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OPTIMIZATION OF AIR-HEATING HEAT-RECOVERY EXCHENGER PARAMETERS BASED ON THE CANONICAL TRANSFORMATION METHOD

Summary. *Based on the exergotechnological approach, optimization of the heat exchange surface of the air-heating plate heat-recovery exchanger of* *the complex heat-recovery system of the gas-fired boiler was carried out.*

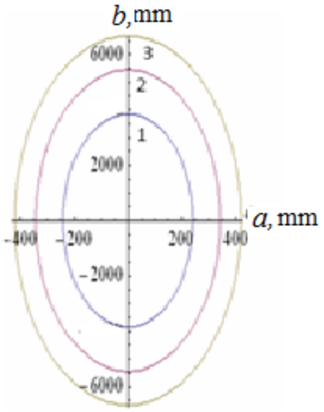
Key words: *exergy, optimization, experimental design theory, heat-recovery system, combustion air.*

Relevance. Increasing the efficiency of heat-recovery equipment of power plants is closely related to the use of complex methods for research, developed on the basis of the exergy approach and some methods of the statistical theory of experimental design. Such methods use criteria for assessing the exergy efficiency of power plants, which include exergy characteristics that are quite sensitive to changes in the technological parameters of the plants. This makes it possible to optimize the design parameters of heat-recovery equipment and obtain the necessary information for designing optimal heat-recovery circuits. Given the above, research in this direction is relevant.

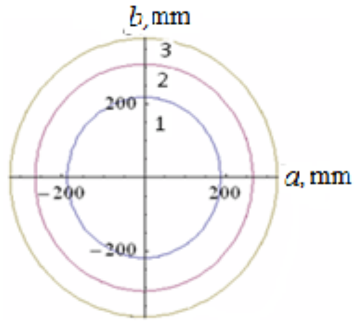
Analysis of recent research and publications. The use of the exergy approach in the development of new areas of management of heat and power facilities is important and promising for increasing their efficiency. Research in this area is becoming increasingly widespread in the world when studying the energy and exergy efficiency of equipment for power plants for various purposes, in particular for heat-recovery equipment [1-5]. But currently, comprehensive methods for studying the exergy efficiency of plants are carried out mainly using thermoeconomic analysis methods. More in-depth research is based on the exergotechnological approach [6-10]. The expansion of these studies will allow establishing the causes of exergy losses and looking for opportunities to reduce them, that is, increase the exergy efficiency of power plants.

The purpose of the work is to optimize the geometric parameters of the heat exchange surface of a plate air-heating heat exchanger used to preheat cold air before it enters to the gas-fired boiler.

Research results. In the work, based on the exergotechnological approach, the heat exchange surface of the air-heating plate heat exchanger of the complex heat-recovery plant of a gas-fired boiler with a capacity of 8 MW was optimized. The initial data for the research are given in Table 4.1, and the schematic circuit is shown in Fig. 4.3 [11]. The combustion air heated by the waste gases is used in the gas burner device of the boiler. A comprehensive methodology was developed, which includes the canonical transformation method used in the statistical theory of experiment planning. The thermal exergy criterion for evaluating efficiency was used as the optimization objective function $\varepsilon = E_{los}/Q$, where E_{los} – exergy losses, Q – heat productivity of the heat exchanger. As variable geometric parameters, the width of the plate a and the height of the plate b were used at the optimal value of the distance between the plates s. The canonical transformation method allows us to obtain a graphical interpretation of the optimum region of functional dependencies $\varepsilon = f(a,b)$ (response surfaces) in the form of a series of contour curves on a plane. Contour curves are formed when the response surface in the optimum region is intersected by a series of planes perpendicular to the ε axis. Large distances between the contour curves indicate the flatness of the response surface, that is, a slight change in the response function when changing the corresponding parameter. This allows us to expand the interval of changing this parameter in practice. Otherwise, it becomes necessary to adhere to the exact values of the optimal parameters when designing the heat exchange surface of the heat exchanger. For an air-heating plate heat exchanger, the functional dependences of the thermal exergy efficiency criterion on the geometric parameters in the optimum region at different values of the ambient temperature t_0 were investigated. For example, at t_0= +5 °C and t_0 = -5 °C the response surfaces in the optimum region are ellipsoidal and spherical depressions. The center of the depressions is a minimum, and the contour curves in the optimum region are an ellipse and a circle. The contour curves for the studied heat exchanger are presented below depending on the plate width *a* and height *b* at the optimal value of the distance between the plates *s* = 5 mm at different values of the ambient temperature t_0 (Fig. 1). A series of contour curves on the plane were obtained at certain values of the heat-exergy criterion ε in the optimum region. For example, for t_0 = +5 °C these values are ε = 0.335, 0.340, 0.350. For t_0 = -5 °C – ε = 0.275, 0.280, 0.285.



a)



b)

Fig. 1. Contour curves for an air-heating heat exchanger depending on the plate width a and height b at the optimal value of the distance between the plates s = 5 mm: ambient temperature t_0 = +5 °C (a) and t_0 = -5 °C (b)

The study of the response functions in the minimum region and the corresponding contour curves allowed us to determine the optimal values and regions of permissible values of the geometric parameters of the heat exchange surface of the air-heating plate heat exchanger (Table 1).

Table 1

Optimal values and ranges of permissible values of geometric parameters of the heat exchange surface of a plate air-heating heat exchanger

Parameter, mm	t_0 = +5 °C		t_0 = -5 °C	
	Optimal values	Valid value ranges	Optimal values	Valid value ranges
a	1400	1300 ÷ 1500	1750	1650 ÷ 1850
b	1750	1500 ÷ 2000	1300	1200 ÷ 1400
s	5.0	5.0 ÷ 6.0	5.0	5.0 ÷ 6.0

When determining the permissible values of the geometric parameters of the heat exchange surface of the plate air-heating heat exchanger, the real requirements for the operational and design features of the heat exchangers were taken into account. Thus, using a comprehensive methodology that includes the method of canonical transformations, the optimal values and areas of permissible geometric values of the parameters of the heat exchange surface of the plate air-heating heat exchanger were determined.

Conclusions and prospects

1. To optimize the geometric parameters of the heat exchange surface of a plate air-heating heat-recovery exchanger of complex heat recovery plant of gas-fired boiler, a comprehensive methodology has been developed, based on one of the methods of the statistical theory of experimental design - the method of canonical transformations.

2. Graphical interpretations of the areas of the optimum response surface have been obtained in the form of a series of contour curves on a plane at different values of the ambient temperature.

3. The results of the research should be used at the design stage of plate air-heating heat-recovery exchangers, which allows developing highly efficient heat-recovery equipment for each individual case, taking into account many technological and operational factors, including climatic conditions.

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