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OPTIMIZATION OF HEAT-RECOVERY SYSTEM PARAMETERS FOR HEATING AND HUMIDIFYING COMBUSTION AIR

Summary. *Based on the exergy approach, a comprehensive methodology for optimizing the parameters of a heat-recovery system designed to heat and humidify combustion air has been developed; the methodology is based on the* *principles of multi-level optimization, exergy analysis methods, statistical methods of experiment planning, and functional analysis methods. The heat-recovery system is divided into four optimization levels, and a recursive level traversal scheme has been developed. Efficiency assessment criteria have been developed, and functional dependencies of the selected criteria on the main system parameters for each optimization level have been obtained.*

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

Relevance. Increasing the level of use of thermal secondary energy resources in Ukraine is largely associated with increasing the efficiency of heat-recovery equipment of energy plants. Ukraine, as an energy-deficient country, has the necessary potential for the implementation of effective heat-recovery technologies. Therefore, the problem of their development, optimization and implementation is relevant both now and in the near future.

Literature review. Currently, complex methods based on the exergy approach are becoming increasingly widespread for the study and optimization of power plants. Such methods usually include methods of thermoeconomic analysis, structural-variant methods, methods of multilevel optimization, statistical methods of experimental planning, methods of functional analysis, the theory of linear systems, thermodynamics of irreversible processes, etc. [1-9]. The development and application of complex methods based on one or another combination of the specified methods allows for maximum efficiency of power plants, including heat-recovery systems for various purposes.

The purpose of the work is to optimize the parameters of complex heat-recovery system for heating circulating water and humidifying combustion air using a comprehensive methodology that combines multi-level optimization methods, statistical methods of experimental planning and functional analysis.

Research results. The work presents an exergy analysis of a complex heat-recovery system (Fig. 1), which is designed to heat and humidify the combustion air by using the heat of waste gases from a boiler plant with a heat output of 0.67 MW. The main elements of the complex heat-recovery system include a surface condensing water heater (SWH), a contact air heater-humidifier (CAH), and surface air heaters at the inlet (AP1) and outlet (AP2) of the air from the contact chamber of the CAH.

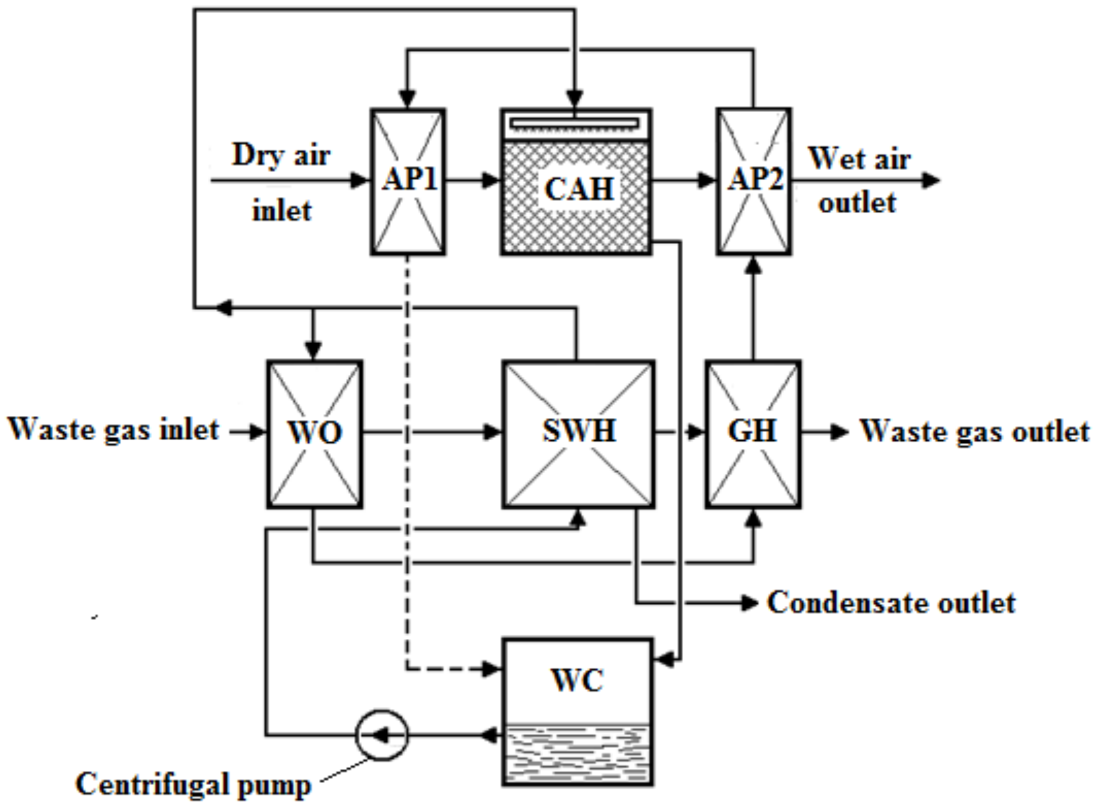

Fig. 1. Schematic circuit of a complex heat-recovery system for heating and humidifying combustion air: AP1 – air heater; CAH – contact heater (air humidifier); AP2 – air heater; WO – water overheater; SWH – surface water heater; GH – waste gas heater; WC – water collector

The study uses a comprehensive methodology that combines multi-level optimization methods, statistical methods of experiment planning, and functional analysis methods.

The main principles of the multi-level optimization method involve dividing the heat-recovery system into several optimization levels and developing a recursive level traversal scheme. For each optimization level, a mathematical model is developed, based on which functional dependencies of efficiency assessment criteria are determined from system parameters to obtain their optimal values. Then, the optimal parameter values of some levels are used as initial parameters of other levels. According to the main principles of multi-level optimization, the heat-recovery system is divided into four optimization levels and a recursive level traversal scheme is developed (Fig. 2).

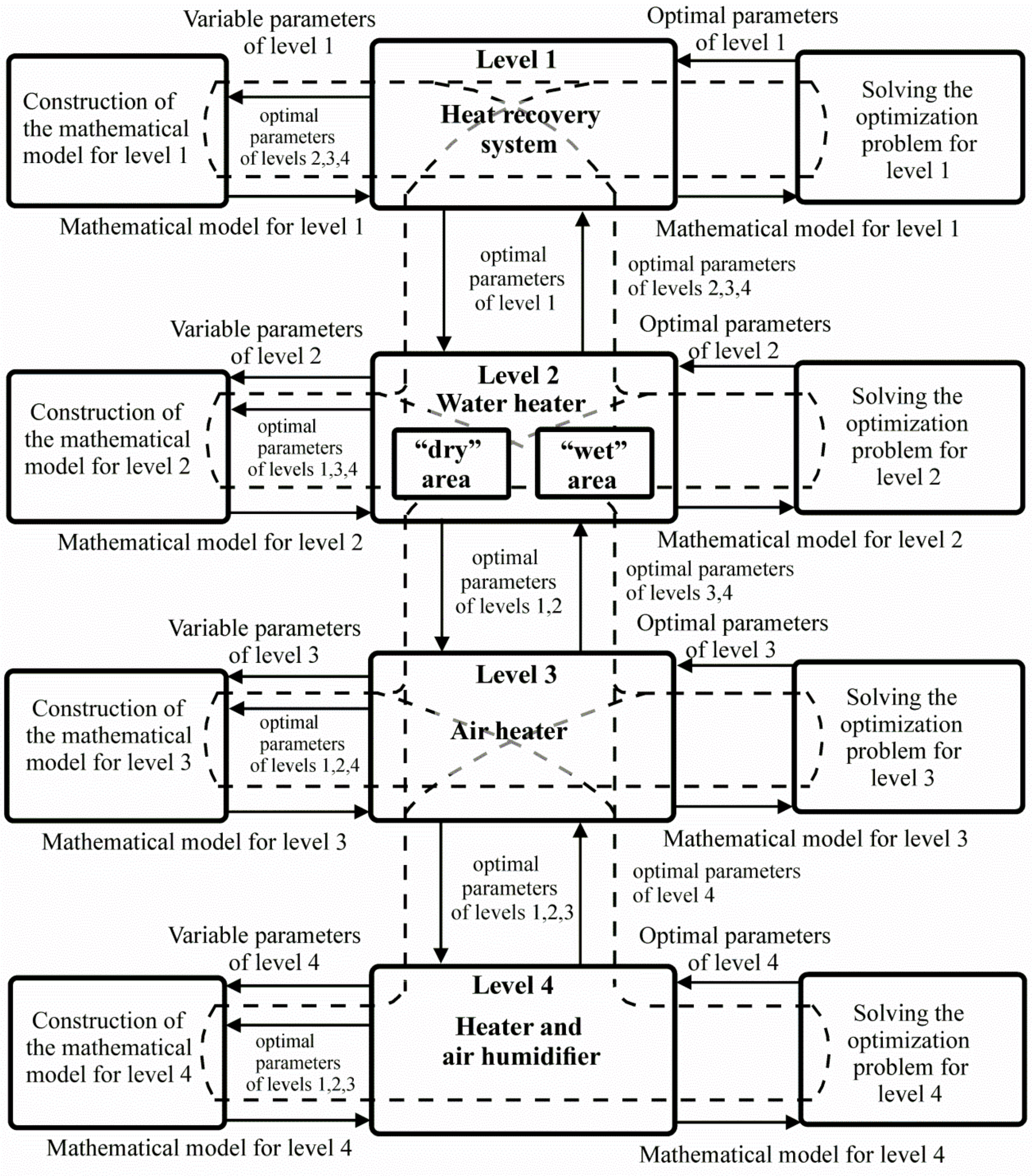

Fig. 2. Scheme of multi-level optimization of heat-recovery system for heating water and humidifying combustion air

The criteria for assessing the efficiency of the heat-recovery system have been developed, including exergy characteristics with high sensitivity to changes in the parameters of the heat-recovery system. The specified criteria are used as target optimization functions when solving optimization problems for each optimization level.

To solve optimization problems, mathematical models have been developed for each optimization level and functional dependencies of the selected criteria on the main parameters of the system have been obtained. By means of the specified complex methodology, the optimal values of the parameters of the heat-recovery system have been determined (Table 1).

Table 1

Optimal parameters of the heat-recovery system for heating water and humidifying the combustion air

Optimization level	Parameters	Optimal values of parameters
Heat-recovery system	Water flow rate in the circulation circuit, kg/s	0.8 ÷ 1.1
	Initial moisture content of waste gases, kg/kg dry gases	0.18 ÷ 0.20
	Water temperature at the inlet to the water heater, *K*	303 ÷ 305
Surface condensing water heater SWH	Ratio of the initial and final moisture content of waste gases.	3.0 ÷ 3.3
	Ratio of the Reynolds numbers of waste gases and water.	1.0 ÷ 1.3
Water heater WO, AP1, AP2, GH (dry zone)	Fin height, mm	10.0 ÷ 11.0
	Fin thickness, mm	4.0 ÷ 6.0
	Interfin pitch, mm	3.0 ÷ 3.5
Surface condensing water heater SWH (wet zone)	Fin height, mm	11.0 ÷ 13.0
	Fin thickness, mm	4.0 ÷ 6.0
	Interfin pitch, mm	4.0 ÷ 5.0
Contact air heater CAH	Plate width, mm	1350 ÷ 1550
	Plate height, mm	1500 ÷ 2000
	Distance between plates, mm	5 ÷ 6
	Ratio of the initial and final moisture content of air	0.05 ÷ 0.06
	Density of irrigation of the packing, m3/m2h	10.0 ÷ 15.0
	Specific surface area of the packing, m2/m3	90.0 ÷ 100.0

At obtaining functional dependencies, balance methods of exergy analysis, statistical methods of experimental design and functional analysis were used.

Conclusions. Based on a comprehensive methodology, an exergy analysis of the complex heat-recovery system and its elements was conducted, the results of which determined the ranges of the main operational and design parameters within which maximum thermal and environmental efficiency is achieved.

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