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MODEL OF A HEAT EXCHANGER AIR HEATING BOOSTER

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МОДЕЛЬ ТЕПЛООБМЕННИКА НАГРЕВАТЕЛЯ ВОЗДУШНОГО ОТОПЛЕНИЯ

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Abstract. To solve the problem of energy crisis in today's world, energy conservation is more and more get the attention of people, heat exchanger occupies an important place in the field of energy saving, however, because of the heat exchanger is a traditional energy-intensive heavy industry, one of the most widely used equipment in it as preheating, mainly in the process of waste heat recovery, refrigeration equipment, made outstanding contributions to energy saving. In this paper, spiral plate heat exchanger as the research object, select the established model, through the analysis of the existing heat transfer enhancement theory, combined with the classical optimization algorithm genetic algorithm spiral plate heat exchanger programming optimization, through iterative calculation to get the optimal spiral plate heat exchanger structure parameters. On this basis, based on the theory of dissipative, puts forward a new physical volume of fire, and established a new heat exchanger performance evaluation standard unit total cost model of heat transfer, and the objective function, analyzes the structural parameters in the spiral plate heat exchanger (cold and hot fluid flow, heat exchanger, plate spacing) and their relationship. Because the total cost per unit heat transfer not only considers the thermodynamic performance of the heat exchanger but also the economic feasibility of the heat exchanger. Finally, combined with the simulation calculation of the performance of the heat exchanger before and after optimization structure parameters, further analysis of its internal flow. The research in this paper provides a theoretical basis for the design, structure optimization and performance prediction of spiral plate heat exchanger.

Аннотация. Для решения проблемы энергетического кризиса в современном мире энергосбережение все больше и больше привлекает внимание людей. Теплообменные процессы занимают важное место в области энергосбережения, однако, поскольку теплообменники являются традиционным и широко используемым энергоемким оборудованием в тяжелой промышленности в качестве предварительного нагрева, в основном в процессе рекуперации отработанного тепла, холодильного оборудования, постольку вносят выдающийся вклад в энергосбережение. В работе спиральный пластинчатый теплообменник в качестве объекта исследования выбирается установленной моделью путем анализа существующей теории улучшения теплопередачи в сочетании с классическим алгоритмом оптимизации путем итеративного расчета, чтобы получить оптимальные параметры конструкции спирального пластинчатого теплообменника. На этом основании, исходя из диссипативной теории, устанавливается новая нормативная единица оценки производительности теплообменника, модель общей стоимости теплопередачи и целевая функция, анализируются конструктивные параметры в спиральной пластине теплообменника (поток холодной и горячей жидкости, теплообменник, расстояние между пластинами) и их взаимосвязь. Общая стоимость единицы теплопередачи учитывает не только термодинамические характеристики теплообменника, но и экономическую целесообразность теплообменника. Наконец, в сочетании с имитационным расчетом производительности теплообменника до и после оптимизации параметров конструкции проводится дальнейший анализ его внутреннего потока. Исследование обеспечивает теоретическую основу для проектирования, оптимизации конструкции и прогнозирования производительности спирального пластинчатого теплообменника.

Keywords: spiral plate heat exchanger, genetic algorithm, small volume dissipation, performance evaluation, fluent simulation.

Ключевые слова: спиральный пластинчатый теплообменник, генетический алгоритм, рассеяние малого объема, оценка производительности, проточное моделирование.

Introduction

Relevance of the research topic. Russia is a country with a huge, branched heating system. Mechanical engineering today cannot provide a complete set of energy-efficient equipment. But there have been positive developments in this direction. In this regard, plate heat exchange equipment is a modern and reliable device with high performance, optimal price, and compact dimensions. Consequently, the operation of such equipment requires a high technological culture and discipline to ensure the required water regime.

Scientific novelty lies in the study of plate heat exchangers and the selection of their rational parameters. The practical significance of the study lies in the use of this technology in practice in the energy sector in general, as well as in resource-supplying organizations. The dissertation consists of an introduction, three chapters, a conclusion, a list of references, applications.

Material and research methods

A plate heat exchanger is a device in which the process of transferring heat from one medium to another is carried out - from a hot coolant to a cold (heated) one and vice versa. Accordingly, depending on the purpose, such heat exchangers are used for both heating and cooling. The plate heat exchanger is a frame consisting of a rear fixed panel and a front movable plate, which are pulled together by guides. Stamped plates made of stainless steel are placed between the plates.

The plates are made of stainless steel or corrosion-resistant alloys. Gaskets are distinguished by high endurance and quality; their service life is measured in decades. Figure 1 shows a collapsible plate heat exchanger of the HH type.

Advantages and disadvantages of collapsible units. In boiler houses, thermal power plants, GRESS, nuclear power plants and other heat supply organizations, collapsible heat exchangers are often used. Their main advantage lies in the possibility of mechanical cleaning. Various deposits can form inside the unit, which can significantly impair the operation of the device. Therefore, the possibility of periodic cleaning makes it easy to maintain collapsible devices. The disadvantages of these devices include the complexity of installation and high cost.

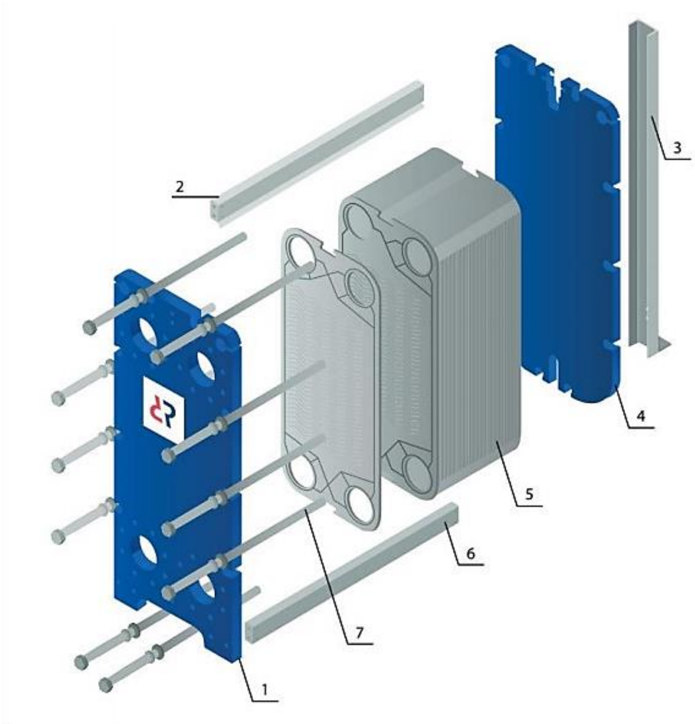

Figure 1. Heat exchanger: 1 - fixed plate, 2 - top guide, 3 - back stand,4 - pressure plate, 5 - package of plates with gaskets,6 - lower guide, 7 - tie rods

In heat supply systems, the transfer of heat to consumers is associated with its multiple transformations in heat exchange equipment. Therefore, the efficiency of systems largely depends on the efficiency of its individual elements, in particular, heat exchange equipment. The most affordable way to improve the efficiency of existing and projected heat exchange equipment is to increase the heat transfer coefficient. Passive methods are based on changing the heat exchange surface, including the installation of additional elements, while increasing the hydraulic resistance of the channels. In active methods, the intensification of heat transfer occurs due to the application of external energy to influence the flow.

The method for calculating plate water heaters can be based on the following initial conditions:

- available pressures of heat carriers are known.
- the optimum speed of heated water is set.

As a result of using this design of the shock assembly, relatively high reliability and stability of its operation are ensured with high-quality generation of pulses of the momentum of the working medium in a wide range of changes in its parameters, a mechanism for automatically adjusting the alternate opening and closing of the shock valves due to the compliance of the springs is implemented, and friction costs are completely eliminated , as a result, the resource of using the device increases many times.

The analysis of the state of the issue made it possible to determine the scientific problem of the study, which consists in substantiating the device for the purpose of the work is to study the operation of a plate heat exchanger in a pulsating mode.

A mathematical model of an installation considering hydraulic processes in a heated (closed) circuit with a pulsating movement of the coolant is proposed, based on the theory of electrical circuits.

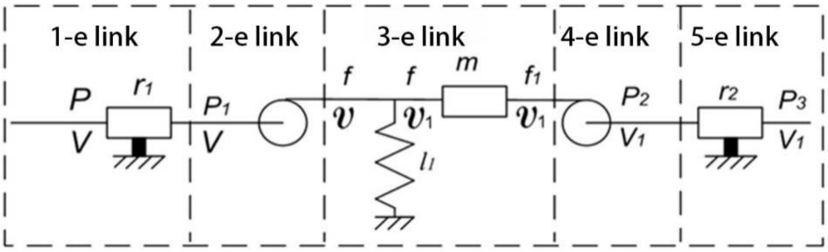

Figure 2. Energy chain of the installation considering hydraulic processes in a heated (closed) circuit with impulse water heating

$$\left\{\begin{matrix} P = r_1 \cdot V^2 + P_1 \\ V = V \end{matrix}\right\} \left\{\begin{matrix} f = P1 \cdot Sp \\ v = \dfrac{V}{S_p} \end{matrix}\right\} \left\{\begin{matrix} f = m \cdot \dot{v}_1 + f_1 \\ v = l_1 \cdot \dot{f} + v_1 \end{matrix}\right\}$$
$$\left\{\begin{matrix} P_2 = \dfrac{f_1}{S_n} \\ V_1 = v_1 \cdot S_n \end{matrix}\right\} \left\{\begin{matrix} P_2 = r_2 \cdot V_1^2 + P_3 \\ V_1 = V_1 \end{matrix}\right\} \qquad (1)$$

Accordingly, the frequency function of the circuit:

$$Z(j\Omega) = \frac{-a_1 \cdot \Omega^2 + a_2 \cdot j\Omega + a_3}{-b_1 \cdot j\Omega - b_2} = \frac{\left(-a_1 \cdot \Omega^2 + a_2 \cdot j\Omega + a_3\right) \cdot \left(b_1 \cdot j\Omega - b_2\right)}{-\left(b_1 \cdot j\Omega + b_2\right) \cdot \left(b_1 \cdot j\Omega - b_2\right)}$$
$$= -\frac{-a_1 \cdot b_1 \cdot j\Omega^3 + a_1 \cdot b_2 \cdot \Omega^2 - a_2 \cdot b_1 \cdot \Omega^2 - a_2 \cdot b_2 \cdot j\Omega + a_3 \cdot b_1 \cdot j\Omega - a_3 \cdot b_2}{\left(b_1 \cdot j\Omega\right)^2 + b_2^2}$$
$$= -\frac{-a_1 \cdot b_1 \cdot j\Omega^3 + a_1 \cdot b_2 \cdot \Omega^2 - a_2 \cdot b_1 \cdot \Omega^2 - a_2 \cdot b_2 \cdot j\Omega + a_3 \cdot b_1 \cdot j\Omega - a_3 \cdot b_2}{-b_1^2\Omega^2 + b_2^2}$$

Real and imaginary parts of the frequency function:

$$\mathrm{Re}(j\Omega) = -\frac{\left(a_1 \cdot b_2 - a_2 b_1\right)\Omega^2 - a_3 b_2}{-b_1^2\Omega^2 + b_2^2} = \frac{a_3 \cdot b_2 - \left(a_1 \cdot b_2 - a_2 \cdot b_1\right) \cdot \Omega^2}{b_1^2\Omega^2 - b_2^2} \qquad (3)$$

$$\mathrm{Im}(j\Omega) = \frac{a_1 \cdot b_1 \cdot j\Omega^3 + \left(a_2 \cdot b_2 - a_3 \cdot b_1\right) \cdot j\Omega}{b_1^2\Omega^2 - b_2^2} \qquad (4)$$

Amplitude-frequency response (AFC):

$$A(j\Omega) = \sqrt{\left(\mathrm{Re}(j\Omega)^2 + \mathrm{Im}(j\Omega)^2\right)} \qquad (5)$$

Phase-frequency characteristic of the circuit (PFC):

$$\varphi(\Omega) = -arctg\frac{\mathrm{Im}(j\Omega)}{\mathrm{Re}(j\Omega)} \qquad (6)$$

Table 1

OBTAINED DATA

Ω	a_1	a_2	a_3	a_4	b_1	b_2	$\mathrm{Re}(j\Omega)$	$\mathrm{Im}(j\Omega)$	$A(j\Omega)$	$F(\Omega)$
0.5	6,48	750.2765	80	0.64	0.00864	1	-80.0021	187.393	203.7557	-1.1673
1	6,48	750.2765	80	0.64	0.00864	1	-80.0084	749.585	753.8431	-1.46446
1.5	6,48	750.2765	80	0.64	0.00864	1	-80.0188	1686.66	1688.558	-1.52339
2	6,48	750.2765	80	0.64	0.00864	1	-80.0335	2998.79	2999.857	-1.54411
2.5	6,48	750.2765	80	0.64	0.00864	1	-80.0523	4686.22	4686.904	-1.55372
3	6,48	750.2765	80	0.64	0.00864	1	-80.0753	6749.29	6749.766	-1.55893
3.5	6,48	750.2765	80	0.64	0.00864	1	-80.1025	9188.42	9188.773	-1.56208
4	6,48	750.2765	80	0.64	0.00864	1	-80.1339	12004.1	12004.39	-1.56412
4.5	6,48	750.2765	80	0.64	0.00864	1	-80.1696	15197	15197.19	-1.56552
5	6,48	750.2765	80	0.64	0.00864	1	-80.2094	18767.7	18767.84	-1.56652
5.5	6,48	750.2765	80	0.64	0.00864	1	-80.2535	22717	22717.1	-1.56726
6	6,48	750.2765	80	0.64	0.00864	1	-80.3018	27045.7	27045.81	-1.56783
6.5	6,48	750.2765	80	0.64	0.00864	1	-80.3544	31754.8	31754.91	-1.56827
7	6,48	750.2765	80	0.64	0.00864	1	-80.4112	36845.3	36845.41	-1.56861
7.5	6,48	750.2765	80	0.64	0.00864	1	-80.4723	42318.3	42318.42	-1.56889
8	6,48	750.2765	80	0.64	0.00864	1	-80.5377	48175.1	48175.16	-1.56912

Table 2

OBTAINED DATA

Ω	a_1	a_2	a_3	a_4	b_1	b_2	$\mathrm{Re}(j\Omega)$	$\mathrm{Im}(j\Omega)$	$A(j\Omega)$	$F(\Omega)$
0.5	12.96	1500.276	80	0.64	0.00864	1	-80.0021	-374.889	383.3306	-1.36055
1	12.96	1500.276	80	0.64	0.00864	1	-80.0084	-1499.59	1501.718	-1.51749
1.5	12.96	1500.276	80	0.64	0.00864	1	-80.0188	-3374.26	3375.204	-1.54709
2	12.96	1500.276	80	0.64	0.00864	1	-80.0335	-5999.24	5999.771	-1.55746
2.5	12.96	1500.276	80	0.64	0.00864	1	-80.0523	-9375.03	9375.375	-1.56226
3	12.96	1500.276	80	0.64	0.00864	1	-80.0753	-13502.3	13502.56	-1.56487
3.5	12.96	1500.276	80	0.64	0.00864	1	-80.1025	-18381.9	18382.11	-1.56644
4	12.96	1500.276	80	0.64	0.00864	1	-80.1339	-24014.9	24015.02	-1.56746
4.5	12.96	1500.276	80	0.64	0.00864	1	-80.1696	-30402.4	30402.48	-1.56816
5	12.96	1500.276	80	0.64	0.00864	1	-80.2094	-37545.7	37545.82	-1.56866
5.5	12.96	1500.276	80	0.64	0.00864	1	-80.2535	-45446.5	45446.56	-1.56903
6	12.96	1500.276	80	0.64	0.00864	1	-80.3018	-54106.4	54106.41	-1.56931
6.5	12.96	1500.276	80	0.64	0.00864	1	-80.3544	-63527.2	63527.24	-1.56953
7	12.96	1500.276	80	0.64	0.00864	1	-80.4112	-73711	73711.08	-1.56971
7.5	12.96	1500.276	80	0.64	0.00864	1	-80.4723	-84660.1	84660.16	-1.56985
8	12.96	1500.276	80	0.64	0.00864	1	-80.5377	-96376.8	96376.88	-1.56996

Table 3

OBTAINED DATA

Ω	a_1	a_2	a_3	a_4	b_1	b_2	$\mathrm{Re}(j\Omega)$	$\mathrm{Im}(j\Omega)$	$A(j\Omega)$	$F(\Omega)$
0.5	19.44	2250.276	80	0.64	0.00864	1	-80.0021	-562.386	568.0477	-1.42949
1	19.44	2250.276	80	0.64	0.00864	1	-80.0084	-2249.59	2251.008	-1.53525
1.5	19.44	2250.276	80	0.64	0.00864	1	-80.0188	-5061.85	5062.483	-1.55499
2	19.44	2250.276	80	0.64	0.00864	1	-80.0335	-8999.69	9000.041	-1.5619
2.5	19.44	2250.276	80	0.64	0.00864	1	-80.0523	-14063.8	14064.07	-1.5651
3	19.44	2250.276	80	0.64	0.00864	1	-80.0753	-20255.3	20255.5	-1.56684
3.5	19.44	2250.276	80	0.64	0.00864	1	-80.1025	-27575.4	27575.56	-1.56789
4	19.44	2250.276	80	0.64	0.00864	1	-80.1339	-36025.7	36025.75	-1.56857
4.5	19.44	2250.276	80	0.64	0.00864	1	-80.1696	-45607.8	45607.83	-1.56904
5	19.44	2250.276	80	0.64	0.00864	1	-80.2094	-56323.8	56323.85	-1.56937
5.5	19.44	2250.276	80	0.64	0.00864	1	-80.2535	-68176	68176.07	-1.56962
6	19.44	2250.276	80	0.64	0.00864	1	-80.3018	-81167	81167.05	-1.56981
6.5	19.44	2250.276	80	0.64	0.00864	1	-80.3544	-95299.6	95299.6	-1.56995
7	19.44	2250.276	80	0.64	0.00864	1	-80.4112	-110577	110576.8	-1.57007
7.5	19.44	2250.276	80	0.64	0.00864	1	-80.4723	-127002	127001.9	-1.57016
8	19.44	2250.276	80	0.64	0.00864	1	-80.5377	-144579	144578.6	-1.57024

Based on the results of the calculation, graphs of the frequency response and phase response of the chain were plotted for 3 mass values: 2.7; 5.4; 8.1 kg; (Figure 3, 4).

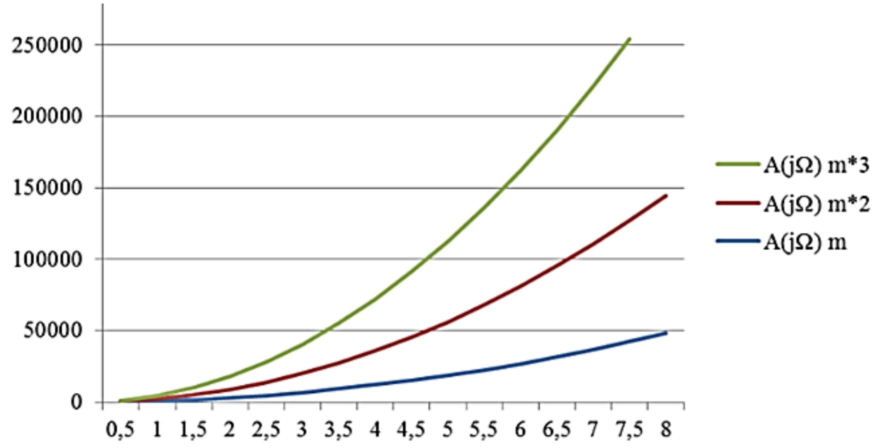

Figure 3. Amplitude-frequency characteristics

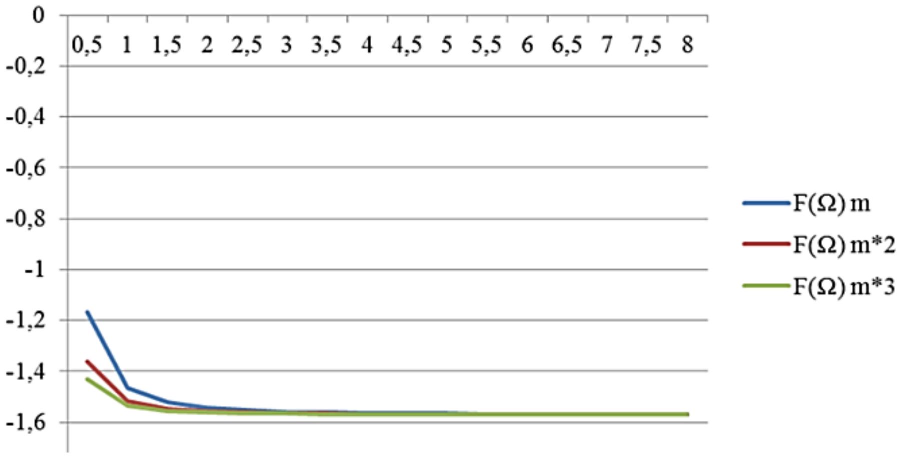

Figure 4. Phase-frequency characteristics

The experimental setup includes: three temperature sensors, a hydraulic accumulator, an impact unit (flow converter), a mechanical gearbox, two counters on different circuits, two check valves, two pressure gauges. A diagram of the cooling circuit with a heat exchanger-supercharger is shown in Figure 5.

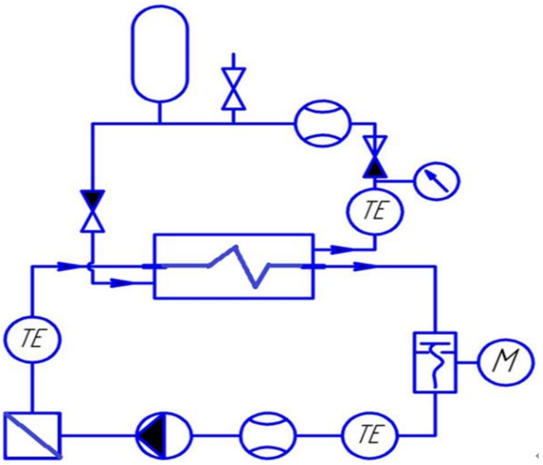

Figure 5. Scheme of the cooling circuit with a heat exchanger-supercharger

Sensor for measuring the temperature of the heat carrier in the heating or hot water preparation pipeline. The working element of the sensor is made of a tube made of copper or stainless steel. For hot water systems, it is recommended to install the sensor without a protective sleeve. This contributes to a faster process of responding to changes in the temperature of the coolant.

On Figure 6. shows a graph of temperature change over time in a heating and closed circuit at a flow interruption frequency of 0.5 Hz (this corresponds to a supply voltage frequency of 10 Hz).

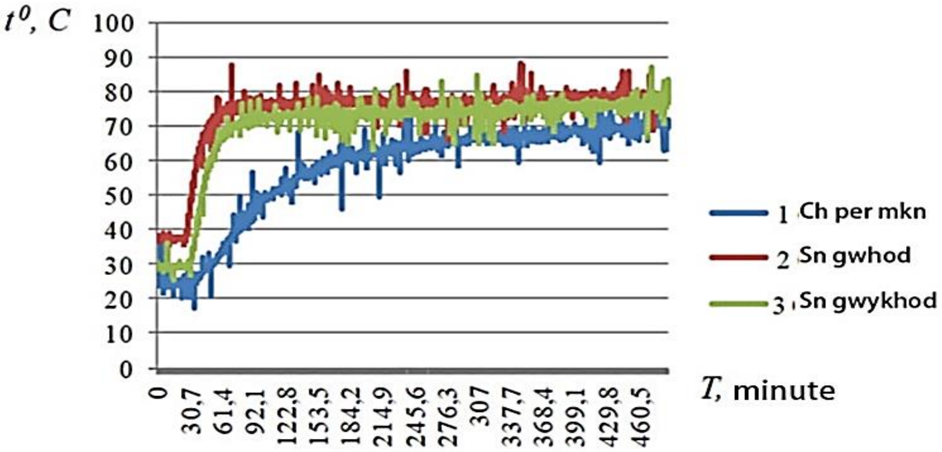

Figure 6. Graph of temperature change over time in the heating and closed loop at a flow interruption frequency of 0.5 Hz

On Figure 7. According to the results of the second experiment, a graph of temperature changes over time in the heating and closed circuits is shown at a flow interruption frequency of 0.6 Hz (this corresponds to a supply voltage frequency of 12 Hz).

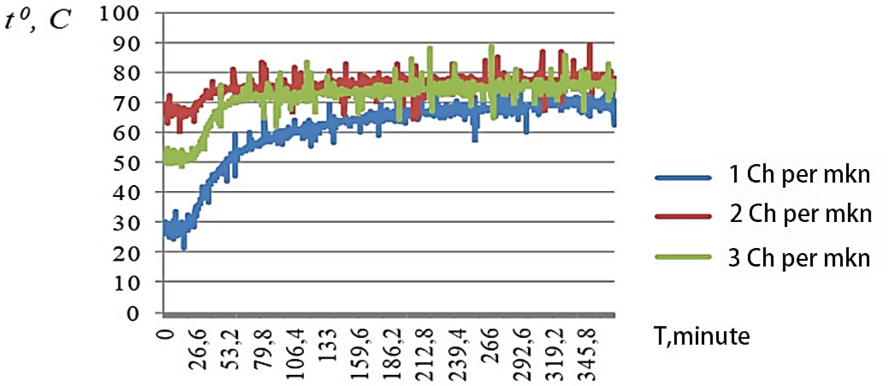

Figure 7. Graph of temperature change over time in the heating and closed loop at a flow interruption frequency of 0.6 Hz

On Figure 8. a graph of the temperature change over time in the heating and closed circuit is shown at a flow interruption frequency of 0.7 Hz (this corresponds to a supply voltage frequency of 14 Hz).

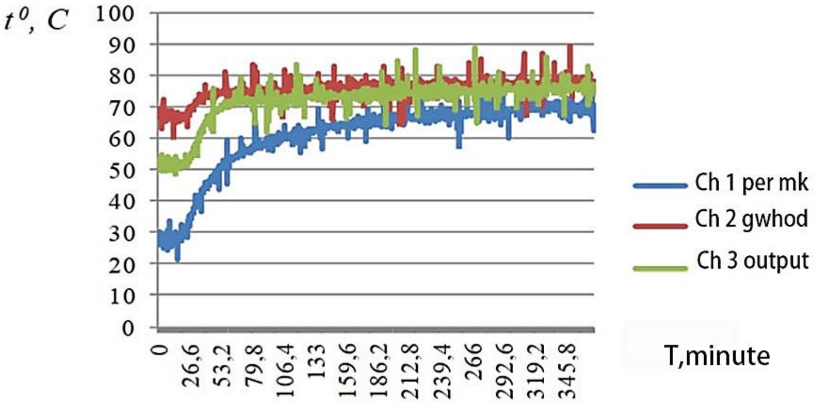

Figure 8. Graph of temperature change over time in the heating and closed circuit at a flow interruption frequency of 0.7 Hz

On Figure 9. a graph of the temperature change over time in the heating and closed circuit is shown at a flow interruption frequency of 0.8 Hz (this corresponds to a supply voltage frequency of 16 Hz).

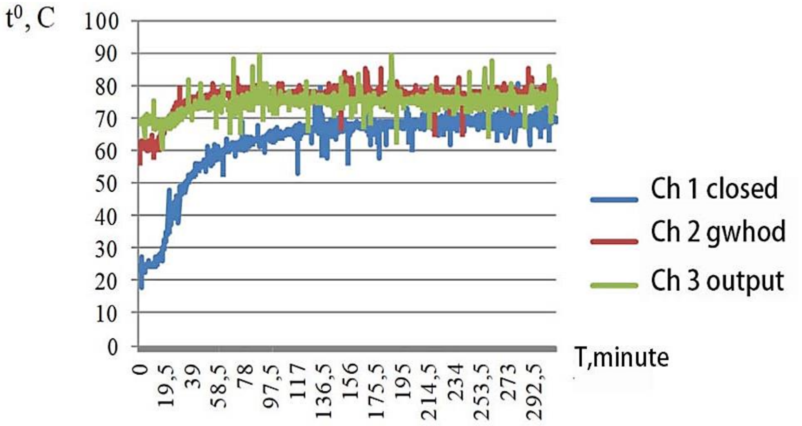

Figure 9. Graph of temperature change over time in the heating and closed loop at a flow interruption frequency of 0.8 Hz

On Figure 10. shows a graph of temperature change over time in the heating and closed circuit at a flow interruption frequency of 0.9 Hz (this corresponds to a supply voltage frequency of 18 Hz).

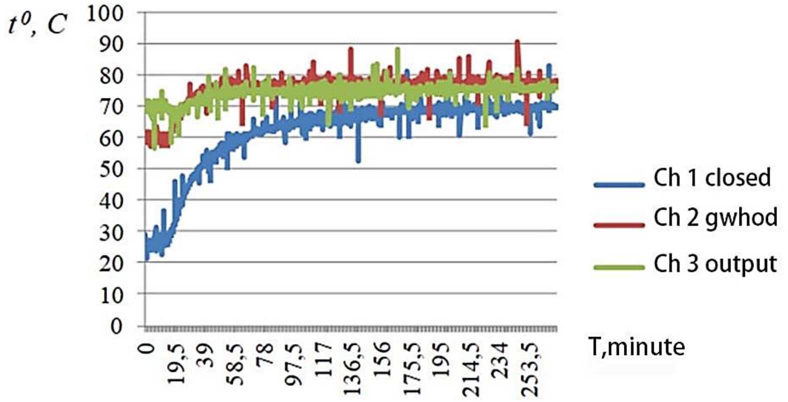

Figure 10. Graph of temperature change over time in the heating and closed loop at a flow interruption frequency of 0.9 Hz

On Figure 11. shows a graph of temperature change over time in a heating (closed) circuit at a flow interruption frequency of 1 Hz (this corresponds to a supply voltage frequency of 20 Hz).

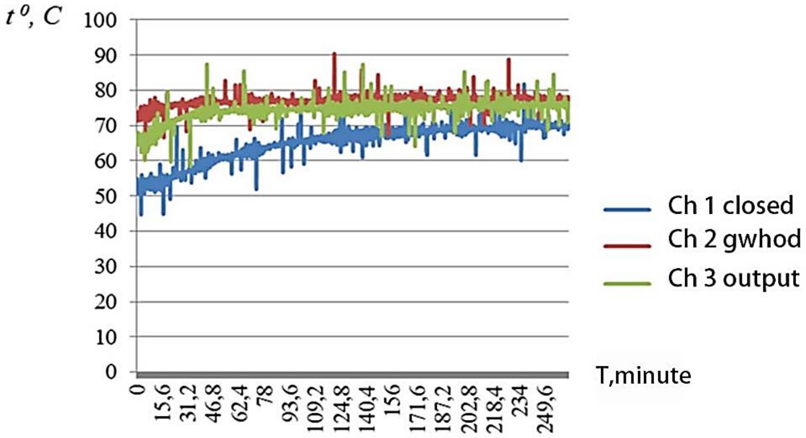

Figure 11. Graph of temperature change over time in the heating and closed loop at a flow interruption frequency of 1 Hz

On Figure 12. a graph of change in the flow rate of the coolant from the frequency of the supply voltage in a closed circuit is shown.

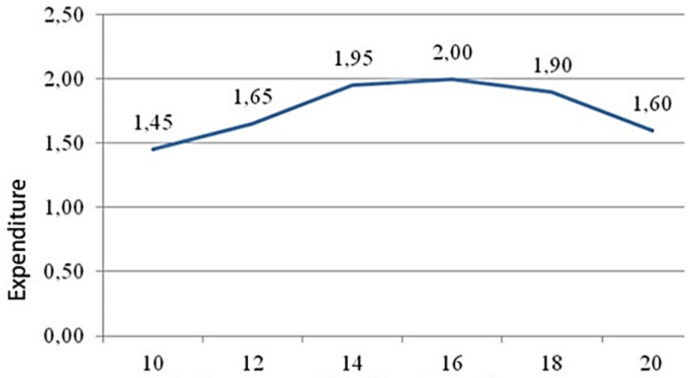

Figure 12. Graph of the dependence of the coolant flow rate on the frequency of the supply voltage in the heated (closed) circuit

On Figure 13. a graph of the change in the flow rate of the coolant from the frequency of flow interruption in a heated (closed) circuit is shown.

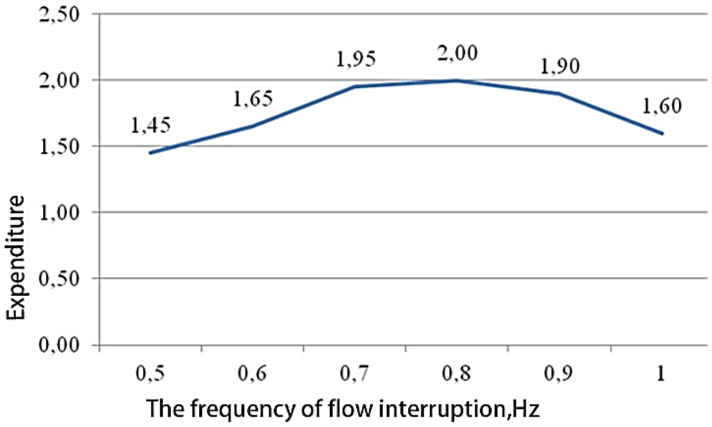

Figure 13. Graph of the dependence of the coolant flow rate on the frequency of flow interruption in a heated (closed) circuit

The thermodynamic analysis of the heat exchanger before and after optimization is done, that is, the related parameters such as entropy production and exergy are calculated for the heat exchanger before and after optimization. The analysis results of the entrance and the thermal resistance of the heat exchanger also show that the thermodynamic performance of the heat exchanger after optimization is better than that before optimization.

References:

1. Kaladgi, A. R., Vishwanath, K. C., Madhu, P., Chandrashekar, A., & Chaluvaraju, B. V. (2021, October). Effect of copper oxide nano fluids as coolant on thermal performance of spiral heat exchanger. In *IOP Conference Series: Materials Science and Engineering* (Vol. 1189, No. 1, p. 012037). IOP Publishing.

2. Mazaheri, N., & Bahiraei, M. (2021). Energy, exergy, and hydrodynamic performance of a spiral heat exchanger: Process intensification by a nanofluid containing different particle shapes. *Chemical Engineering and Processing-Process Intensification*, *166*, 108481. https://doi.org/10.1016/j.cep.2021.108481

3. Tamborrino, A., Veneziani, G., Romaniello, R., Perone, C., Urbani, S., Leone, A., & Servili, M. (2021). Development of an innovative rotating spiral heat exchanger with integrated microwave module for the olive oil industry. *LWT*, *147*, 111622. https://doi.org/10.1016/j.lwt.2021.111622

4. Sultan, K. F., Jabal, M. H., & Jaddoa, A. A. (2021). Energetic and Exergetic Assessment of Spiral Heat Exchanger Using Mineral and Oxide Mineral Oil Nanofluid. *Journal homepage: http://iieta. org/journals/ijht*, *39*(2), 531–540. https://doi.org/10.18280/ijht.390223

5. Davoudi, A., Daneshmand, S., Monfared, V., & Mohammadzadeh, K. (2021). Numerical simulation on heat transfer of nanofluid in conical spiral heat exchanger. *Progress in Computational Fluid Dynamics, an International Journal*, *21*(1), 52–63.

6. Bahiraei, M., & Mazaheri, N. (2021). A comprehensive analysis for second law attributes of spiral heat exchanger operating with nanofluid using two-phase mixture model: Exergy destruction minimization attitude. *Advanced Powder Technology*, *32*(1), 211-224. https://doi.org/10.1016/j.apt.2020.12.005

7. Fei, Z., Yanxia, L., Zhongliang, L., & Yongzhi, T. (2020). Flow and heat transfer characteristics of oil-based drilling cuttings in a screw-driving spiral heat exchanger. *Applied Thermal Engineering*, *181*, 115881. https://doi.org/10.1016/j.applthermaleng.2020.115881

8. Hong, Y., & Reimers, J. L. (2020). *U.S. Patent No. 10,718,571*. Washington, DC: U.S. Patent and Trademark Office.

Список литературы:

1. Kaladgi A. R., Vishwanath K. C., Madhu P., Chandrashekar A., Chaluvaraju B. V. Effect of copper oxide nano fluids as coolant on thermal performance of spiral heat exchanger // IOP Conference Series: Materials Science and Engineering. IOP Publishing, 2021. V. 1189. №1. P. 012037.
2. Mazaheri N., Bahiraei M. Energy, exergy, and hydrodynamic performance of a spiral heat exchanger: Process intensification by a nanofluid containing different particle shapes // Chemical Engineering and Processing-Process Intensification. 2021. V. 166. P. 108481. https://doi.org/10.1016/j.cep.2021.108481
3. Tamborrino A., Veneziani G., Romaniello R., Perone C., Urbani S., Leone A., Servili M. Development of an innovative rotating spiral heat exchanger with integrated microwave module for the olive oil industry // LWT. 2021. V. 147. P. 111622. https://doi.org/10.1016/j.lwt.2021.111622
4. Sultan K. F., Jabal M. H., Jaddoa A. A. Energetic and Exergetic Assessment of Spiral Heat Exchanger Using Mineral and Oxide Mineral Oil Nanofluid // Journal homepage: http://iieta.org/journals/ijht. 2021. V. 39. №2. P. 531-540. https://doi.org/10.18280/ijht.390223
5. Davoudi A., Daneshmand S., Monfared V., Mohammadzadeh K. Numerical simulation on heat transfer of nanofluid in conical spiral heat exchanger // Progress in Computational Fluid Dynamics, an International Journal. 2021. V. 21. №1. P. 52-63.
6. Bahiraei M., Mazaheri N. A comprehensive analysis for second law attributes of spiral heat exchanger operating with nanofluid using two-phase mixture model: Exergy destruction minimization attitude // Advanced Powder Technology. 2021. V. 32. №1. P. 211-224. https://doi.org/10.1016/j.apt.2020.12.005
7. Fei Z., Yanxia L., Zhongliang L., Yongzhi T. Flow and heat transfer characteristics of oil-based drilling cuttings in a screw-driving spiral heat exchanger // Applied Thermal Engineering. 2020. V. 181. P. 115881. https://doi.org/10.1016/j.applthermaleng.2020.115881
8. Hong Y., Reimers J. L. Spiral heat exchanger as preheater in polymer devolatilization processes: пат. 10718571 США. 2020.

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