Technical Sciences

UDC 621.036.7

Fialko Nataliia

Doctor of Technical Science, Professor, Head of Department,

Honored Worker of Scientist of Ukraine, Corresponding Member of the

National Academy of Science of Ukraine

Stepanova Alla

PhD, Leading Researcher

Institute of Engineering Thermophysics of

National Academy of Science of Ukraine

Navrodskaya Raisa

PhD, Senior Researcher, Leading Researcher

Institute of Engineering Thermophysics of

National Academy of Science of Ukraine

Meranova Nataliia

PhD, Senior Researcher, Leading Researcher

Institute of Engineering Thermophysics of

National Academy of Science of Ukraine

USING SOME ALGORITHMS OF PLANNING THEORY OF EXPERIMENT FOR ANALYZING THE EFFICIENCY OF AIR HEATER OF HEAT UTILIZATION SYSTEM

Summary. *Some optimization algorithms used in the planning theory of experiment in combination with exergy analysis methods are considered. The Box-Wilson steep climb method combines the positive aspects of three methods - the Gauss-Seidel method, the gradient method and the methods of full or fractional factor experiments. The method of canonical transformations allows you to get a graphical and analytical interpretation of the optimum region using a series of* *contour curves in the plane. The possibility of using optimization algorithms to obtain optimal values and intervals for changing the geometric parameters of the heat transfer surface of the air heater of the heat recovery system is considered.*

Key words: *exergy analysis, optimization, heat recovery system.*

Some optimization algorithms used in the theory of experiment planning and the possibility of their use in analyzing the exergic efficiency of a contact surface air heater of a heat recovery system are considered [1]. Optimization algorithms in combination with methods of exergic analysis were used to obtain optimal values and intervals of changes in the geometric parameters of the heat exchange surface of the heater. Exergy research methods in world practice are quite common. As an example of research based on the application of a class of exergy methods, one can cite works [2–6]. In accordance with the statistical methods of experiment planning, the functional dependences of the exergic efficiency criteria on the main geometric parameters of the heat exchange surface of heat exchangers can be described by regression equations. In some cases, in these equations, terms of the second order can be neglected in accordance with Student's criterion. For such functional dependencies, it is rational to use the Box-Wilson steep ascent algorithm, which combines the positive aspects of the three methods — the Gauss-Seidel method, the gradient method, and the full or fractional factorial experiments – as a means of obtaining a linear mathematical model. The task of the steep ascent algorithm is to perform a step motion in the direction of a quick change of the output variable, that is, along $grad\ y(x_i)$. In contrast to the gradient method, the direction of the step motion is not adjusted after each next step, but after reaching the largest or smallest value of the objective function at a certain point on a given direction, as is done using the Gauss-Seidel method. When calculating it is necessary to keep in mind that if any of the factors in the process of movement reaches the limit of the domain of definition, then it can be fixed and continue moving along other factors. Let us consider as an example the dependence of the heat-exergic efficiency criterion obtained for the air heater under study $\varepsilon = E/Q$ from the width a and the height b of the plate of the heat utilizer, as well as the distance between the plates s. Here E is the power of exergy losses, Q is the heat power. Taking into account the insignificance of some coefficients of the regression equation in accordance with Student's criterion, this dependence at ambient temperature $t_0 = 5°C$ has the form:

$$\varepsilon = 2{,}70 \cdot 10^{-1} - 1{,}90 \cdot 10^{-4}a + 2{,}08 \cdot 10^{-6}b + +3{,}07 \cdot 10^{-2}s - 1{,}19 \cdot 10^{-5}as.$$

In this case, the linear model is not adequate, since the resulting equation includes, in addition to linear terms, terms describing the interaction, which indicates a certain curvature of the response function. However, in this case, it may be rational to use the Box-Wilson steep ascent method. In accordance with the algorithm of this method, one can approach the smallest values of the objective function on a given interval using only the linear terms of the equation. Indeed, in this case, the steep ascent method turned out to be effective with an accuracy of 5...6%. In the process of approaching the region of the smallest values of the objective function, the factor a reached its optimal value a = 1400 mm, and two other factors reached the boundaries of the area of change: b - the upper limit of the corresponding interval of variation b = 2000mm, s - the lower limit s = 5mm. Thus, the values a = 1400 mm, b = 2000 mm, s = 5 mm are the optimal geometrical parameters of the heat exchange surface of the heater being investigated.

For regression equations of the second order, there are certain difficulties in the geometric interpretation of the surface of the response functions, which increase with an increase in the number of factors n. When $n \geq 3$, it is impossible to give a visual representation of the geometry of such a surface. With the number of factors n = 2, the volumetric image, although it gives a visual representation of the geometry of the surface of the response function, however, does not allow a detailed study of this surface in the optimum region. In this case, in all cases, if we consistently consider the change of two factors with constant others, such a study is possible using the method of canonical transformations. This method allows to obtain a graphical and analytical interpretation of the optimum region using a series of contour curves in the plane. A detailed study of the surface of the response function in the optimum region with the help of flat contour curves is necessary to determine technologically reasonable intervals of change of parameters of the heat-exchange surface of the heater based on the exact values of the optimal parameters. A slight change in the response function with a change in the corresponding parameter allows in practice to extend the interval of change of this parameter. Otherwise, the interval changes is narrowed and there is a need to adhere to the exact values of the optimal parameters when designing the heat exchange surface of the heat exchanger. For the studied heat exchanger with $t_0 = 0°C$, the regression equations are second order equations. As an example, we give some dependencies. For a fixed value of the optimal distance between the plates, s = 5mm and $t_0 = 0°C$:

$$\varepsilon = 0{,}58 - 3{,}54 \cdot 10^{-4}\, a + 1{,}19 \cdot 10^{-7}\, a^2 - 1{,}75 \cdot 10^{-5}\, b + 3{,}77 \cdot 10^{-9}\, b^2 + 2{,}43 \cdot 10^{-9}\, a\, b.$$

In canonical form:

$$\varepsilon - 3{,}03 \cdot 10^{-1} = 1{,}19 \cdot 10^{-7}\, a^2 + 3{,}79 \cdot 10^{-9}\, b^2,$$

The geometrical interpretation of the response surface in the optimum region is an ellipsoid depression, in the center of which there is a minimum, and contour curves in the optimum region are ellipses. In figure 1 shows, as an example, the graph of the above dependence and the corresponding contour curves for the air heater under study at $t_0 = 0°C$. The contour curves of the response surfaces are plotted for the values of the response functions, which differ, on average, by 2%, 4% and 6% of the values of the response functions at the minimum points. As can be seen from the figure, the distances between the contour curves of the response surface for the parameter a are approximately the same and insignificant, but for the parameter these distances are much larger. This means that the technologically based intervals of change of parameter b can be significantly extended.

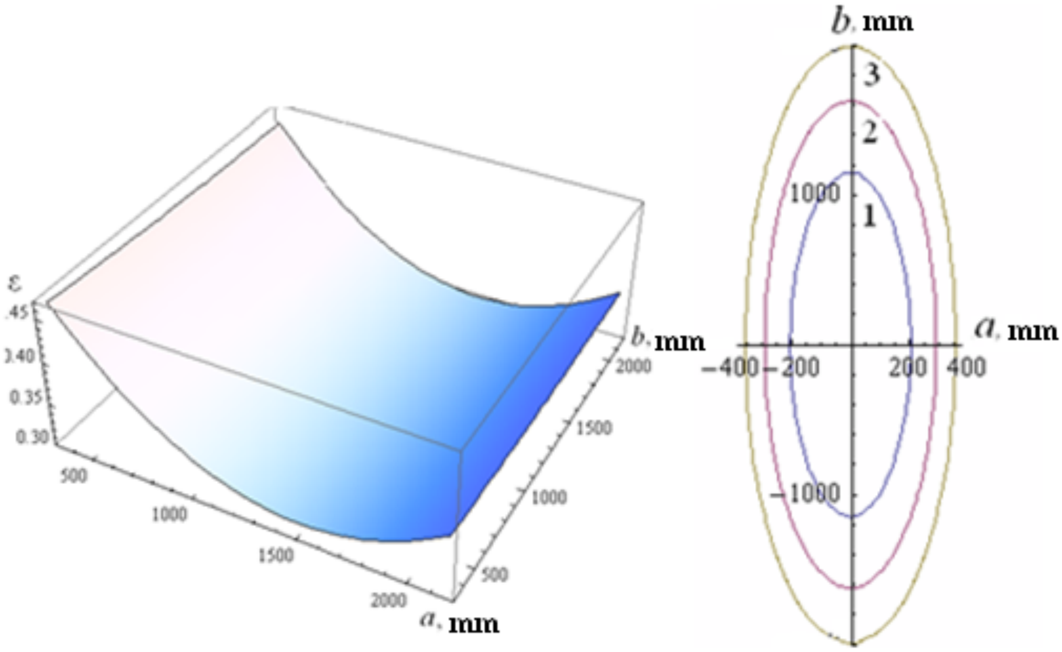

Fig. 1. Dependence of the heat-exergic efficiency criterion ε on the plate width *a* and height *b* at *s* = 5 mm for t_0 = 0°*C*; and contour curves in the optimum range: 1 - ε = 0.308, 2 - ε = 0.313, 3 - ε = 0.318

Conclusion

1. The possibility of using the Box-Wilson steep ascent algorithm and the method of canonical transformations to obtain optimal values and intervals for changing the geometric parameters of the heat exchange surface of the contact surface heater of the heat recovery system is shown.
2. The dependences of the heat-exergic efficiency criterion on the geometrical parameters of the heat exchange surface and technologically based intervals of change of these parameters are determined for the investigated air heater.

References

1. Nalimov V. Experiment Theory / Nalimov V. // M .: Science, 1971. 207 p.
2. Sahin Z. Importance of Exergy Analysis in Industrial Processes / Z. Sahin. // 2014. URL: https://www.researchgate.net/publication/228988818.

3. Cziesla F. Avoidable thermodynamic inefficiencies and costs in an externally fired combined cycle power plant / F. Cziesla, G. Tsatsaronis, Z. Gao // Energy. 2006. V. 31, Issues 10–11. PP. 1472–1489.
4. Morosuk T. A new approach to the exergy analysis of absorption refrigeration machines / T. Morosuk, G. Tsatsaronis // Energy. 2008. V. 33. Issue 6. P. 890–907. doi.org/10.1016/j.energy. 2007.09.012.
5. Fialko N. Efficiency of the air heater in a heat recovery system at different thermophysical parameters and operational modes of the boiler / N. Fialko, A. Stepanova, R. Navrodska, N. Meranova, J. Sherenkovskii // East European Advanced Technology Journal. 2018. 6/8 (96). PP. 43–48.
6. Fialko N. Efficiency of combined heat-recovery systems of boiler plants (part 1) / N. Fialko, A. Stepanova, R. Navrodska // Power engineering and automation. 2018. №1. PP.78–90.