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COMPARATIVE ANALYSIS OF EXERGETIC LOSSES IN HEAT RECOVERIES OF GLASS FURNACES

Summary. *The paper presents the results of a comparative analysis of the exergy losses of heat recovery units of various types included in the waste gas* *heat recovery systems of glass melting furnaces. Based on the principles of universality and additivity of exergy characteristics, as well as design features of heat recoveries, a comprehensive methodology for studying exergy losses in heat recoveries has been developed. With the help of the developed technique, exergy losses in hot water and hot air heat recoveries, as well as in individual heat exchanger modules, were calculated. A comparative analysis of exergy losses and technological features of heat recovery units included in various schemes for the utilization of waste gases from glass melting furnaces has been carried out. For water-heating heat recoveries, the value of energy losses is less than the value of losses for air-heating heat recoveries. When using water-heating heat recovery units in heat recovery schemes, the coefficient of heat using of the furnace fuel increases, on average, by 20%. Despite the higher level of exergy losses in hot air heat recoveries, taking into account a number of important technological factors determined their competitiveness in heat recovery technologies of glass melting furnaces. At the same time, the heat utilization factor of the furnace fuel increases, on average, by 12.5%.*

Key words: *heat recovery, exergy losses, complex methods.*

Introduction. The development, research and implementation of highly economical standard equipment for glass melting furnaces is an important and urgent problem for the country's energy sector. The solution to this problem involves conducting research from the standpoint of modern methodological approaches. One of these approaches is the exergy approach, which underlies complex methods for assessing the exergy efficiency of power plants.

Statement of the problem and research method. Papers [1-8] are devoted to the development and application of complex methods based on exergy analysis methods for studying the exergy efficiency of power plants of various types. New research in this area contributes to the creation of highly economical heat recovery equipment and significantly expands the possibilities of using exergy analysis methods in various fields of knowledge. The properties of exergy characteristics, as well as an analysis of the design features of heat recovery units, made it possible to develop a comprehensive methodology for studying exergy losses in heat recovery units of glass melting furnaces. The technique is based on the use of the structural-modular principle and the integral balance method of exergy analysis.

The aim of the work and the objectives of the research. The aim of the work is a comparative analysis of exergy losses in hot water and air-heated heat recoveries included in the waste gas utilization systems of glass melting furnaces.

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

- based on the principles of universality and additivity of exergy characteristics, as well as design features of heat recovery units, to develop a comprehensive methodology for studying exergy losses in heat recovery units of glass melting furnaces;
- calculate exergy losses in hot water and hot air heat recoveries, also in separate heat exchanger modules;
- conduct a comparative analysis of exergy losses and technological features of heat recovery units included in various schemes for the utilization of waste gases from glass melting furnaces.

Research results. Currently, the efficiency of glass melting furnaces of various types does not exceed 60%, the temperature of the exhaust gases, as a rule, is 250 ... 600 ° C, and the heat loss with the exhaust gases is, on average, 55%. Utilization of waste gas heat can significantly compensate for the needs of enterprises for the production of glass in heat energy for heating and hot water supply, which will significantly increase the efficiency of glass melting furnaces. The paper considered surface hot water and hot air heat recoveries, which are included in the heat recovery systems of glass melting furnaces. The hot water heat recovery is included in heat recovery systems designed to heat water in heat supply systems. It consists of three panel-type modules arranged vertically and connected to each other along the gas and water paths. The air-heating heat recovery is included in the heat recovery systems designed to heat the blast air entering the furnace regenerators. It consists of two modules which include panels formed by tubes with outer membranes and inner annular air flow turbulators. The properties of exergy characteristics and design features of heat recovery units determined the possibility of developing a comprehensive methodology for studying exergy losses in heat recovery units. The technique is based on the use of the structural-modular principle and the integral balance method of exergy analysis. For a comparative analysis of hot water and hot air heat recoveries, the exergy losses E_{los}, in heat recoveries, the heat exergy efficiency criterion ε and the exergy technological efficiency criterion k, which serve as exergy criteria for evaluating the efficiency of heat recovery units, are calculated. The heat-exergy efficiency criterion shows the value of exergy losses per unit of heat output N, the exergy-technological efficiency criterion also allows taking into account the mass of the heat recovery or its individual modules (Table 1).

Table 1

Calculation results of exergy losses in hot water and hot air heat recoveries

Parameter	Hot water heat recovery				Air heating heat recovery		
	Heat recovery	Heat recovery module number			Heat recovery	Heat recovery module number	
		1	2	3		1	2
N, kW	433,0	181,0	141,0	111,0	393,0	197	196
E_{los}, kW	148,9	66,9	49,9	32,1	157,5	88,7	68,8
ε	0,34	0,37	0,35	0,29	0,40	0,45	0,35
k, kg/kW	1,85	1,59	1,96	2,03	1,96	2,13	1,67

A decrease in the value of exergy losses corresponds to an increase in the exergy efficiency of heat recovery units.

As can be seen from Table 1, the exergy losses for an air-heating heat recovery exceed the exergy losses for a hot-water heat recovery by an average of 1.2 times. As for the analysis of exergy losses for heat recovery modules, E_{los} and ε decrease for modules located along the flue gas flow. This is due to a decrease in the thermodynamic irreversibility of the transfer processes, which is determined by the finite temperature difference during heat recovery between heat carriers. Taking into account the mass of individual modules leads to some decrease in the exergy efficiency for the second and third modules of the hot water heat recovery. For an air-heating heat recovery, the exergy losses for the second module are less than for the first module. When using a water-heating heat recovery in heat recovery schemes for heating heat supply water, the coefficient of heat using from the furnace fuel increases, on average, by 20%. However, despite the lower exergy efficiency of hot air heat recoveries, a number of important technological factors determine their competitiveness in heat recovery technologies of glass melting furnaces. These are such factors as the need for a certain type of coolant during the entire period of operation of the furnace, the cost of fuel, the possibility of using efficient heating surfaces, the duration of the heat recovery equipment, and a fairly stable load of the thermal unit. Thus, heat recovery schemes for heating the combustion air, which use hot air heat recoveries, can be recommended for implementation. When using these heat recovery units, the efficiency of the furnace increases, on average, by 12.5%.

The obtained research results can be used in the design of hot water and hot air heat recoveries for specific heat recovery schemes for glass melting furnaces and other power plants.

Conclusions

1. Based on the principles of universality and additivity of exergy characteristics, as well as design features of hot air and hot air heat recoveries, a comprehensive methodology for exergy studies for heat recoveries of glass melting furnaces has been developed.
2. Calculated exergy losses in hot water and hot air heat recoveries, as well as in individual modules of heat recoveries.
3. A comparative analysis of the exergy and technological features of heat recovery units included in various schemes for the utilization of waste gases from glass melting furnaces has been carried out.

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