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RESEARCH OF EXERGY EFFICIENCY OF AIR HEAT RECOVERY GLASS FURNACES

Summary. *The results of exergy efficiency study of an air-heating heat exchanger of glass-melting furnaces under conditions of heat-exchange surface dustiness are presented. To assess the exergy efficiency of the heat exchanger, a complex technique was used, including the methods of exergy analysis and the selection of the necessary evaluation criteria. A correspondence between a sharp decrease in the exergy efficiency of an air-heating heat exchanger and an increase in the thickness of dust deposits on the heat-exchange surface has been established. The maximum permissible degree of dustiness of the heat exchange surface has been determined. This degree is characterized by a pollution factor of* $\xi = 0.02 - 0.03$ *and is achieved, on average, in 12 days of operation of the heat exchanger,.*

Key words: *exergy analysis methods, efficiency criterion, degree of dustiness.*

Introduction. The operation of heat exchangers in systems for utilizing the heat of glass-melting furnaces is associated with certain difficulties, which are caused by the presence of solid particles of soot and dust, corrosive compounds of nitrogen, sulfur, and other harmful and chemically aggressive substances in the exhaust flue gases of the furnace. These substances are deposited on the heat exchange surfaces of the heat exchanger, which significantly reduces the efficiency of its operation. Therefore, the study of the exergy efficiency of heat recovery units in conditions of dustiness of the heat exchange surface using modern complex techniques is an urgent problem.

Analysis of recent research and publications. In world practice, exergy methods are successfully used to assess the thermodynamic perfection of the installation [1-7]. In [1], to analyze the efficiency of a boiler plant, the balance method of exergy analysis was used, with the help of which two main types of exergy losses associated with irreversible fuel combustion and heat transfer are considered. In the robot [2], the concept of exergy losses is used for comparative analysis of various heat recovery systems. In work [3], an exergy analysis of the components of a power plant was carried out to identify the components with the maximum exergy losses. The use of individual exergy characteristics often does not reflect the essence of the processes under study. The use of integrated approaches for the study of heat recovery technologies increases the effectiveness of research. This is the subject of works [4-7]. The development and application of complex techniques allow to ensure the maximum efficiency of heat recovery equipment for power plants.

The purpose of the work and research objectives. The aim of the work is to analyze the exergy efficiency of an air-heating heat exchanger for glass-making furnaces in conditions of dustiness of the heat exchange surface and to determine the maximum allowable degree of dustiness.

To achieve this goal, it is necessary to solve the following tasks:

- to develop a comprehensive technique for studying the exergy efficiency of an air-heating heat exchanger in conditions of dustiness of the heat-exchange surface;
- to establish the patterns of change in the exergy efficiency of the heat exchanger depending on the degree of dustiness of the heat exchange surface.

Materials and research methods. An air-heating heat exchanger used in heat recovery circuits designed to heat the blast air supplied to the regenerators of a glass-making furnace has been investigated. The heat exchange surface of the heat exchanger is a package of panels formed by membrane pipes.

To analyze the exergy efficiency of a heat exchanger under conditions of dustiness of the heat exchange surface, a complex technique has been developed, including the methods of exergy analysis and the selection of the necessary criteria for assessing the exergy efficiency of the heat exchanger and the degree of dustiness of the heat exchange surface.

Results of the work and their discussion. A comprehensive methodology for studying the exergy efficiency of a heat exchanger under conditions of dustiness of a heat exchange surface includes balance methods of exergy analysis, the choice of a complex multiplicative criterion for assessing the exergy efficiency of a heat exchanger and the choice of a criterion for assessing the degree of dustiness of a heat exchange surface. The choice of the exergy efficiency criterion was carried out taking into account the need to assess the efficiency of the heat recovery unit from various positions: thermodynamic, heat engineering and technological. Therefore, the complex multiplicative exergy criterion $k = E_{los}m / Q^2$ was used as a criterion for the efficiency of the heat exchanger. Here E_{los} is the loss of exergy, m is the mass of the heat exchanger, and Q is the thermal power. The exergy losses were calculated using a system of balance equations of exergy analysis, compiled for the case under study. To characterize the degree of dustiness of the heat exchange surface of an air-heating heat exchanger, the pollution factor is used, which is the ratio of the heat transfer coefficients of dusty and clean heating surfaces. The dependences of the exergy efficiency criterion k on the pollution factor were obtained ξ for various Reynolds numbers of flue gases Re^g (Fig. 1). The verification of the adequacy of the obtained dependences to the data used was carried out according to the Fisher criterion. An increase in the exergy efficiency criterion corresponds to a decrease in the efficiency of the heat exchanger.

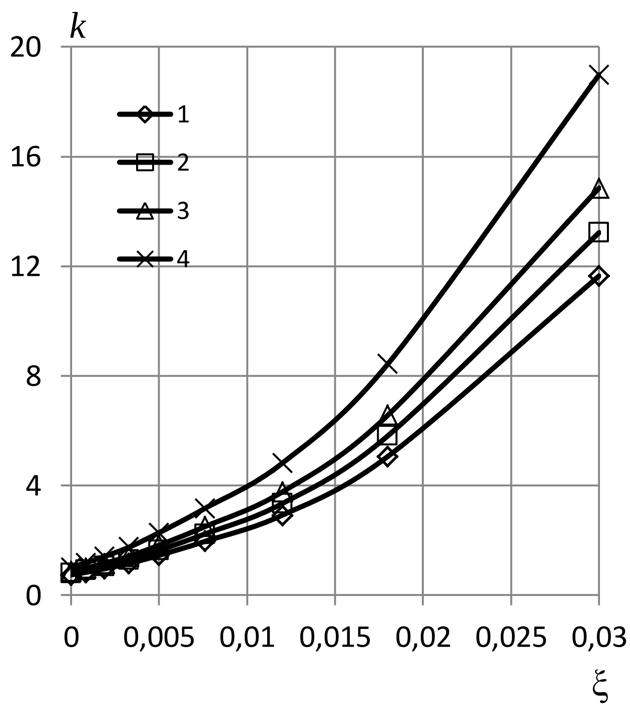

Fig 1. Dependence of exergy efficiency criterion *k* on the coefficient of contamination of the heat exchange surface of the air-heating heat exchanger ξ:

1– Re^g = 15000; 2 – 1200; 3 – 1000; 4 – 700

As can be seen from Figure 1, an increase in the Reynolds number of flue gases leads to a decrease in the exergy criterion of efficiency, and, consequently, to an increase in the exergy efficiency of the heat recovery unit. In this case, the degree of influence of the Reynolds number on the exergy efficiency of the heat exchanger increases with an increase in the degree of surface contamination. For all values of the Reynolds numbers, there are three areas of change in the pollution coefficient, in which the exergy criterion *k* increases with varying degrees of intensity. In the range of values from 0 to 0.01, a slow increase in *k* occurs; in the range of values from 0.01 to 0.016 *k* increases somewhat faster. And in the third section, starting from the values ξ = 0.016, there is a fairly rapid increase in *k*, the rate of increase, on average, is 2.7 times greater than in the first two sections. Consequently, in the third section, there is a rapid decrease in the exergy efficiency of the heat exchanger. In this case, the exergy efficiency and thermal power of the heat exchanger decrease, on average, 2 times. Thus, the permissible degree of contamination of the heat exchange surface of the heat exchanger can be determined by the degree of decrease in its exergy efficiency. The degree of contamination of the heat exchange surface ξ = 0.02 – 0.03 corresponds to the thickness of the layer of dust deposits, on average, 4mm, after which their consistency turns from loose to dense, which greatly complicates their removal. Such a thickness of the sediment layer is achieved in approximately 12 days of operation of the heat recovery unit. Thus, after 12 days of operation of the air-heating heat exchanger, for the normal operation of the heat recovery equipment of the glass furnace, it is advisable to remove dust deposits from the heat exchange surface of the heat exchanger using a special cleaning system.

Conclusions

1. A complex method for studying the exergy efficiency of an air-heating heat exchanger under conditions of dustiness of the heat-exchange surface has been developed.
2. The regularities of the change in the exergy efficiency of the heat exchanger depending on the degree of dustiness of the heat exchange surface have been established:
   - starting from values ξ = 0.016, there is a fairly rapid increase in *k* and, consequently, a sharp decrease in the exergy efficiency of the heat exchanger;
   - a decrease in the exergy efficiency of the heat exchanger is associated with the thickness and consistency of the layer of dust deposits on the heat exchange surface;
   - the maximum permissible degree of dustiness of the heat exchange surface corresponds to ξ = 0.02 – 0.03 and is achieved, on average, in 12 days of operation of the heat exchanger.

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