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THE LOOP WITH PULSE CIRCULATION OF OIL FOR FUEL OIL HEATING

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ЦИКЛ С ИМПУЛЬСНОЙ ЦИРКУЛЯЦИЕЙ МАСЛА ДЛЯ ПОДОГРЕВА МАЗУТА

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Abstract. The energy issue is an important strategic factor that determines the sustainable development. Fuel oil is the main raw material in most power plants and boiler houses. Energy conservation is an important issue in the 21st century. This article focuses on pulse circulation for heating fuel oil. The heating system of fuel oil with pulsating circulation of oil in the heating circuit can be provisionally represented as an energy chain consisting of separate links and functioning as a single whole. In the master's thesis the process of heat transfer from the vibrating bellows heater to fuel oil was investigated. On the basis of the conducted experiments on the heating of fuel oil, it has been shown that when the bellows heater oscillates with significant amplitudes, the boundary layer breaks down, and the heat transfer is affected mainly by forced convection, in experiments it amounts to 4-8% of the total heat flux of the bellows heater in the barrel with fuel oil.

Аннотация. Энергетическая проблема является важным стратегическим фактором, определяющим устойчивое развитие. Мазут является основным сырьем на большинстве электростанций и котельных. Энергосбережение — важный вопрос в XXI веке. В этой статье основное внимание уделяется импульсной циркуляции для нагрева мазута. Система отопления мазута с пульсирующей циркуляцией масла в отопительном контуре может быть условно представлена в виде энергетической цепи, состоящей из отдельных звеньев и функционирующей как единое целое. В магистерской диссертации был исследован процесс теплопередачи от вибрирующего сильфонного нагревателя к мазуту. На основании проведенных экспериментов по нагреву мазута было показано, что, когда сильфонный нагреватель колеблется со значительными амплитудами, пограничный слой разрушается, а теплопередача осуществляется в основном принудительной конвекцией, в экспериментах она составляет 4–8% от общего теплового потока сильфонного нагревателя в цилиндре с мазутом.

Keywords: fuel oil, pulse circulation, energy chain.

Ключевые слова: мазут, импульсная циркуляция, энергетическая цепочка.

Research Background and Theoretical Research

Energy, environment and materials are the three major challenges facing human development in the 21st century [1]. The energy issue is an important strategic factor that determines the sustainable development of our country, and it is also the bottleneck that restricts the development of our national economy. Heat transfer problems are common in high-tech fields such as power, metallurgy, petroleum, chemicals, and materials, as well as aerospace, electronics, and nuclear power. In the past few years, with the continuous development of the country's economy and the increasing reliance on energy, we have realized the importance of energy conservation and efficient use of energy [2]. Enhanced heat transfer technology is exactly what people have developed in the long-term use of energy. Its main task is to increase the rate of heat transmission in order to achieve the use of more economical equipment to deliver the prescribed heat or to use more efficient cooling methods. Protect the safe operation of high-temperature components, or use a high thermal efficiency to achieve the rational use of energy [3]. In energy utilization, the transfer method of convection heat transfer is the most widely used in industrial practice, and the research on it is also the most active.

Over 30% of the oil produced in the process of its processing is converted to heating oil, the main consumer of which are power stations and boiler houses [4].

It should be noted that a large number of power plants and large boiler houses use fuel oil as their main fuel, there are reserve fuel oil facilities at all power stations and gas-fired boiler houses, and coal-fired power plants often use fuel oil to kindle and illuminate the torch[5-8].

Fuel oil facilities of the power plant, which is a whole complex of structures, apparatus and pipelines, is one of the main consumers of energy that goes to the station's own needs.

In modern conditions, when the prices for liquid organic fuel and gas are high enough, the issues of increasing the efficiency of thermal engineering schemes of fuel oil farms through the introduction of energy-saving technologies are very relevant [9].

The major share of energy costs in the structure of the energy consumption of the fuel oil facilities of thermal power plants, especially for power plants with large storage tanks, for servicing which requires a large number of parallel-connected fuel oil heaters, is to maintain the temperature in the tanks and to heat the fuel oil supplied to the boilers.

According to whether the flow is related to the time, convection heat transfer can be divided into two major categories (1): steady state and unsteady state. Steady-state convective heat transfer treatment is relatively simpler than the non-steady state, and people have more researches on it. The non-steady-state convective heat transfer problem is also widespread in nature and engineering practice. The common pulsed convection heat transfer is more common.

Pulse flow is a flow phenomenon that is common in nature and engineering practice, such as blood flow in a human body, the flow of a fluid discharged from a positive displacement pump and a reciprocating compressor, and the like. Because pulsed flow will cause changes in the flow and thermal boundary layer and thus affect heat transfer, the associated flow and heat transfer issues have drawn attention very early. For example, the study of blood pulse flow transfer process has always been an important part of a modern medical research. There are many related articles in the "Journal of Biomechanics", "Ultrasound in Medicine and Biology" and other journals every year [10-13]. Due to the complexity of the pulsed flow convection heat transfer process, despite a large number of studies that have been conducted, the issue of whether pulsed flow enhances heat transfer has been the subject of controversy.

The flow of a fluid driven by a pressure that changes with a positive cosine function is called an oscillating flow. As shown in the following Equation, it is a periodic, unsteady flow [14]. According to whether the average velocity of the fluid is zero, the oscillating flow can be divided into pulse flow. The average flow velocity is not zero. In formula one, the equations are not equal to zero and the reciprocating flow average flow velocity is zero [15]. In formula one, where is equal to zero, and the execution is not equal to zero.

$$\frac{dp}{dx} = A_0 + A_1 \cos(\omega t)$$

Since the reciprocating velocity distribution in the pulse flow has a "speed loop effect", the flow velocity near the wall is greater than the flow velocity at the center of the tube, and the velocity distribution of the entire cross section is flatter than that of the steady flow. Therefore, it is believed that pulsed flow will intensify convection heat transfer and studies have been conducted on this [16]. Due to the extensive engineering application background of pulse flow, the research on convective heat transfer of pulsed flow has continued until now. So far, there are many research literatures. The research methods cover experimental research, numerical calculation and theoretical analysis.

Theoretical background

The perfection of most technical devices is determined mainly by the efficiency of transformation and movement of a limited number of substances: mass, energy, momentum, electric charge, information. These processes are subject to the fundamental laws of nature, which constitute an object of study of mechanics, physics, chemistry and other natural sciences. Not always in the development of technology, these laws played a primary role [17]. Many examples of the invention of technical devices, which, on the contrary, led to the discovery or refinement of fundamental scientific positions. Apparently, such situations are possible and at the present time.

But the main line for creating fundamentally new and improving existing technical devices is the realization of the opportunities that arise when using the results of fundamental research. This, in particular, explains the modern emphasis in engineering education on fundamental scientific training [18]. A decisive role in the implementation of the results of such studies is played by mathematical modelling.

On the way to implementing the most promising scientific discoveries and developments in technology, usually, there are obstacles associated with the lack or limited possibilities of constructional or functional materials and with the lack of the technological level achieved. Therefore, the process of implementing scientific and technical ideas in the process of finding a reasonable compromise between what is desired and possible[19-20].

The heating system of fuel oil with pulsating circulation of oil in the heating circuit can be provisionally represented as an energy chain consisting of separate links and functioning as a single whole.

The functional diagram of the experimental setup is shown in Figure 1. The scheme includes: a heat source 1; circulating pump 2; pipeline; impact unit 3; flow meter 4, bellows heater 5; capacity with fuel oil 6.

Experimental Research

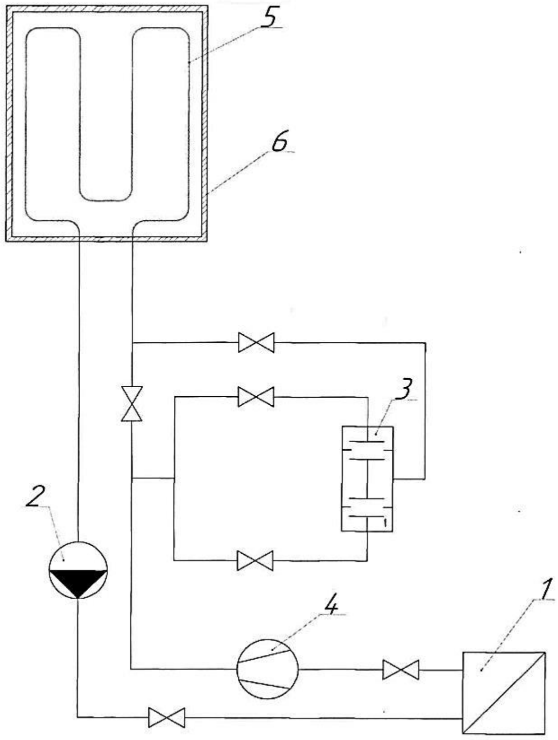

Figure 1 Experimental installation diagram.

Working principle

The circuit works as follows. By circulating pump 2 from the return pipeline, the heating medium is supplied to the heat source 1, where it is heated to the design temperature and sent to the supply pipeline. On the supply line, with a pulsed feed, the coolant enters the impact unit 3.

To launch the impact unit, we increase the difference in the forces acting on the impact valves of the assembly by drastically changing the flow toward the reduction with the help of a ball valve. Then again restore the previous flow through one of the shock valves. As a result, a hydraulic shock is generated and, accordingly, the pressure in the supply line rises sharply. Because of this, the coolant directed into the bellows heater 5 stretches it. Then, the return pressure wave, reflected from the impact unit, opens the valve, and the coolant from it is directed through the return line to the circulation pump 2, resulting in a pressure drop in the supply line, and the corrugated metal pipe 5 returns to its original position due to its own elasticity. Simultaneously, the coolant from the pipes through the non-return valve is sucked into the pump casing. Thus, the reciprocating motion of the corrugated metal pipe 5 in the tank with fuel oil 6, which circulates the heat transfer medium in the means of transfer of thermal energy in the form of a variable head, is carried out. At the same time, heat transfer is exchanged between the heat transfer medium in the means of transferring heat energy in the form of a set of pipes and in a corrugated metal pipe 5. The impact unit, due to its constant operation, provides generation of a hydraulic shock with a frequency of 0.2 Hz to 2 Hz, circulation of the coolant. As a result of this process, the corrugated metal pipe 5 is constantly moving in the vessel 6, which significantly increases the heat transfer coefficient and power of the device.

Equipmental devices

Figure 2. Equipmental devices.

Results

The results of the experiment were obtained as follows. The circulation circuit was filled with a coolant (AI-20 oil). The experiment begins with a pulsed circulation of the coolant (oil) G1. To do this, with the help of valves in the circuit of the experimental installation, the flow is directed through the impact valve. After a steady flow, we include a heat source into the circuit, which heats the oil and only then record the temperature and time for which the fuel oil will be heated to 55°C. Temperature is controlled by temperature sensors installed in the lower and upper part of the tank with fuel oil. Also with the help of temperature sensors, we track the uniformity of heating oil over the entire container for stationary and pulsed oil circulation.

In the next experiment, a new stationary oil flow rate G2 was set, directing the flow of the coolant in the circuit in addition to the impact assembly. As a result of the experiment, we carried out 2 experiments: one for pulse circulation of oil and one for stationary circulation. The data was taken 1 time every 5 minutes.

All the indications of the conducted experiment are recorded in Table.

From the data obtained, we determine the heat transfer coefficient of the bellows heater. The heat transfer coefficient is the density of the heat flow passing through the wall separating the two media, with the difference in the temperature of the media. In the heating device of the fuel oil heating system, the metal wall separates the oil from the inside and the fuel oil from the outside. The value of the heat transfer coefficient depends mainly on the heat transfer conditions on the inner and outer sides.

Heat transfer coefficient of bellows heater K, W/(m^2·°C)

$$K = \frac{1}{\frac{1}{\alpha_1} + R_{CT} + \frac{1}{\alpha_2}}$$

α_1, α_2 –heat transfer coefficients, respectively, on the inner and outer surface of the wall, $\frac{W}{(m^2 \cdot °C)}$;

R_{CT} – thermal resistance of the wall, depending on its thickness and thermal conductivity of the material, $\frac{(m^2 \cdot °C)}{W}$.

Table.

RESULTS OF EXPERIMENTAL STUDIES

Pulsating mode						
options	*Time τ, min.*					
	0	*50*	*100*	*150*	*200*	*250*
G_1, kg/s	0.7	0.7	0.7	0.7	0.7	0.7
t_{in}, °C	25.5	64.8	65.9	65.8	65.3	65.9
t_{out}, °C	25.5	44.5	47.7	48.8	54.6	60.1
t_{o1}, °C	25.3	30.8	40.1	45	50.2	56.8
t_{o2}, °C	25.3	27.1	37.3	41.9	48.3	55.7
Stationary mode						
options	*Time τ, min.*					
	0	*50*	*100*	*150*	*200*	*250*
G_2, kg/s	0.7	0.7	0.7	0.7	0.7	0.7
t_{in}, °C	25.5	65	66	65.9	65.2	66.1
t_{out}, °C	25.5	46.7	48.8	51.5	56.6	57.8
t_{o1}, °C	25.3	30.5	40	44.8	49.4	51.7
t_{o2}, °C	25.3	25.5	31.5	38	43.3	45.9

In heating appliances made of metal, with a small wall thickness, R_{CT} it does not matter much. The amount of heat given by the bellows heater to fuel oil Q, W is determined by the formula:

$$Q = KS(t_{cp} - t_o)$$

Q — heat transfer (heat output, bellows heater), W;

K — heat transfer coefficient of bellows heater, $\frac{W}{(m^2 \cdot °C)}$;

t_{cp} — the average temperature of the coolant in the bellows tube, °C;

t_o — temperature of fuel oil in the tank, °C;

S — the area of the external surface of the bellows heater, m^2

The area of the outer surface of the bellows heater S is determined by the formula:

$$S = S_r + S_B$$

S_r –is the surface of the horizontal sections of the intercostal ends;

$S_В$ – the area of the vertical surface of the ribs, at a length of 1m.

The surface of the horizontal sections of the intercostal ends S_r is determined by the formula:

$$S_r = \pi d_H (1 - \delta_o / S_p) + \frac{\pi D_p \delta_r}{S_p}$$

$d_н$ — outer diameter of bellows pipe, m;

S_p — Rib pitch, m;

δ_o, δ_r — thickness of the rib at the base and at the end, m;

D_p — diameter of the pipe along the ribs, m.

$$S_r = 3.14 \cdot 0.017 \cdot (1 - 0.002 / 0.004) + \frac{3.14 \cdot 0.022 \cdot 0.002}{0.004} = 0.061 m^2 .$$

The area of the vertical surface of the ribs, at a length of 1 m S_B is determined by the formula:

$$S_B = \frac{\pi (D_P^2 - d_H^2)}{S_p}$$

$$S_B = \frac{3.14 \cdot (0.022^2 - 0.017^2)}{0.004} = 0.153m^2$$

$$S = 0.061 + 0.153 = 0.214m^2 .$$

The average temperature of the heat carrier in the bellows tube t_{cp} ,°C, defined as the average value of the coolant temperatures at the entrance to the device and at the outlet from it:

$$t_{cp} = \frac{t_{in} + t_{out}}{2}$$

$t_{in.}$ — coolant temperature at the inlet to the bellows heater, °C;

$t_{out.}$ — coolant temperature at the outlet of the bellows heater, °C.

The heat transfer coefficient can be determined using the equation:

$$K = \frac{Q}{S(t_{cp} - t_o)}$$

Heating capacity of the fuel oil heater Q, kW is calculated by the formula:

$$Q = G_{oil} C_{oil} (t_{in} - t_{out})$$

C_{oil} –heat capacity of industrial oil, kJ/(kg ·°C), (C_{oil} =1.85 kJ/(kg·°C));

G_{oil} – Mass flow of oil, kg/s.

To analyze the performance of a bellows heater, it is necessary to determine the number of transport units (TUN) for a hot coolant:

$$TUN_r = \frac{KS}{G_{oil} C_{oil}}$$

The efficiency of the heat exchanger can be determined by the formula:

$$E = TUN_{\min} \frac{\Delta t_{cp}}{\Delta t_{\min}}$$

The results of the calculations are presented graphically in Figures 3-8

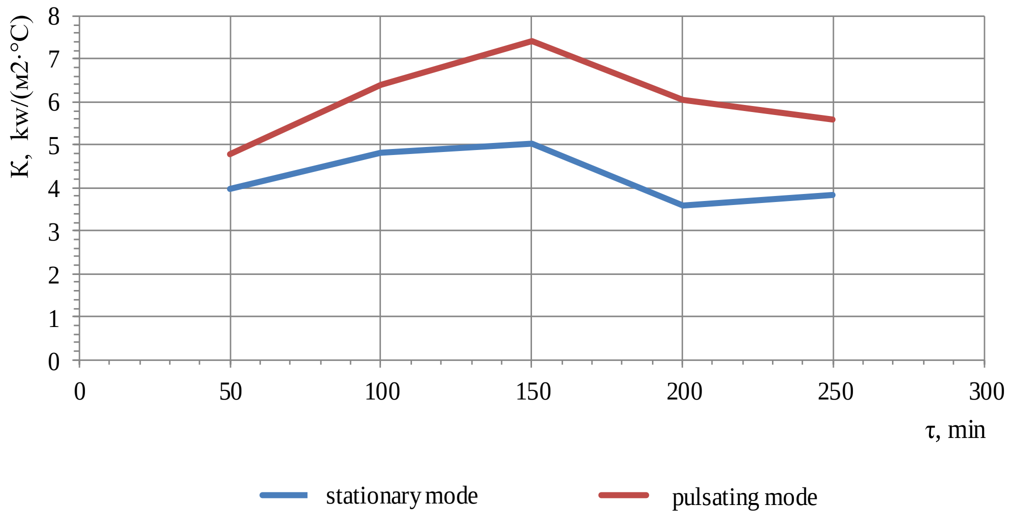

Figure 3. The value of the heat transfer coefficient for stationary and pulsating modes of the coolant motion as a function of the heating time.

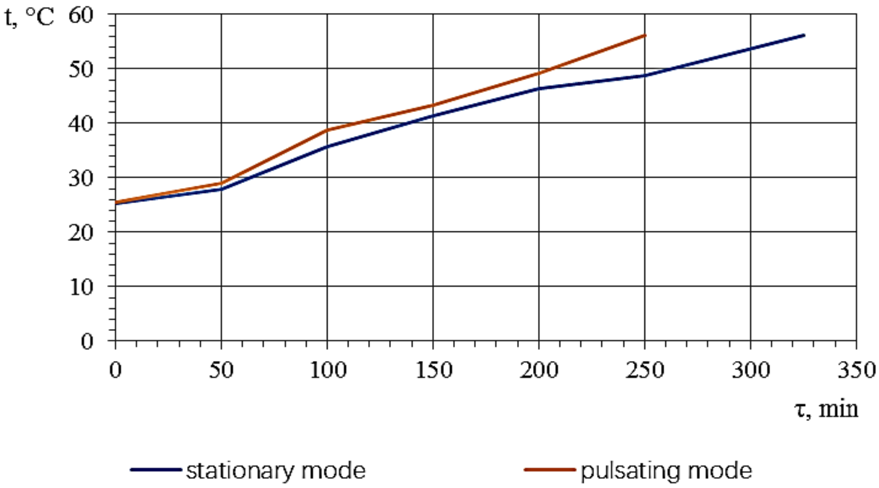

Figure 4. Time spent on heating fuel oil for stationary and pulsating modes of coolant motion.

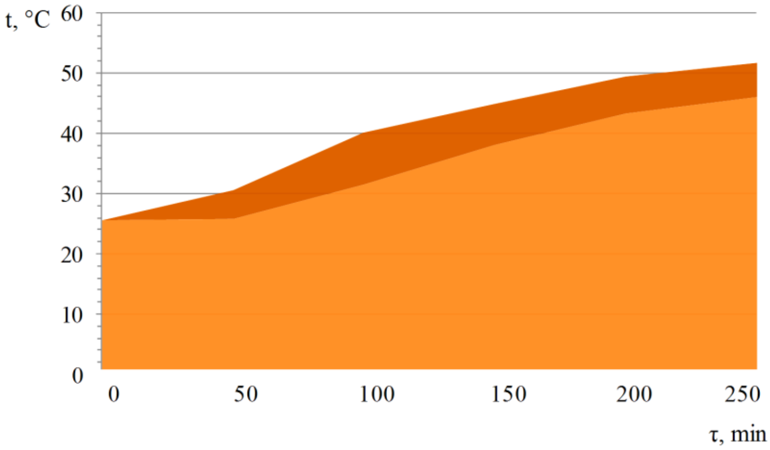

Figure 5. Uniform heating of fuel oil in the stationary regime of coolant motion.

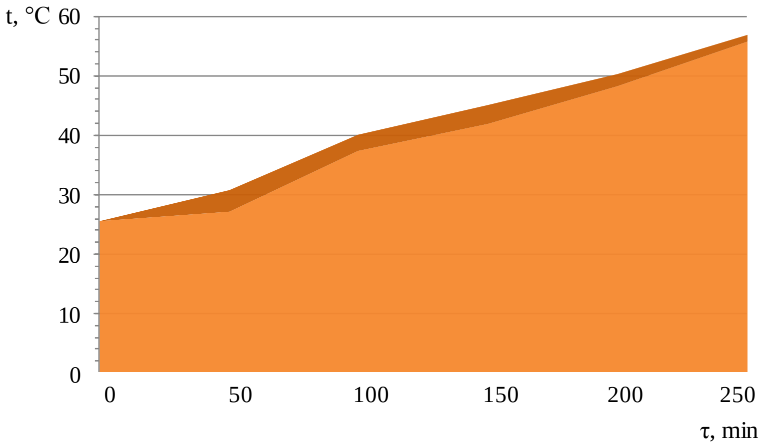

Figure 6. Uniform heating of fuel oil in the pulsating regime of coolant motion.

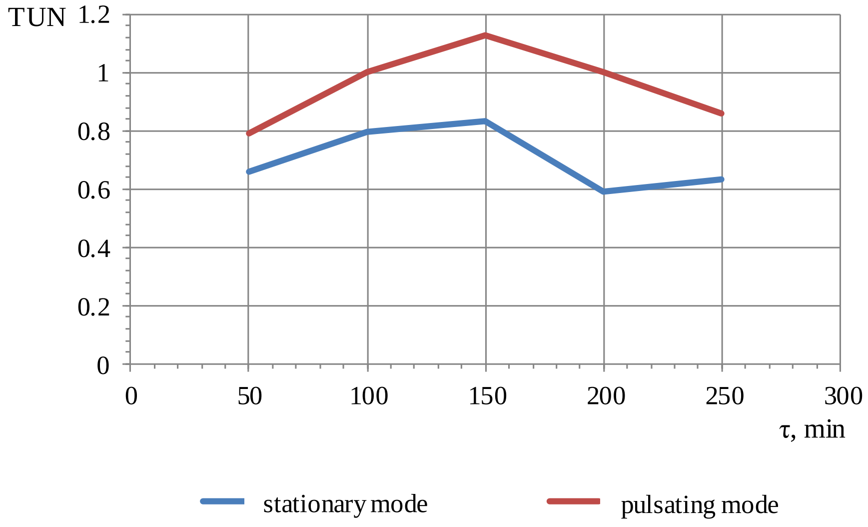

Figure 7. Number of transfer units for the hot coolant in the stationary and pulsating modes of the coolant motion.

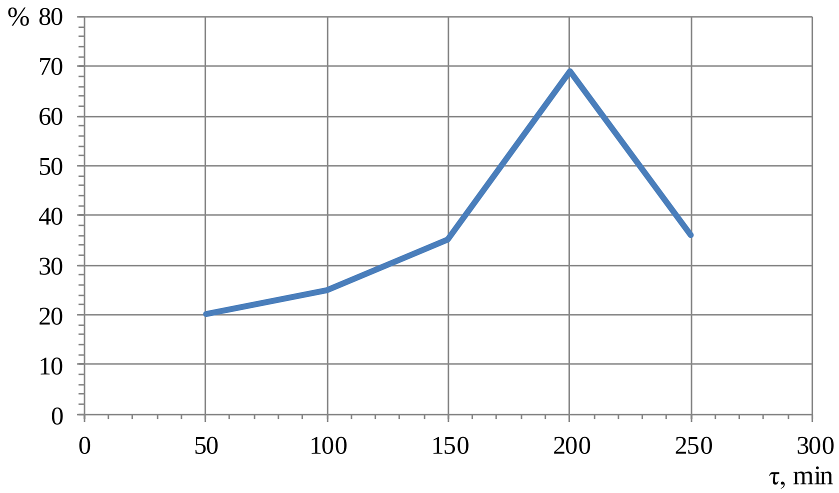

Figure 8. Increase the efficiency of the heat exchanger in percents with pulsating movement of the coolant relative to the stationary motion.

Conclusion

From the experimental results, the following conclusions can be drawn:

In this paper, the process of heat transfer from a vibrating bellows heater to fuel oil in an open tank was studied. On the basis of the conducted experiments on the heating of fuel oil, it can be noted that when the bellows heater of the fuel oil oscillates with significant amplitudes, the boundary layer breaks down. As a result of this process, the heat transfer to the main images is due to forced convection, and in the conducted experiments it is 4-8% of the total heat flux from the bellows heater in the tank with fuel oil. The carried out researches have shown, that at fuel oil heating the heat transfer coefficient depends on the speed of oscillations of the bellows heater. With a heater oscillation frequency of 0.4 Hz, the heat transfer coefficient increases by 35-45% compared to the heat transfer coefficient from the fixed surface. Thus, the pulsating mode of heating medium motion in bellows type heaters makes it possible to intensify the heat transfer process, which in turn opens the possibility of creating small-sized high-efficiency fuel oil heaters in tanks.

Sources:

(1). GOST 10585-99 Fuel oil. Fuel oil. Technical conditions. Moscow. 1999. P. 39- 42.

Источники:

(1). ГОСТ 10585-99 Мазут. Горючее. Технические условия. М., 1999. С. 39-42.

References:

1. Yakovlev, P. V., Alyautdinova, Yu. A., & Gorbaneva, E. A. (2009). Design of processes of heat-mass transfer while transportation of high-viscosity loads by water. Bulletin of Astrakhan State Technical University. Series: Marine Engineering and Technology, (2). 104-109

2. Yakovlev, P.V., Alyautdinova, Yu.A., & Achilova, N.B. (2010). Boundary conditions at heat losses calculation through the double side of a tanker. Bulletin of Astrakhan State Technical University. Series: Marine Engineering and Technology, (2). 114-118.

3. Yakovlev, P. V., Alyautdinova, Yu. A., & Gorbaneva, E. A. (2009). Research of influence of structural features of tanks of oil tankers on the processes of heat-mass exchange at transportation of high-viscosity loads by water transport. Bulletin of Astrakhan State Technical University. Series: Marine Engineering and Technology, (2), 99-103.

4. Bratsun, D. A. (1997). Dynamic properties of thermal convection in a two-phase medium: Author's abstract. dis. Cand. fiz.-mat. sciences. Perm, 14-16.

5. Vasilieva, I. A. (2004). Thermophysical properties of matter. St. Petersburg: SPbSU ITMO. 70-80.

6. Gupta, S. K., Patel, T. R. D., & Ackerberg, R. C. (1982). Wall heat/mass transfer in pulsatile flow. Chemical Engineering Science, 37(12), 1727-1739.

7. Gavrikov, M. B., & Pestryakova, N. V. (1997). Numerical modeling of convective heat transfer in a limited region. Moscow. 21-23.

8. Gavrilin, I. V. (2000). Melting and crystallization of metals and alloys. Vladimir: Vladimir State University. 257.

9. Galiev, I. M. (1999). Investigation of currents and heat transfer in channels in the presence of natural convection: Author's abstract of thesis. sciences. Tyumen. 21-23.

10. Deineko, V. V. (1996). Mathematical models of viscous fluid dynamics and heat transfer. Novosibirsk. 355-360.

11. Diligensky, N. V., Efimov, A. P., & Livshits, M. Yu. (2000). Application of the perturbation method for the solution of the Stefan problem in industrial thermophysics. IV Minsk International Forum on Heat and Mass Transfer (May 22-26, 2000). Minsk, (3). 14-20.

12. Feng Ziping. (1996). Flow Instabilities of Steam-water Two-phase Flow in Helically Coiled Tubes: [dissertation]. Xi ’an: Xi ’an Jiaotong University, 24.

13. Kordon, M. Ya. (2005). Heat engineering. Penza. Publishing House of the PGU, 164-167.

14. Lyashkov, V. I. (2005). Theoretical foundations of heat engineering. Moscow: Mashinostroenie, 258-260.

15. Gerrard, J. H. (1971). An experimental investigation of pulsating turbulent water flow in a tube. *Journal of Fluid Mechanics*, *46*(1), 43-64.

16. Guo, Z., Kim, S. Y., & Sung, H. J. (1997). Pulsating flow and heat transfer in a pipe partially filled with a porous medium. *International Journal of Heat and Mass Transfer, 40*(17), 4209-4218.

17. Selivanov, N. V. (2001). Influence of variable viscosity on heat exchange during laminar free convection. *Proceedings of the Russian National Symposium on Energy*. Kazan: KGEU, (1). 397-400.

18. Selivanov, N. V. (2001). Investigation of the influence of the viscosity of a liquid on temperature on heat transfer under free convection. Astrakhan: ASTU, 235-238.

19. Selivanov, N. V. (2000). Investigation of the work of a dead-end heater. *ENTZh. Energy saving in the Volga region.* Ulyanovsk, 99-101.

20. Selivanov, N. V. (2001). Heat exchange of high-viscosity liquids in tanks. Astrakhan: ASTU, 229- 232.

Список литературы:

1. Яковлев П. В., Аляутдинова Ю. А., Горбанева Е. А. Моделирование процессов тепломассообмена при перевозке высоковязких грузов водным транспортом // Вестник Астраханского государственного технического университета. Серия: Морская техника и технология. 2009. №. 2. С. 104-109

2. Яковлев П. В., Аляутдинова Ю. А., Ачилова Н. Б. Граничные условия при расчете потерь тепла через двойной борт танкера // Вестник Астраханского государственного технического университета. Серия: Морская техника и технология. 2010. №. 2. 114-118.

3. Яковлев П. В., Аляутдинова Ю. А., Горбанева Е. А. Исследование влияния конструктивных особенностей танков наливных судов на процессы тепломассообмена при перевозке высоковязких грузов водным транспортом // Вестник Астраханского государственного технического университета. Серия: Морская техника и технология. 2009. №. 2. С. 99-103

4. Брацун Д. А. Динамические свойства тепловой конвекции в двухфазной среде: автореф. диссер. канд. физ.-мат. наук. Пермь, 1997. С.14-16.

5. Васильева И. А. Теплофизические свойства вещества. СПб: СПбГУ ИТМО. 2004. С. 70-80.

6. Gupta S. K., Patel T. R. D., Ackerberg R. C. Wall heat/mass transfer in pulsatile flow // Chemical Engineering Science. 1982. Vol. 37. N. 12. P. 1727-1739.

7. Гавриков М. Б., Пестрякова Н. В. Численное моделирование конвективного теплообмена в ограниченной области. М., 1997. С. 21-23.

8. Гаврилин И. В. Плавление и кристаллизация металлов и сплавов. Владимир: Владимирский государственный университет, 2000. 257 с.

9. Галиев И. М. Исследование течений и теплообмена в каналах при наличии естественной конвекции: автореферат диссер. наук. Тюмень. 1999. С. 21-23.

10. Дейнеко В. В. Математические модели динамики вязкой жидкости и теплопередачи. Новосибирск. 1996. С. 355-360.

11. Дилигенский Н. В., Ефимов А. П., Лившиц М. Ю. Применение метода возмущений для решения задачи Стефана в промышленной теплофизике // IV Минский международный форум по тепломассообмену (22-26 мая 2000 г.). Минск, 2000. Т. 3. С. 14-20.

12. Feng Ziping. Flow Instabilities of Steam-water Two-phase Flow in Helically Coiled Tubes:[dissertation]. Xian: Xian Jiaotong University, 1996. P. 24

13. Кордон М. Я. Теплотехника. Пенза: Издательский дом ПГУ. 2005. С. 164-167.

14. Ляшков В. И. Теоретические основы теплотехники. М.: Машиностроение, 2005. С. 258-260.

15. Gerrard J. H. An experimental investigation of pulsating turbulent water flow in a tube // Journal of Fluid Mechanics. 1971. Vol. 46. N. 1. P. 43-64.

16. Guo Z., Kim S. Y., Sung H. J. Pulsating flow and heat transfer in a pipe partially filled with a porous medium // International Journal of Heat and Mass Transfer. 1997. Vol. 40. N. 17. P. 4209-4218.

17. Селиванов Н. В. Влияние переменной вязкости на теплообмен при ламинарной свободной конвекции // Труды Российского национального симпозиума по энергетике. Казань: КГЭУ. 2001. Т. 1. С. 397-400.

18. Селиванов Н. В. Теплообмен высоковязких жидкостей в емкостях. Астрахань: Изд-во АГТУ, 2001. С. 235-238.

19. Селиванов Н. В. Исследование работы тупикового нагревателя // ENTZh. Энергосбережение в Поволжье. Ульяновск, 2000. С. 99-101.

20. Селиванов Н. В. Теплообмен высоковязких жидкостей в резервуарах. Астрахань: АСТУ, 2001. С. 229-232.

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