Effect of Recirculation of the Hydrocarbon Flow on the Thickness of the Viscous Sub layer and the Efficiency of Heat Transfer

Ismailov, O. Yu., Khurmamatov A. M., Buriyeva Z. R.
Institute of General and inorganic chemistry of the Academy of Sciences of Uzbekistan, Tashkent

Abstract: The results of computational and experimental studies of heating of an oil and gas condensate mixture with recirculation of a part of the flow in an experimental tubular apparatus are presented. At the same time, the share of recirculation of the flow is from 10 to 30% of the total volume of the mixture. It was found that when recirculating 25 % of the volume of the oil and gas condensate mixture, the temperature of its exit from the apparatus increases by an average of 1.2 times, which leads to a decrease in its viscosity to 1.17 times and an increase in the flow rate in the tubes by 1.25 times. Due to the change in the mode of movement in the tubes, an intense pulsation of the flow rate occurs, which reduces the thickness of the viscous sub layer on the walls of heat transfer pipes by 1.33 times. An additional increase in the temperature of the heated mixture also leads to an increase in its heat capacity by 1.22 times, an increase in the value of the heat transfer coefficient in the apparatus by 1.14 times and an increase in the amount of heat transferred by 1.4 times. In addition, it was found that intensive movement of the mixture flow can lead to a three-fold decrease in the rate of scale formation in the tubes.

Keywords: oil and gas condensate mixture, viscous sub layer, flow rate, Reynolds criterion, Darcy coefficient, flow recirculation, heat exchange, scale.

To date, various methods have been proposed and investigated for the intensification of heat exchange in tubular heat exchangers [1]. One of the practical and effective ways to increase the intensity of heat transfer in tubular oil refining apparatuses is the organization of recirculation of the flow of heated hydrocarbon raw materials [2]. However, in our opinion, the share of the recirculation volume flow to be heated of raw material should be established technical and economic calculations, taking into account temperature changes of properties of raw materials and their impact on the duration of the process heating and energy costs of pumping it through a heat exchanger [3].

Based on this, we investigated the effect of the degree of recirculation of the flow of oil and gas condensate mixture on the intensity of heat exchange in an experimental two-tube heat exchanger under various hydrodynamic conditions [4].

During the experiments, the main attention was paid to the change in the temperature of the heated mixture at the outlet of the heat exchanger. The essence of the experiments is as follows. A part of the working mixture heated in the heat exchanger in the amount of 10-30 % of its total volume is selected and added to the flow of the cold mixture entering the apparatus.

At the same time, an increase in the volume flow rate of the mixture V supplied by the pump contributes to an increase in the flow rate in the inner pipe of the experimental apparatus. As a result, the hydrodynamic regime in the apparatus changes, and the values of the Reynolds criterion *Re* increase. With an increase in the number of *Re*, the intensity of convective heat exchange increases, as a result of which the temperature of the mixture at the outlet of the heat exchanger additionally increases.

In the experiments, an oil and gas condensate mixture of 70% GC+30% O was used as a working mixture, which had a density of ρ_{20} = 787 kg/m^3 and a kinematic viscosity coefficient of ν_{20} = 1.42·10^{-6} m^2/s [5].

Further, we determined the influence of amount of recycled gas mixtures on the hydrodynamic parameters of the process in a horizontal tube experienced two-tube heat exchanger by calculating the number of *Re*, the thickness of a viscous sublayer δ_v in and the heat transfer coefficient *K* in the apparatus. The value of the Reynolds criterion, which determines the mode of motion of the oil and gas condensate mixture in the horizontal pipe of the experimental apparatus, was determined by the well-known formula [6]:

$$\mathrm{Re}_{ж} = \frac{\upsilon \cdot d}{\nu}, \qquad (1)$$

Where υ is the flow rate of the mixture in the inner pipe, m/s; *d* is the inner diameter of the pipe, m; ν is the kinematic viscosity coefficient of the mixture, mm^2/s.

When the liquid moves in the heat transfer pipe on its wall (the inner surface of the pipe) the flow rates, including pulsation, are zero. Near the wall there is a very thin layer of the mixture (a viscous sublayer) with a thickness of δ_v [7]. The rest of the pipe cross-section is occupied by the turbulent flow core, where intense velocity pulsations and particle mixing occur. Within a viscous sublayer, the flow rate increases linearly from zero at the wall to a certain value of u_v at the layer boundary.

The thickness of the viscous sublayer of the liquid δ_v is calculated by the formula [8]:

$$\delta_{в} \approx \frac{30d}{\mathrm{Re}\sqrt{\lambda}}, \qquad (2)$$

Where λ is the Darcy coefficient?

It follows from (2) that with an increase in the number of *Re*, as well as the coefficientλ, the thickness of the viscous sublayer δ_v in the pipe decreases.

The value of the coefficient λ in the laminar flow regime was determined by the expression [9]:

$$\lambda = \frac{64}{\mathrm{Re}}, \qquad (3)$$

And for the turbulent flow regime, the Altschul formula was used [10]:

$$\lambda = 0.11(\Delta / d + 68 / \mathrm{Re})^{0.25}. \qquad (4)$$

The numerical value of the heat transfer coefficient *K* in the experimental heat exchanger is calculated by the equation [11]:

$$K = \frac{1}{\frac{1}{\alpha_1 r_o} + \frac{1}{\alpha_2 r_r} + \frac{1}{\lambda} 2{,}3\lg\frac{r_o}{r_r} + \frac{1}{r_{\text{pollo}}} + \frac{1}{r_{\text{polli}}}}, \qquad (5)$$

Where r_o and r_i are the outer and inner radius of the inner tube of the apparatus, m; r_{pollo} and r_{polli} are the thermal conductivity of contamination on the outer and inner surfaces of the tube, Wt/(m^{2}·K).

The amount of heat transferred from the hot heat carrier (gas condensate vapors) to the heated mixture is determined from the basic heat transfer equation [12]:

$$Q = KF\Delta t_{cp}\,, \quad (6)$$

Where t_{med} is the average temperature head, °S; *F* is the pipe surface, m^2.

Results of calculations for determining the number Re, the thickness of the viscous sublayer δ_v (mm) and the heat transfer coefficient *K* (Wt/m^{2}·K) at different recirculation volumes ΔV (in %) of the mixture 70% GC+30% O are presented in table 1.

Table 1. Effect of recirculation of the flow of oil and gas condensate mixture on the thickness of the viscous sub layer and the efficiency of heat transfer

V, %	ν_t mm^2/s	*Re*	λ	$\delta_v \cdot 10^3$, mm	*K*, Wt/(м^2·K)
-	1,42	3605	0,0410	4,0	1865
10	1,38	4217	0,0393	3,6	1899
15	1,33	4586	0,0382	3,4	1937
20	1,28	4968	0,0376	3,2	1963
25	1,21	5471	0,0366	3,0	2081
30	1,18	5847	0,0360	2,8	2136

The data in table 1 show that with an increase in the value of the *Re* number, the intensity of convective heat exchange increases, and the amount of heat transferred from the hot coolant to the cold flow of the mixture increases. At the same time, the thermal efficiency of this method of heating the oil and gas condensate mixture is characterized by the degree of increase in its temperature at the outlet of the device. With an increase in the volume of the recirculated mixture from 10 to 30%, the *Re* value increases from 3605 to 5471, the coefficient of friction of the flow against the walls of the heat transfer pipe decreases from 0.041 to 0.036, the thickness of the viscous sub layer decreases from 4.0 to 3.0·10^{-3} mm, and the heat transfer coefficient in the experimental apparatus increases from 1865 to 2081 Wt/(m^{2}·K).

Figure 1 shows the curve of changes in the values of the criterion *Re* and the heat transfer coefficient *K* in the experimental heat exchanger from the volume of the recirculated oil and gas condensate mixture in the range from 10 to 30 %.

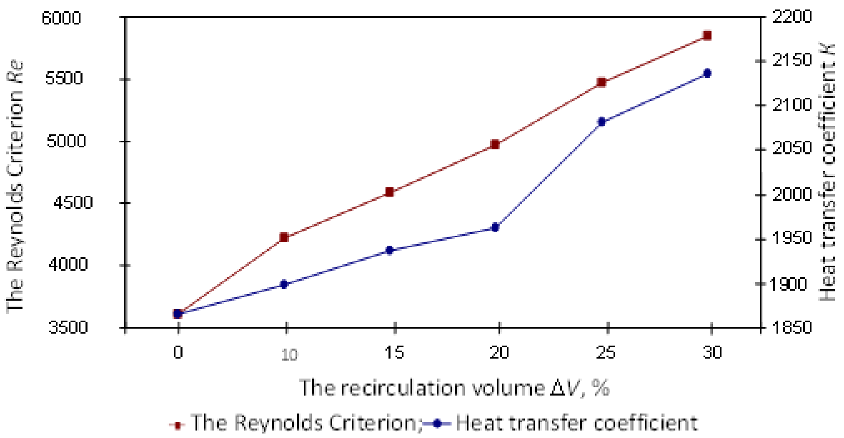

Fig. 1. Changes in the criterion *Re* and the heat transfer coefficient *K* from the recirculated volume of the flow of the oil and gas condensate mixture

As can be seen from Fig. 1, in the investigated range of variation of the volume of the recycled stream (10÷30 %) additional increase in temperature of the heated mixture leaving the up to 14 ^{o}S leads to improvement of the hydrodynamics of the flow in the pipe, which is characterized by intensive growth of the values of *Re* (upper curve) and significant increase in the heat transfer coefficient *K* in the device.

An analysis of the calculated and experimental data presented in tables 2 shows that an additional increase in the temperature of the mixture during its heating with recirculation of part of the flow has a positive effect on the change in its physical and thermophysical properties (fig. 2).

For example, when recirculating 25 % of the volume of the oil and gas condensate flow, the final temperature of the mixture increases by an average of 1.2 times, which leads to a decrease in its viscosity to 1.17 times and an increase in the flow rate by 1.25 times. Intense pulsations of the flow rate, which occur when the flow mode changes in the apparatus, contribute to a decrease in the thickness of the viscous sublayer on the walls of heat exchange pipes by 1.33 times. An additional increase in temperature of the mixture also leads to the increase of the heat capacity of 1.22 times, increases the heat transfer coefficient in the apparatus of 1.14 times and growth of heat load heat exchanger by 1.4 times. In addition, it was found that intensive flow movement can lead to a three-fold decrease in the rate of scale formation in heat exchange tubes, which is especially important when operating heat exchangers of oil refineries.

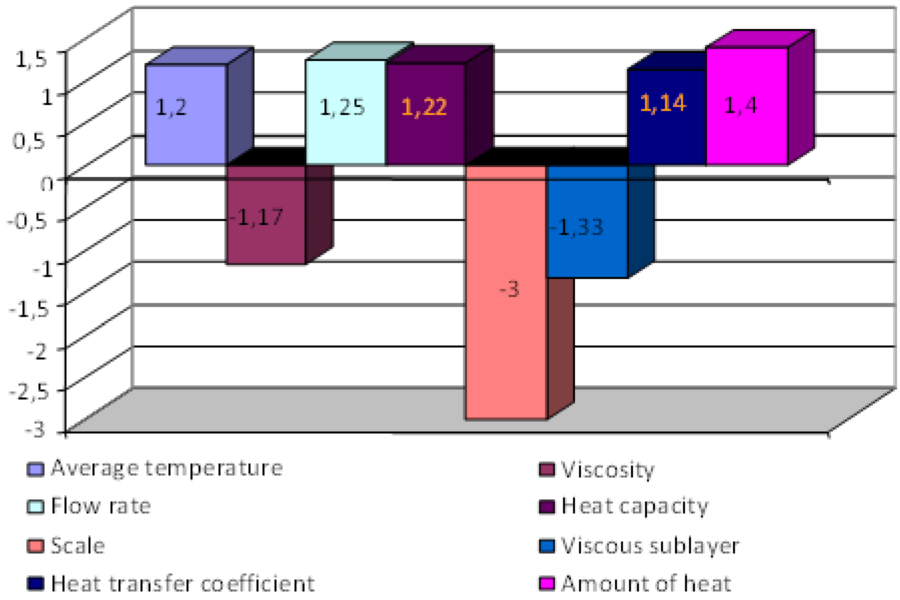

Fig. 2. Change in physical and thermo physical properties during recirculation of part of the flow by 25 %

Thus, according to the results of the conducted studies, it can be concluded that the organization of the process of heating oil and gas condensate mixtures with recirculation of part of the flow is a practical way to increase the efficiency of tubular heat exchangers of oil refineries. The use of this method of heating liquid hydrocarbon raw materials makes it possible to achieve an additional rise in the temperature of the heated raw materials to 14 ^{o}S, improve the hydrodynamic conditions of heat exchange in the apparatus and increase the heat capacity of heat exchangers up to 15 %.

REFERENCES

1. Intensification of heat transfer. Heat transfer gains, 2 // Ed. Zhukauskas A.A. and Kalinina E.K. - Vilnius: Mokslas, 1988.- 186 p.
2. Kalinin E.K., Dreitser G.A., Yarkho S.A. Intensification of heat exchange in the channels. - M.: Mechanical Engineering, 1981.- 205 p.
3. Ismailov O.Yu., Khurmamatov A.M., Khudaiberdiev A.A. Influence of flow recirculation on the intensity of heat exchange in a two-pipe apparatus // Scientific and technical journal "Oil refining and petrochemistry". Moscow. - 2018. - N. 5. - P. 39-42.
4. Ismailov O.Yu. Influence of the regime of flow of raw materials to the value of the heat transfer coefficient in the tubular apparatus Materials of the II International Scientific and Technical Conference "Bulatov Readings". March 31, 2018 - Samara. -P. 117-120.
5. Salimov Z., Ismailov O.Yu. Density and viscosity of liquid hydrocarbons at temperatures of 20-98 °S. Scientific and technical journal "Oil refining and petrochemistry". - Moscow. 2014. - N. 1. - P. 18-22.
6. Salimov Z., Ismailov O.Yu., Saidakhmedov Sh.M., Khudaiberdiev A.A. Investigation of heat transfer during heating of oil and gas condensate mixture. International scientific and technical journal “Chemical technology. Control and management”. - Tashkent, 2012. - N. 5. - P. 5-9.
7. Siebert G.K., Zaporozhets E.P., Valiullin I.M. Preparation and processing of hydrocarbon gases and condensate: A reference guide. - 2nd ed., Rev. and add. - M.: OOO Nedra-Business Center, 2008. - 734 p.
8. Shterenlikht D.V. Hydraulics. - M .: Energoizdat, 1984.- 640 p. (in Russian).
9. General course processes and devices of chemical technology: Textbook. In 2 books. /V.G. Einstein, M.K. Zakharov, G.A. Nosov and others; Ed. V.G. Einstein. - M.: Logos, 2002.-1758 p. Book 1. - 888 p.
10. Ismailov O.Yu. Determination of Darcy coefficient of oil, gas condensate and their mixtures in a horizontal pipe. Materials of the II International Scientific and Technical Conference "Bulatov Readings". March 31, 2018 - Samara. -P. 68-71.
11. Salimov Z.S., Ismailov O. Yu., Saydahmedov Sh., Zaikov G. Influence of hydrodynamic regimes of oil and gas mixtures on the efficiency of heat exchange. Bulletin of the Volgograd State University. - Volgograd, -2015. - N. 2. - P. 25-33. DOI: 10.15688 / jvolsu10.2015.1.4
12. Pavlov K.F., Romankov P.G., Noskov A.A. Examples and tasks for the course of processes and devices of chemical technology. Textbook for universities. Ed. P.G. Romankov. - 10th ed., Revised. and add. - L.: Chemistry, 1987.578 p.