergy loss graph is effective. In the general case, the graph of exergy losses is understood as a graph whose set of vertices corresponds to heating E and heated H streams. The set of arcs corresponds to the possible distribution of exergy losses in the corresponding elements of the system of heat exchangers in the interaction of heating and heated flows (1).

$$
\begin{aligned}
&E \cap H = \varnothing, \\
&(\forall e_i \in E)\tilde{A}_{\ddot{I}}\, e_i \subset H, \\
&(\forall h_j \in H)\tilde{A}_{\ddot{I}}\, h_j = \varnothing, \\
&E = \{e_1, e_2, \dots, e_i, \dots, e_m\}, \\
&H = \{h_1, h_2, \dots, h_j, \dots, h_n\}.
\end{aligned}
\qquad (1)
$$

In this case, the problem of optimal heating can be formulated as follows: it is required to distribute many heating fluxes along the heated flow, so that the parameters of the heated flow after the heat exchanger system are in a given interval of values, and the selected optimality criterion takes the minimum value. Using the constructed graph of exergy losses, we found the optimal number and optimal distribution of heat exchangers in a combined heat recovery system designed to preheat the return heat network water and the blast air of the boiler unit. Two options are possible: the first is two series-connected water-heating heat exchangers and one air-heating one, the second is series-connected water-heating and air-heating heat exchangers. The analysis of the operation of the installation, including the boiler and the combined heat recovery system with one water heater and one air heat exchanger (Figure 1-3), was carried out. The optimal distribution of heat exchangers ensured a decrease in the temperature of flue gases from 170–180 ° C to 30–40 ° C with the help of such coolants as reverse heating network water and blast air. The total exergy losses in the system of heat exchangers, which included hot water and air heating heat exchangers, were maintained at the minimum level and ranged from 0.5 kW at 30% of the installed boiler power to 23–24 kW at 100% of the installed power.

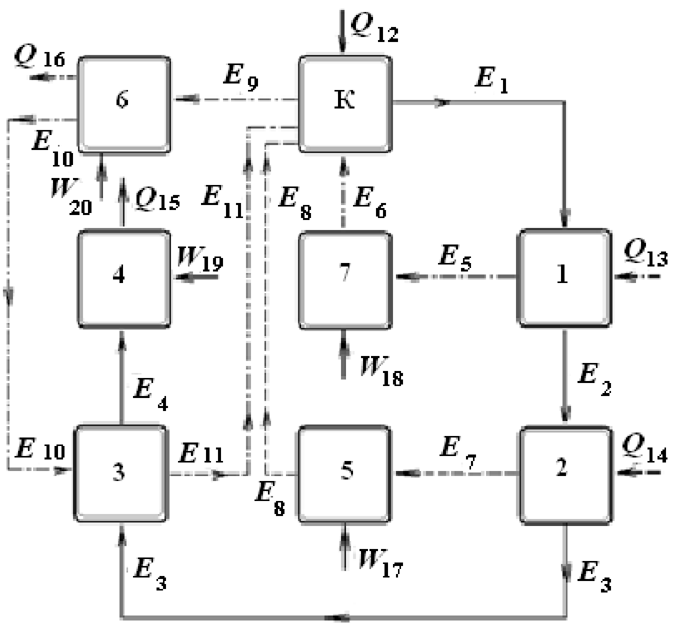

Fig.1. Block diagram of the installation:

K – boiler; 1,2 – hot water and air heat exchangers; 3 – gas heater; 4 – exhauster; 5 – fan; 6.7 – pumps; ⟶ – flue gases; - - ➔ – air; — - ⇛ – water; $E_1 - E_{11}$ – exergy streams; $Q_{12} - Q_{16}$ – heat flow; $W_{17} - W_{20}$ – energy flows (author development).

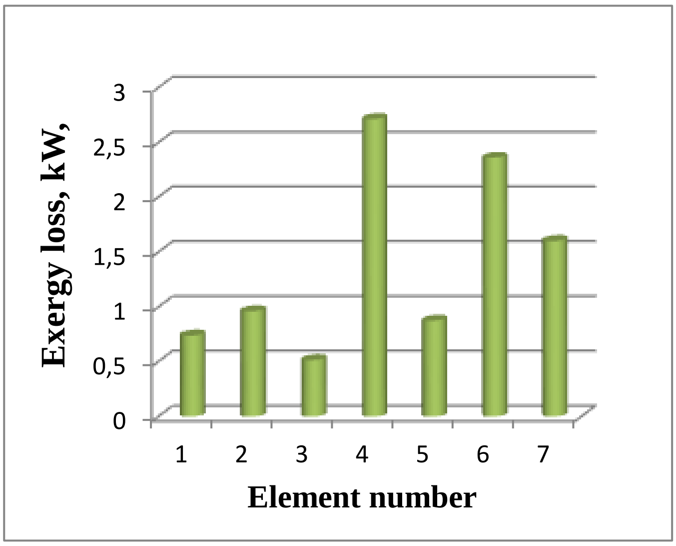

Fig. 2. Losses of exergy power in the elements heat recovery system at 50% of the installed boiler capacity: 1, 2 – hot water and air heat exchangers; 3 – gas heater; 4 – exhauster; 5 – fan; 6,7 – pumps (author data).

The smallest exergy losses in the installation under study correspond to the hot-water and air-heating heat-utilizers, the greatest losses occur in the heat pump system. The carried out studies allowed making the corresponding structural changes to the installation scheme.

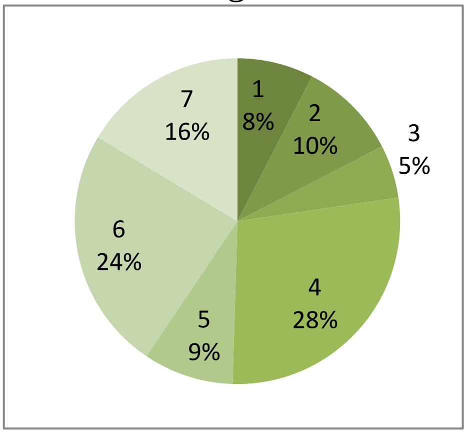

Fig.3. The relative contribution of each element of the heat recovery system to the total loss of exergy power: 1, 2 – hot water and air heat exchangers; 3 – gas heater; 4 – exhauster; 5 – fan; 6,7 – pumps (author data).

Conclusion

1. Using representations of graph theory, we have found the optimal number of heat exchangers and their optimal distribution in the combined heat recovery system of a boiler plant designed to heat water and blast air.
2. A comparative analysis of the exergy power losses in various elements of the installation was carried out, the total losses of exergy and the relative

contribution of each element of the installation to the total losses were determined.

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