Technical Sciences

UDC 621.036.7

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OPTIMIZATION OF HEAT RECOVERY VARIOUS TYPE

Summary. *The paper presents the results of optimization of different types of heat utilizers included in the heat recovery systems of glass furnaces and* *boiler units, obtained using a complex technique based on exergy analysis methods, statistical methods of experiment planning and performance evaluation criteria.*

Key words: *heat utilization systems; optimal parameters; integrated approaches; exergy methods.*

Relevance. The situation that has developed in recent years in the fuel and energy complex of Ukraine determines the need to improve the efficiency of heat and power equipment for various types of power plants. An important step in improving the efficiency of equipment is its optimization. Research aimed at solving this problem can be considered important and relevant.

Analysis of recent research and publications. In the world practice of researching power plants of various types, increasing attention is paid to assessing their effectiveness and optimization [1-5]. So, the aim of the studies conducted in [Taner T., 2018] is to develop modeling and increase the performance of fuel cells by studying their energy and exergy efficiency, as well as experimental optimization. In [Terzi R., 2016], it has been stated that a large number of exergy studies have been conducted for traditional energy technologies, in which useful results have been obtained. In the work [Sahin A., 2014] it is noted that using the methods of exergy analysis it is advisable to determine the stages of the technological process for which optimization is possible. In [Fialko N., 2017], [Fialko N., 2018] presents the results of studies of the exergy efficiency of combined heat recovery systems and optimization of their parameters. Further works in this direction will significantly increase the efficiency of power plant equipment.

The purpose of the work and research studies. Optimization of heat recoveries of various types included in the heat recovery systems of glass melting furnaces and boiler plants.

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

- Using the balance methods of exergy analysis, obtain the functional dependences of the performance criteria on the parameters of the hot-water panel heat recovery for a glass melting furnace, on the basis of which to establish the areas of optimal values of operating and structural parameters;
- Based on the methods of exergy analysis and statistical methods of designing the experiment, obtain the functional dependences of the performance criteria on the geometric parameters of the heat recovery surface of the water-heating water pipe heat recovery and gas-water heater for a boiler installation and determine the areas of optimal values of geometric parameters.

Materials and research methods. For heat recoveries of various types, complex methods of studying efficiency and optimization based on exergy analysis methods were used.

Research results and discussion. Based on a system of exergy, heat and material balance equations, supplemented by the corresponding hydrodynamic equations and heat transfer equations, the functional dependences of the exergo-technological $k_{ex}^{\text{т}} = E_{\text{loss}} \cdot m / Q^2$ and heat exergy $\varepsilon = E_{\text{loss}} / Q$ efficiency criteria on the parameters of the air-heating panel heat recovery for a glass melting furnace are obtained (here E_{loss} – exergy loss, Q – heat power, m - mass). Minimization of the obtained dependences made it possible to obtain optimal values of operating and structural parameters of the heat exchanger. The areas of permissible changes in these parameters were determined on the basis of their optimal values, analysis of contour curves in the minimum region and technological features of the heat exchanger (table 1). Contour curves were obtained using one of the algorithms of the theory of experimental design - the method of canonical transformations.

Table 1

Areas of optimal values of operating and structural parameters for a panel air-heating heat exchanger

Parameter	Area optimal values
Pollution factor, ξ	0…0,012
Turbulization coefficient, k	1,9…2,2
Inlet flue gas temperature, t^{gas}, ^{0}C	660…700
Inlet air temperature, t^{air}, ^{0}C	20…50
The ratio of the Reynolds numbers of coolants, $\mathrm{Re}^{gas}/\mathrm{Re}^{air}$	1,4…2,7
The distance between the panels, s_1, mm	60…65
The distance between the pipes in the panel, s_2, mm	60…65
The outer diameter of the pipe, d_2, mm	30…35

Using a complex technique based on exergy analysis methods and statistical experimental design methods for a hot water heat exchanger and a gas-gas heater for a boiler plant heat recovery system, functional dependences of the performance criteria on the geometric parameters of the finned heat-exchange surface (regression equations) are obtained. The independent variable geometrical parameters of the heat exchange surface are the fin height *h*, rib thickness *b* and intercostal pitch *s*. When functional dependencies were obtained, randomization was performed in each series of studies. The dispersion homogeneity was evaluated according to the Kochren criterion. Validation of the coefficients of the regression equation is in accordance with the Student's criterion. Checking the adequacy of the obtained equations with the data used is in accordance with the Fisher criterion. On the basis of the minimization of functional dependencies, the optimal values of geometric parameters are determined.

Water pipe heat exchanger:

$$k_{ex}^{\text{т}} = 6,61\cdot10^{-3}h^2 + 1,11\cdot10^{-2}b^2 + 3,07\cdot10^{-4}s^2 + 8,96\cdot10^{-3}hb + 2,83\cdot10^{-4}hs + \\ + 5,55\cdot10^{-3}bs - 1,29\cdot10^{-2}h - 3,42\cdot10^{-2}b + 1,48\cdot10^{-2}s + 5,09\cdot10^{-2}.$$

Gas-water heater:

$$\varepsilon = -1,34 \cdot 10^{-4} h^2 + 3,06 \cdot 10^{-4} b^2 - 3,12 \cdot 10^{-4} s^2 - 1,20 \cdot 10^{-4} hb + 5,65 \cdot 10^{-5} hs - \\ - 2,78 \cdot 10^{-4} bs - 2,70 \cdot 10^{-3} h - 3,74 \cdot 10^{-3} b + 7,46 \cdot 10^{-3} s + 5,44 \cdot 10^{-2}.$$

Graphical dependences of the performance criterion $k_{ex}^{\text{т}}$ on the indicated parameters for a water-heating water-tube heat exchanger are presented in Fig. 1, and the results of solving the optimization problem are shown (table 2).

The scientific novelty of the results. Using an integrated approach based on exergy methods of analysis, statistical methods of experiment planning, and exergy criteria, regions of optimal values of mode and design parameters for heat utilizers of various types was obtained.

Practical value. The obtained results of solving optimization problems for the studied heat recovery units allow us to develop designs of effective heat recovery systems.

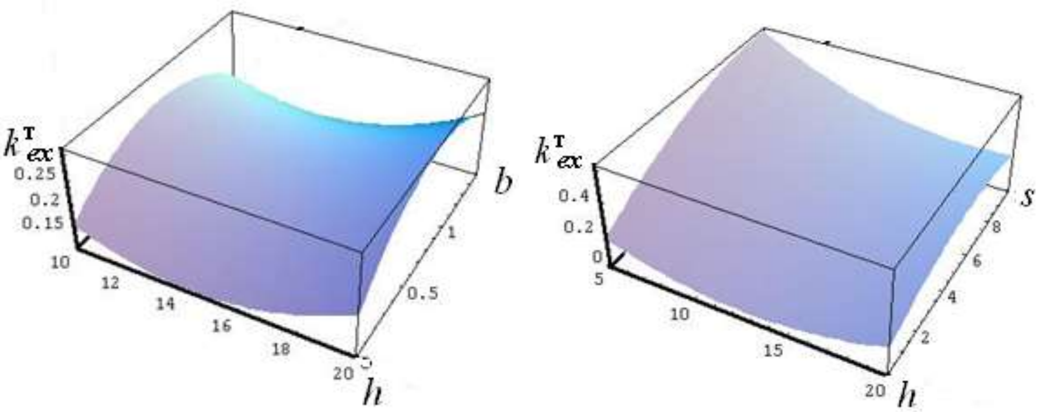

Fig. 1. Dependences of the exergo-technological efficiency criterion on the geometric parameters of the heat recovery surface of the hot water heat recovery

Table 2

The results of solving the optimization problem for heat recovery and gas heater

Parameter	Areas of optimal values of the geometric parameters of the heat exchange surface	
	Hot water heat recovery	Water-gas gas heater
h, mm	12,0…14,0	7,0…9,0
b, mm	0,4…0,5	0,4…0,5
s, mm	2,5…3,0	2,5…3
$k_{ex}^{\text{т}}$, kg/kW	0,190	0,215
ε	0,062	0,077

Conclusions

1. Based on the solution of optimization problems using exergy analysis methods, the regions of optimal values of operating and structural parameters of a panel gas-air air-heating heat exchanger for a glass melting furnace were established;
2. Using the methods of exergy analysis and statistical methods of designing the experiment, the regions of the optimal values of the geometric parameters of the heat exchange surface of the water-heating heat exchanger and the gas-gas heater of the heat recovery system for a boiler plant were established.

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