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ANALYSIS OF LOCAL EXERGY LOSSES IN HEAT CONDUCTION PROCESSES FOR AN AIR-HEATING HEAT EXCHANGER OF A BOILER PLANT

Summary. *The work investigated local exergy losses associated with heat conduction processes for a plate air-heating heat exchanger. The heat recovery unit is part of the heat recovery system of the heating boiler, designed to heat the blast air. For the research, a complex technique developed at the ITTF NASU was used, combining exergy methods with methods of the theory of thermal conductivity. The patterns of changes in local exergy losses associated with heat conduction processes and boiler operating modes have been established. The areas of variation of the specified parameters are determined at which local exergy losses in the air-heating heat exchanger have the lowest values and, accordingly, the values of the exergy efficiency of the heat exchanger are the greatest. The indicated range of change in the thermal conductivity coefficient is 0.025 kW/mK - 0.04 kW/mK.*

Key words: *air-heating heat exchanger, exergy efficiency, thermal conductivity, exergy losses.*

Introduction. One of the important problems for the national economy of Ukraine is the creation of effective energy-saving technologies for recycling the heat of exhaust gases from power plants and highly economical heat recovery equipment. This problem is associated with certain difficulties, which are caused by a number of features of heat recovery schemes. The decision on the advisability of implementing a particular heat recovery scheme and using heat recovery units of a certain type should be based on comprehensive studies that take into account the influence of the maximum possible number of factors on the efficiency of heat recovery. With this in mind, the research, the results of which are presented in the work, are important and relevant.

Statement of the problem and research method. Exergy analysis methods are increasingly used in world practice to study the efficiency of power plants of various types [1-10]. Thus, the works [1-4] present the results of studies aimed at increasing the exergy efficiency of fuel cells, coal gasification systems, heating and hot water supply systems of multifunctional buildings. In works [5-10], the exergy approach is used to study the efficiency of heat recovery systems for various purposes. For these studies, complex techniques have been developed that combine methods of exergy analysis with methods of the theory of linear systems, thermodynamics of irreversible processes, multi-level optimization, etc. Such techniques make it possible to study various types of exergy losses both in heat recovery systems and in their individual elements. In this work, local exergy losses associated with thermal conduction processes for a plate air-heating heat exchanger are investigated. The heat recovery unit is part of the heat recovery system of the heating boiler, designed to heat the blast air. For the research, we used a complex technique developed at Institute of Engineering Thermophysics of NAS of Ukraine, combining exergy methods with methods of the thermal conductivity theory [5].

Purpose and objectives of the study. The purpose of the work is to increase the exergy efficiency of a plate air-heating heat exchanger by reducing local exergy losses associated with heat conduction processes.

To achieve this purpose, the following tasks were set:

– for an air-heating heat exchanger, calculate local exergy losses associated with heat conduction processes, as well as their relative contribution to the total local exergy losses;

– to establish patterns of changes in local exergy losses associated with thermal conductivity processes when the thermal conductivity coefficient and boiler operating modes change;

– determine areas of change in the thermal conductivity coefficient and boiler operating modes that are characterized by the lowest local exergy losses and, accordingly, the highest exergy efficiency of the heat exchanger.

Research results. Local exergy losses associated with heat conduction processes in the air heater of a boiler installation are calculated when the thermal conductivity coefficient changes from 0.01 kW/mK to 0.04 kW/mK for seven boiler operating modes (1-7). The boiler operating modes correspond to a change in its heating output from 30 to 100% during the heating period. At an ambient temperature close to 0°C (modes 5-7), when the thermal load of boilers, as a rule, is 50% of the nominal one, the corresponding number of boilers is transferred to the nominal mode while reducing the total number of operating boilers. Boiler modes 1-4 correspond to the heat exchanger's heat output of 71.5-35.4 kW, and modes 5-7 correspond to its heat output of 52.9 kW-23.8 kW. Graphs of the dependences of local exergy losses E_{los} (kW) on the thermal conductivity coefficient (kW/mK) for various boiler operating modes are presented (Fig. 1). The transition from the first mode to the seventh is accompanied by a decrease in local exergy losses for all values of the thermal conductivity coefficient. The greatest local exergy losses in the heat exchanger occur during the first, second and fifth operating modes of the boiler. The dependence of exergy losses on the thermal conductivity coefficient for all boiler operating modes has two distinct sections. At small values of the thermal conductivity coefficient, the dependence of exergy losses on the thermal conductivity coefficient is more pronounced than at large thermal conductivity coefficients for all boiler operating modes.

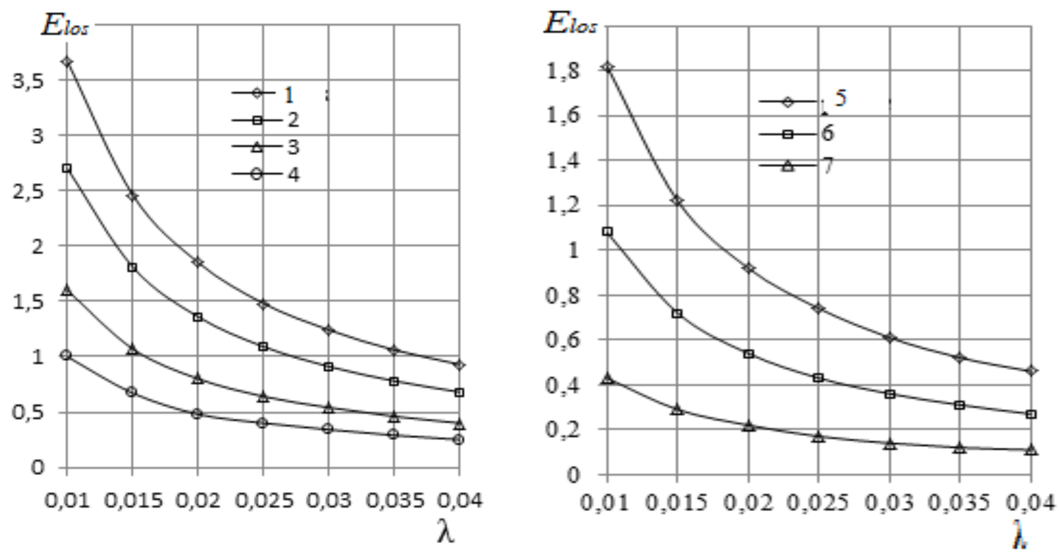

Fig. 1. Dependence of local exergy losses associated with thermal conductivity processes on the thermal conductivity coefficient under various boiler operating modes (1-7)

For all operating modes of the boiler in the first section, when the thermal conductivity coefficient changes from 0.01 kW/mK to 0.025 kW/mK, the reduction in local exergy losses in the heat exchanger is more significant than in the section where the thermal conductivity coefficient changes from 0.025 kW/mK to 0.04 kW/mK. In the first section, this decrease is, on average, 1.1 kW, in the second – 0.21 kW. For the first, second and fifth modes of boiler operation, these changes are more significant than for other modes. For the first mode they are 2.2 kW, for the second – 1.7 kW, for the fifth – 1.1 kW. A similar picture is observed for the dependence of the relative contribution of local exergy losses to the total local exergy losses in the heat exchanger on the thermal conductivity coefficient. However, in this case there is practically no dependence of the relative contribution of local exergy losses on the boiler operating mode. Thus, for a plate air-heating heat exchanger included in the heat recovery system of boiler plant for heating the blown air, the lowest local exergy losses and, accordingly, the highest exergy efficiency are characterized by the range of changes in the thermal conductivity coefficient from 0.025 kW/mK to 0.04 kW/mK, as well as boiler operating modes 3, 4, 6, 7.

Conclusions.

1. Using a complex methodology that combines exergy methods with methods of thermal conductivity theory, local exergy losses associated with heat conduction processes, as well as their relative contribution to the total local exergy losses, were calculated for an air-heating heat exchanger.
2. The patterns of changes in local exergy losses with changes in the thermal conductivity coefficient and boiler operating modes have been established.
3. The areas of change in the thermal conductivity coefficient and boiler operating modes that are characterized by the lowest local exergy losses and, accordingly, the highest exergy efficiency of the heat exchanger are determined.

This is the range of variation of the thermal conductivity coefficient from 0.025 kW/mK to 0.04 kW/mK, as well as boiler operating modes 3, 4 and 6, 7.

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