THE DESIGN PROCEDURE OF RECUPERATIVE HEAT-EXCHANGER FOR HEATING OIL MOVING IN A PIPELINE

МЕТОДИКА РАСЧЕТА РЕКУПЕРАЦИОННОГО ТЕПЛООБМЕННИКА ДЛЯ НАГРЕВА ДВИЖУШЕЙ НЕФТИ В ТРУБОПРОВОДЕ

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***Abstract** : Transportation of oil and oil products through the pipeline, due to their high viscosity and the paraffin content is technically and technologically complex process. At present, for the purpose of improving rheological parameters of oil, one of the most effective methods consists in its heating in heat-exchange installations to a certain temperature. The degree of improvement of rheological parameters of oil depends on its heating temperature and conditions of subsequent cooling. Heat treatment improves the inlet capabilities of pumps and allows improving the oil transportation process through the main pipes and pipelines.*

The given paper dwells on the design procedure of the heat-exchange installation "the pipe in pipe". Such type of heat-exchanger is characterized by a simple design and low hydraulic resistance, in which the hot heat transmitter is ecologically clean water.

The process of oil heating in heat-exchanger is the process of convective heat exchange, the intensity of which depends on a number of parameters, including the oil density and viscosity, which in turn are the values depending on temperature. On that basis, the paper dwells on the design procedure of the heat-exchange installation ("the pipe in pipe") that should enable us to ensure the optimal heating temperature and calculation of geometrical sizes of heat-exchanger through mathematical way.

***KEY WORDS:** OIL; HEAT-EXHANGER; RHEOLOGICAL PARAMETERS; TRANSPORTATION.*

1. Introduction

Production and pumping of high-viscosity oil still remain a tough technical and technological challenge. The most popular means of pipeline transport of high-viscosity oil is its pumping by heating.

The thermal treatment of oil is referred to as its thermal treatment intended for improving rheological parameters. The thermal treatment (2) of oil allows reducing its viscosity and lowering the freezing point, that ensures the pump inlet capability and improving the oil transportation process through the main pipes and pipelines.

The degree of improvement of rheological parameters of oil depends on its heating temperature and conditions of subsequent cooling. For the paraffin-base oil, there exists the optimal heating temperature at which there is obtained the highest heat treatment effect. This temperature is always higher than melting temperature of paraffin contained in oil.

Since the different types of oil have the various contents of paraffin, the optimal temperature of thermal treatment is determined experimentally for each type of oil.

2. Preconditions and means for resolving the problem

The given paper dwells on the heating design procedure of the heat-exchange installation "the pipe in pipe" (Fig. 1) for the purpose of further experimental investigation of rheological parameters of heated oil. The installation is comprised of continuously acting heat-exchanger, into which the water heating the heat carrier moves through the inner steel pipe, but the heating up oil moves in counter-flow by annular channel between pipes.

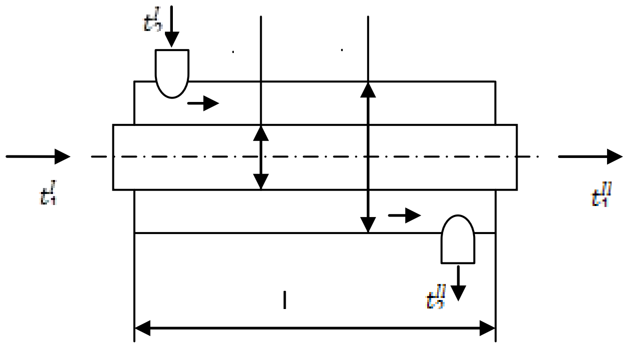

Fig. 1. *"The pipe in pipe" heat-exchanger*

When doing designing of continuously acting heat-exchangers it is possible to face the following tasks:

1. Determination of the heating area F, which ensures the passage of the preset amount of heat from the hot heat carrier to the cold one.
2. Determination of the amount of heat Q, which can be transferred from the hot liquid to the cold one at the known heating area.
3. Determination of the final temperatures of heat carriers at the known values of F and Q.

The main design equations for solution of set problems are the Q=KFΔT heat-transfer and heat-balance equations (1)

$$Q = G_1 C_1 (t_1^I - t_1^{II}) = G_2 C_2 (t_2^{II} - t_1^I)$$

where, G_1, G_2 – are the flow rates of the hot heat carriers; t_1^I, t_1^{II} as well as t_2^{II}, t_1^I - are the initial and final temperatures of the hot and cold heat carriers.

In the heat-balance equation, the value G is usually determined by product of Wρf (where, W – is the heat carrier's velocity, f – is the cross section area of the channel, ρ – the density), and the heat-balance equation takes the following form:

$$W_1 f_1 \rho_1 C_1 (t_1^I - t_1^{II}) = W_2 f_2 \rho_2 C_2 (t_2^{II} - t_2^I)$$

In the heat-transfer equations, the ΔT is an average temperature drop determined by the nature of changes in temperatures of working liquids along the heating surface. If the heating and heated liquids move along the heating surface in a similar direction, then such flow of movement is called counter-flow. Actually, an average temperature drop at counter-flow is obtained larger (Fig. 2), and therefore the heat-exchanger itself will be more compact than at counter-flow.

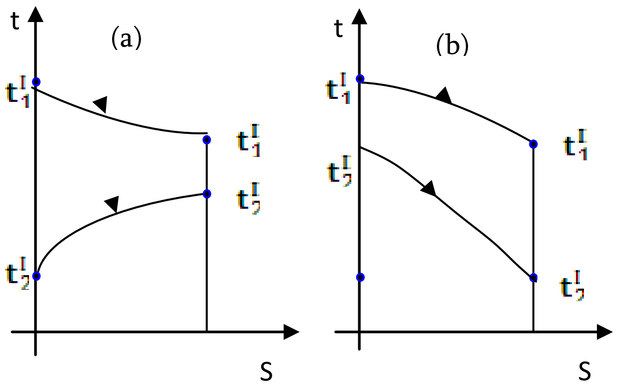

Fig. 2 *Changes in temperatures of heat carriers at counter-flow (a) and (b).*

An average logarithmic temperature drop at counter-flow is determined as follows:

$$\Delta t = \frac{\left(t_1^I - t_1^{II}\right) - \left(t_2^{II} - t_2^I\right)}{\ln\left(\frac{\left(t_1^I - t_2^{II}\right)}{\left(t_1^{II} - t_2^I\right)}\right)}$$

The process of oil heating in heat-exchanger is the process of convective heat exchange, and the heat-transfer coefficient is directly influenced by moving modes and physical parameters of liquids: specific heat, density, viscosity and thermal conductivity. The heat-transfer coefficient is equal to

$$K = \frac{1}{\frac{1}{\alpha_1} + \frac{\delta_c}{\lambda_c} + \frac{1}{\alpha_2}}$$

The values of the heat-transfer coefficients α_1 and α_2 are determined from the appropriate criteria equations at an average temperature of working liquids.

In solution of the problem, we determine the amount of transferred heat and temperature of heating liquid at the output

$$Q = G_2 C_2 (t_2^{II} - t_1^I); \quad t_1^{II} = t_1^I - \frac{Q}{G_1 C_1}$$

By arithmetic mean values $t_1 = 0{,}5\left(t_1^I + t_1^{II}\right)$, $t_2 = 0{,}5\left(t_2^I + t_2^{II}\right)$ we determine the values of physical properties of the heat carriers at these specified temperatures: the densities ρ_1, ρ_2; the heat-transfer coefficients λ_1, λ_2; viscosities ν_1, ν_2; Prandtl numbers Pr_1, Pr_2.

The movement velocities of the heat carriers are determined as follows:

$$W_1 = \frac{4G_1}{3600\rho_1 \pi d_1^2}$$

$$W_2 = \frac{4G_2}{3600\rho_2 \pi (D - d_2)^2}$$

The Prandtl numbers for the flow of heating liquid

$$R_{e1} = \frac{W_1 d_1}{\nu_1}$$

If the flow regime is turbulent Re≥10000, then calculation of the Nusselt number and heat-transfer coefficient is made by the following formulas:

$$N_{u1} = 0{,}021\, R_{e1}^{0{,}6} \cdot P_{r1}^{0{,}43} \left(\frac{P_{r1}}{P_{re1}}\right)^{0{,}25}$$

$$\alpha_1 = N_{u1} \cdot \frac{\lambda_1}{d_1}$$

The Reynolds number for the flow of heated oil

$$R_{e2} = \frac{W_2 d}{\nu_2}$$

If the flow regime of the heated oil is turbulent, then calculation of the Nusselt number and heat-transfer coefficient is made by the following formulas:

$$N_{u2} = 0{,}17\, R_{e2}^{0{,}28} \cdot P_{r2}^{0{,}4} \left(\frac{P_{r2}}{P_{re2}}\right)^{0{,}25} \cdot \left(\frac{D}{d_2}\right)^{0{,}18}$$

$$\alpha_2 = N_{u2} \cdot \frac{\lambda_2}{d_э}$$

where, $d_э$ - is an equivalent diameter for the annular channel $d_э = D - d_2$

By values K and Δt the density of the thermal flow is equal to q=к· Δt, but the heating surface and the number of sections of the heat-exchanger is determined by formulas F=Q/q and $n = F/\pi d_1 l$.

3. Conclusion

Thus and so, the proposed design procedure enables us to define the optimal design sizes of the heat-exchange installation ("the pipe in pipe") by known heating value and heat-transfer temperature, or by using of this design procedure it is also possible to determine the final temperatures of the heat-transmitters on the basis of known area of heat-exchanger and initial temperatures of temperature and calculation of geometrical sizes of heat-exchanger through mathematical heat-transmitters.

4. Literature

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