Increase in efficiency of high-viscosity fluid transportation on the facilities of FEC

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Annotation. The thermal method of increasing the efficiency of high-viscosity fluid transportation is considered, using the example of M100 fuel oil. The graphical dependences of the dynamic fluid viscosity on the temperature, the kinematic viscosity on the consumption of a heating steam and on the power of heating pads provided that high-viscosity fluid is heated, as well as the Prandtl number on the heat output of a heater, are obtained.

The high-viscosity fluid is a fluid in which the kinematic viscosity at a temperature of the medium surrounding the pipeline is so great that pumping of such a substance is associated with very large pressure losses. To increase the efficiency of high-viscosity fluid transportation, thermal heating is widely used. Let us consider this method as an example of the high-viscosity fluid - residual fuel oil of mark M100.

Nowadays mazout is widely used on the facilities of FEC (Fuel and Energy Complex) as a fuel for steam boilers and industrial furnaces, and certain types of residual fuel oils are used to lubricate rough machinery. The methods and duration of drain and bulk operations, the fuel transportation conditions are determined by viscosity.

The viscosity is a main technical property of residual fuel oils and it determines their marking. The viscosity of residual fuel oils is determined by a composition of the oil from which they are obtained, by a nature of the technical process and a depth of selection of the oil and lighter fractions. It strongly depends on temperature and can double when the temperature decreases by 10 °C. Under such the conditions, a flow of the residual fuel oil does not qualitatively differ from a flow of some ordinarily homogeneous fluid and corresponds to the Newton equation, however, it requires increased energy consumptions, since the viscosity of residual fuel oil is much higher than the viscosity of light oil products [1-3].

The dynamic viscosity of the residual fuel oil of mark M100 can be calculated according to the Walter formula, which is valid in the temperature range 40-100°C [1]:

\[ \mu = [\exp_{10} (\exp_{10} (9,855 - 3,751 \cdot \lg (t + 273))) - 0,8] \cdot 10^{-6} \cdot \rho \]

where \( \mu \) is a coefficient of dynamic viscosity of fuel oil, Pa·s; \( t \) is a temperature of residual fuel oil, \( \rho \) is a density of residual fuel oil, kg/m³.
Fig. 1 shows a dependence of the dynamic viscosity of fuel oil on temperature. Verification of the adequacy of the expression was carried out by comparing with the experimental data of Zdor V.O. The experimental data correlate well with the calculated data. The discrepancy was less than 10%.

Thermal heating of the high-viscosity fluid in FEC is carried out in pipelines and special heaters. For heating in pipelines, heaters are used in the form of steam satellites, which are located in one heat-insulating casing with a pipeline being heated. Electric heating systems are also used: of direct (current is passed directly through the pipeline being heated) and indirect heating (with the use of a satellite heater which is parallel or spirally wound onto the pipeline and in the form of heating cables and tapes). Heat-exchange apparatuses of various designs are used as special heaters.

The amount of heat, obtained by the high-viscosity fluid, is determined by the expression:

$$Q = Gc_p(t_2 - t_1)$$

where $G$ is a volume flow of the high-viscosity fluid, m³/h; $c_p$, $\rho$ are a density (kg/m³) and a specific thermal capacity of the high-viscosity fluid (J/(kg·K)); $t_2$, $t_1$ are a final and initial temperature of the high-viscosity fluid at the outlet and inlet of the preheater, K.

The Prandtl number for the high-viscosity fluid can be determined by the formula:

$$Pr = \frac{\nu \cdot c_p}{\lambda},$$

where $\nu$ is a kinematic viscosity, m²/s; $\lambda$ is a thermal conductivity, W/(m·K).

Using these expressions, the dependence of the Prandtl number on a thermal performance of the heater is determined (Fig. 2). The calculation is made at a flow rate of the residual fuel oil 0.36 m³/h and a temperature range 30-100 °C. The Prandtl number characterizes physical properties of the fluid; it is a measure of the similarity of temperature and velocity fields in a heat carrier flow. With an increase in the thermal performance of the heater, the Prandtl number decreases [7-9].
Fig. 2. Dependence of the Prandtl number on thermal performance of the heater

Fig. 3 and 4 show the dependences of the kinematic viscosity changes on thermal heating by a heating steam and electric pads.

Fig. 3. Dependence of the kinematic viscosity on the heating steam consumption

Fig. 4. Dependence of the kinematic viscosity on the electric pad power capacity
According to the obtained dependences, it is clear that during the temperature increase, the viscosity of the residual fuel oil M100 decreases. The optimal dynamic viscosity parameters for transportation of the considered high-viscosity fluid through pipelines and for a normal operation of residual fuel oil pumps are 0.17-0.32 Pa·s, which corresponds to 60-70°C, with a further increase in the temperature of the substance, the viscosity reduction is insignificant. At a consumption of the high-viscosity fluid 3.6 m³/h, the required amount of the heat energy transferred to reduce the viscosity is 112-147 kg/h of heating steam, and the required power of electric pads at 1 hour of operation is about 70 000 W.

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