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DEVELOPMENT OF METHODS FOR CALCULATING EXERGETIC LOSSES IN AIR-HEATING OF HEAT UTILIZATION SYSTEMS OF BOILER PLANTS

Summary. *A reasoned choice of the method of researching the exergetic efficiency of the heat recovery equipment of power plants allows optimizing the heat recovery parameters responsible for the equipment's efficiency. The results of the development of a complex methodology for calculating exergy losses in plate and smooth-tube air-heated heat exchangers of boiler plants are presented. Exergetic losses are used as a criterion of exergetic efficiency of heat exchangers. The methodology is based on systems of integral equations of functional analysis and differential equations of heat transfer theory. Formulas for calculating exergy losses in flat and cylindrical walls of heat exchangers are obtained. The processes of heat conduction, heat transfer from flue gases to the wall and heat transfer from the wall to the air are considered. The developed technique makes it possible to ensure the necessary reduction of losses of a certain type in order to increase the exergetic efficiency of heat utilization systems of boiler plants.*

Key words: *exergetic efficiency; exergetic losses; heat exchangers.*

Introduction. The solution to the general problem of energy saving in Ukraine is associated with the need to increase the efficiency of energy installations. An important indicator of the thermodynamic perfection of an installation is its exergy efficiency. A well-founded choice of methodology for studying exergy efficiency makes it possible to optimize the structural, technological and thermal parameters responsible for the efficiency of installations, which contributes to the introduction of installations with high efficiency indicators into the energy sector of Ukraine. This determines the importance and relevance of research in this direction.

Problem statement and research method. Currently, complex methods using exergetic, exergoeconomic analysis, structural theory of thermoeconomic methods are most often used to study the exergetic efficiency of various types of installations [1-5]. The problem of increasing the exergetic efficiency of installations requires the application of complex methods based on exergotechnological methods in combination with methods of functional analysis and the theory of thermal conductivity. Such complex methods make it possible to calculate local exergetic losses of various types in thermal engineering processes of installations and ensure their necessary reduction in order to increase exergetic efficiency.

Purpose of the work, materials and research methods. The purpose of the work is to develop complex methods for calculating exergy losses in plate and smooth-tube air-heating heat exchangers of boiler plants.

To achieve the goal, you must complete the following tasks:

– establish the types of local exergy losses for plate and smooth-tube air-heated heat exchangers;
– develop systems of integral and differential equations for calculating local exergy losses in heat transfer processes through the flat and cylindrical walls of heat recovery units;
– based on systems of integral and differential equations, obtain formulas for calculating exergy losses.

We considered plate and smooth-tube air-heated heat exchangers used in the heat recovery system of a heating boiler. To study exergy losses in heat exchangers, a complex methodology has been developed, which is based on systems of integral equations of functional analysis and differential equations of heat transfer theory.

Research results. Local exergy losses in heat exchangers are losses in the processes of thermal conductivity, heat transfer from flue gases to the wall and heat transfer from the wall to the air. A comprehensive methodology has been developed for calculating exergy losses in these processes for flat and cylindrical walls of heat exchangers. Within the framework of the comalex technique, systems of integral and differential equations have been developed. For a flat wall:

$$E^{p}_{\text{los},\lambda} = -T_0 \int_v \frac{q}{T^2} \frac{\partial T}{\partial x} dv$$

$$E^{p}_{\text{los},\lambda} = -T_0 \iint_S dydz \int_0^{\delta} \frac{q}{T^2} \frac{\partial T}{\partial x} dx;$$

$$E^{p}_{\text{los},\lambda} = -T_0 S \int_0^{\delta} \frac{q}{T^2} \frac{\partial T}{\partial x} dx;$$

$$E^{p}_{\text{los},\lambda} = T_0 S\lambda \int_0^{\delta} \left(\frac{dT}{dx} \right)^2 \frac{1}{T^2} dx;$$

$$q = -\lambda \frac{dT}{dx};$$

$$T = T_{\text{w}1} - \frac{T_{\text{w}1} - T_{\text{w}2}}{\delta} x.$$

Where E – exergy; *N* – heat capacity; *q* – heat flow; *S* – surface; r1, r2 – outer and inner radii of pipes; *T* – absolute temperature; T_0 – ambient temperature; *V* – volume; δ – wall thickness; α – heat transfer coefficient; λ is the thermal conductivity coefficient. **Upper indices:** p – plate; c is a cylinder. **Lower indices**: *los* – exergy losses; *los*λ, *los*1, *los*2 – heat conduction and heat transfer losses; *w*1, *w*2 – walls from the side of flue gases and air; α_1, α_2 are coefficients of heat transfer from flue gases to the wall and from the wall to the air.

Formulas were obtained for calculating exergy losses during thermal conductivity, heat transfer from flue gases to the wall and heat transfer from the wall to air: $E^{p}_{\text{los},\lambda} = \frac{T_0 N^2 \delta}{\lambda S T_{\text{w}1} T_{\text{w}2}}$, $E^{p}_{\text{los},\alpha 1} = \frac{T_0 N^2}{S\alpha 1 T_{\text{w}1} T_{\text{w}2}}$, $E^{p}_{\text{los},\alpha 2} = \frac{T_0 N^2}{S\alpha 2 T_{\text{w}1} T_{\text{w}2}}$.

For a cylindrical wall:

$$E^{c}_{\text{los},\lambda} = -T_0 \int_V \frac{q}{T^2} \frac{\partial T}{\partial r} dv,$$

$$E^{c}_{\text{los},\lambda} = -T_0 2\pi l \int_{r_1}^{r_2} r \left(\frac{q}{T^2} \frac{\partial T}{\partial r} \right) dr,$$

$$E^{c}_{\text{los},\lambda} = 2\pi l T_0 \lambda \int_{r_1}^{r_2} r \left(\frac{1}{T} \frac{\partial T}{\partial r} \right)^2 dr,$$

$$T = T_{w1} - \frac{(T_{w1} - T_{w2})}{\ln\frac{r_2}{r_1}} \ln\frac{r}{r_1},$$

Formulas for calculating exergy:

$$E^c_{\text{los},\lambda} = \frac{T_0 N^2 \ln\frac{r_2}{r_1}}{2\pi\lambda l T_{w1} T_{w2}} ; E^c_{\text{los},\alpha1} = \frac{2N^2 T_0 (r_1 + 2r_2)(r_1 + r_2)}{r_2{}^2 S\alpha_1 (T_g + T_w)^2} ; E^c_{\text{los},\alpha2} = \frac{2T_0 N^2 (r_1 + r_2)}{r_1 S\alpha_2 (T_a + T_w)^2} .$$

The resulting formulas serve to calculate and compare exergy losses, and therefore exergy efficiency, in plate and smooth-tube air-heated heat exchangers of recovery systems of power plants.

Conclusions.

1. The types of local exergy losses for plate and smooth-tube air-heating heat exchangers of boiler plants have been established.
2. Within the framework of a complex methodology for calculating exergy losses in heat transfer processes through the flat and cylindrical walls of heat exchangers, systems of integral equations of functional analysis and differential equations of heat transfer theory have been developed.
3. Based on systems of equations, formulas were obtained for calculating exergy losses in plate and smooth-tube air-heated heat exchangers.

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