Methods of hydrodynamic calculation oil pipeline sequential transportation of small batches of various oil

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ABSTRACT

Purpose: To improve the technologies of different oil types of sequential pumping through the pipeline by establishing the laws of changing the throughput and energy efficiency of the oil pipeline operator in the process of pumping and displacing oil batches. The identified regularities would contribute to more effective management of the mixture realisation process at the end of the oil pipeline and reliable forecasting of the results of the different oil types of mixture formation.

Design/methodology/approach: Carrying out theoretical studies and applying mathematical modelling methods in order to establish the regularities of hy-drodynamic processes during the injection into the oil pipeline and the displacement of oil different grades from it.

Findings: The regularities of changes in oil pipeline capacity and specific electricity costs for transportation as a function of the coordinates of different oil types of batches contacts and the time of sequential pumping cycle implementation they have been established.

Research limitations/implications: The next stage of the research is to establish the influence of the hydrodynamic processes features on the intensity of the oil different grades mixture formation in the process of their successive pumping in the oil pipeline.

Practical implications: A method and software have been developed that make it possible to predict the throughput and energy efficiency of oil pipeline operation for each moment of the sequential pumping cycle of small batches of different grade oil. The application of the method for the conditions of an operating oil pipeline proved that during the cycle of four types of sequential oil pumping, the change in throughput exceeds 20%, and the change in energy consumption exceeds 10%.

Originality/value: The originality of the method consists in taking into account the regularities of the hydrodynamic process of the movement of several batches of oil of different grades in the pipeline, the features of the profile of the pipeline route and the physical properties of the liquid that fills the cavity of the pumps.

Keywords: Sequential pumping, Small batches of oil, Contact zone, Route profile, Throughput, Specific electricity consumption

METHODOLOGY OF RESEARCH, ANALYSIS AND MODELLING

RESEARCH PAPER

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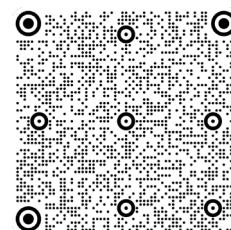
1. Introduction

In global practice, the technology of sequential pumping of various oil and petroleum products is widely used on main oil pipelines and petroleum product pipelines [1-5]. In Ukraine, there is considerable experience in using the specified technology in the pipeline transport of light petroleum products. The effective application of sequential pumping technology for the transportation of various grades of oil through main oil pipelines, which Ukraine receives from alternative sources of supply, has become particularly relevant today [6,7].

The scientific principles of the technology of sequential pumping of various oil or petroleum products through pipelines have been developed for over fifty years. In the works available today, special attention is paid to the patterns of mixture formation of different types of liquids due to turbulent diffusion during their sequential movement through a pipeline [8-10]. Formulas for the effective mixing ratio, the volume of the mixture, and its decomposition into tanks with marketable products are proposed. Most of the works consider issues related to implementing the specified technology in relation to the transportation of various petroleum products [2,5,6,9,10].

There are a number of features of the several liquids sequential movement hydrodynamic process characterized by a noticeable difference in physical and chemical properties, the oil pipeline, and these features still need to be sufficiently studied. It is these features that are the subject of consideration in the work that is offered.

2. Calculation methods of oil pipeline sequential transportation of small batches of various oil

The work aims to establish the peculiarity of the hydrodynamic process oil different grades of sequential pumping in small batches through the oil pipeline.

The process of sequential pumping liquids through the pipeline could be more stable. However, it could be considered quasi-stationary in practical hydrodynamic calculations for each contact position of different oil types in the oil pipeline, taking into account the relatively small rate of hydrodynamic parameters changing over time [11,12].

The corresponding value of the throughput capacity of the oil pipeline and the value of the specific electricity consumption for oil transportation corresponds to each position of the contacts of different oil type s on the oil pipeline route. The proposed technique makes it possible to establish patterns of changes in throughput and energy efficiency of oil pipeline operation in the process of moving contacts of various oil along the pipeline route.

It is assumed that at the beginning of the sequential pumping cycle, the entire empty-on oil pipeline is filled with oil, which would be called the base oil. At a certain point in time, the first oil grade begins to be pumped into the pipeline, and after a while – the second oil grade, then – the third oil grade. The specified oil types differ significouldtly in their physical and chemical properties after the sequantial pumping of batches of three oil types, the cavity of the pipeline is again filled with base oil. This completes the cycle of sequential pumping of various oil.

It is assumed that the volumes batches of all three oil grades are small and their total length in the cavity of the oil pipeline is less than the oil pipeline length L.

Determine the batches of i-th oil grade length in the process of transportation through the oil pipeline

$$l_i = \frac{4V_i}{\pi D^2}, \tag{1}$$

where V_i – the volume of the i-th oil grade; D – the internal oil pipeline diameter.

The linear coordinate is calculated from the contact zone of base oil and grade 1 oil. In the process of sequantial pumping of various oil, the specified oil contact zone would move along the oil pipeline length with a certain speed. For each moment of sequantial pumping, there is a certain position of batches of different oil type s in the pipeline and the corresponding throughput value.

The throughput capacity of the oil pipeline for each moment of sequential pumping, for which there is a corresponding value of the linear coordinate, would be found by the method of iterations according to oil consumption Q_h, taking into account the equations of the material and energy balance.

The hydraulic calculation of the linear part of the oil pipeline is performed according to the following method. Let call the calculated length of the lot of the i-th oil grade its length within the cavity of the oil pipeline. Let express the calculated length of oil batches as a function coordinates x.

Also, the number of separators on the oil pipeline route, which depends on the coordinates and the number of contacts of different oil types, would be found by us.

Upon fulfilment of the condition

$$x \leq l_1, \tag{2}$$

$$m = 1; l_{c_1} = x; l_{c_2} = 0; l_{c_3} = 0. \tag{3}$$

If the condition is met

$$l_1 < x \leq (l_1 + l_2), \tag{4}$$

$$m = 2; \; l_{c_1} = l_1; \; l_{c_2} = x - l_1; \; l_{c_3} = 0. \tag{5}$$

Upon fulfilment of the condition

$$(l_1 + l_2) < x \le (l_1 + l_2 + l_3), \tag{6}$$

$$m = 3; \; l_{c_1} = l_1; \; l_{c_2} = l_2; \; l_{c_3} = x - (l_1 + l_2). \tag{7}$$

If the condition is met

$$(l_1 + l_2 + l_3) < x \le L, \tag{8}$$

$$m = 3; \; l_{c_1} = l_1; \; l_{c_2} = l_2; \; l_{c_3} = l_3. \tag{9}$$

After reaching the contact zone between base oil and grade 1 oil at the end of the pipeline, the process of displacing batches of different oil grades with base oil from the cavity of the pipeline continues. This would be the second period of the sequential pumping cycle. Conditionally extend the linear coordinate beyond the actual oil pipeline length.

If the condition is met

$$L < x \le (L + l_1), \tag{10}$$

$$m = 3; \; l_{c_1} = l_1 - (x - L); \; l_{c_2} = l_2; \; l_{c_3} = l_3. \tag{11}$$

Upon fulfilment of the condition

$$(L + l_1) < x \le (L + l_1 + l_2), \tag{12}$$

$$m = 2; \; l_{c_1} = 0; \; l_{c_2} = l_2 - (x - L - l_1); \; l_{c_3} = l_3. \tag{13}$$

If the condition is met

$$(L + l_1 + l_2) < x \le (L + l_1 + l_2 + l_3), \tag{14}$$

$$m = 1; \; l_{c_1} = 0; \; l_{c_2} = 0; \; l_{c_3} = l_3 - (x - L - l_1 - l_2). \tag{15}$$

For an arbitrary value of the coordinate, the calculated length of the base oil is equal to

$$l_{c_b} = L - l_{c_1} - l_{c_2} - l_{c_3}. \tag{16}$$

Let us find the movement speed and Reynolds number for each oil type in the oil pipeline

$$w = \frac{4Q}{\pi D^2}, \tag{17}$$

$$Re_i = \frac{wD}{\nu_i}, \tag{18}$$

where Q – volumetric consumption of sequential transported oils in the oil pipeline; ν_i – estimated kinematic viscosity of the i-th oil grade.

To determine the first transition Reynolds number, a formula, which is a transcendental equation and requires the application of the method of sequential approximation, is proposed

$$\varepsilon = \frac{8.15}{Re_t \sqrt{0.0032 + 0.221 \, Re_t^{-0.237}}}, \tag{19}$$

where ε – relative equivalent roughness of the inner surface of the pipe,

$$\varepsilon = \frac{k_e}{D}, \tag{20}$$

k_e – absolute equivalent roughness of the inner surface of the pipe.

To simplify the computational algorithm, the obtained approximation of equation (19) is used in the form of a third-order polynomial.

$$Re_t = 8.804 \cdot 10^5 - 3.967 \cdot 10^9 \varepsilon + 7.339 \cdot 10^{12} \varepsilon^2 - 4.823 \cdot 10^{15} \varepsilon^3. \tag{21}$$

First, the value of the hydraulic resistance coefficient for each oil type is calculated according to the traditional Blasius formula.

$$\lambda_i = \frac{0.3164}{Re_i^{0.25}}. \tag{22}$$

Upon fulfilment of the condition

$$Re_i < Re_t, \tag{23}$$

the effective equivalent roughness of the pipe is found

$$k_{ee_i} = k_e \frac{Re_i - 4000}{Re_t - 4000}. \tag{24}$$

It is accepted for the zone of mixed friction of the turbulent mode of movement of oil in the oil pipeline.

$$k_{ee_i} = k_e. \tag{25}$$

The hydraulic resistance coefficient for each oil grade is found by the modified Hofer formula, which is an adequate approximation of the Colebrook-White formula

$$\lambda_i = \frac{1}{\left\{2 \, lg\left[\frac{4.518}{Re_i} lg\left(\frac{Re_i}{7}\right) + \frac{k_{ee_i}}{3.71D}\right]\right\}^2}. \tag{26}$$

The larger of the two calculated values of the hydraulic resistance coefficient in the oil pipeline is chosen as the final result for each oil types.

Pressure losses due to friction on the section of the oil pipeline filled with the i-th oil grade are calculated.

$$P_{\tau_i} = \lambda_i \frac{l_{c_i}}{D} \cdot \frac{w^2}{2} \rho_i, \tag{27}$$

where ρ_i – calculated density of the i-th oil grade.

Analogous hydraulic calculations are performed for the base oil grade, which fills the entire cavity of the oil pipeline at the beginning of the cycle.

The arrays of the lengths of the ascending and descending oil pipeline sections l_{s_j} and the geodetic marks of the route points z_{s_j} corresponding values are used to take

into account the effect of gravity on the hydraulic calculation results. The number of sections of the pipeline n.

In order to find the total pressure losses within each oil grade, it is necessary to find the difference between the geodetic markings of the beginning and end points of the corresponding oil batches on the pipeline route.

The sum of the track section lengths is found as a function of the section number.

$$L_j = \sum_{j=1}^{j} l_{s_i}. \tag{28}$$

Starting the calculation from the first section of the oil pipeline route, the value $j = k$ for which the value L_k becomes greater than the value of the linear coordinate x is determined by us. This means that the point is within the k-th section of the oil pipeline route. The geodetic mark of the contact zone of base oil and first grade oil is found by the formula

$$z_x = z_{s_{k-1}} + \frac{\left(z_{s_k} - z_{s_{k-1}}\right)}{l_{s_\kappa}}(x - L_{k-1}). \tag{29}$$

where $z_{s_k}, z_{s_{k-1}}$ – geodetic marks of k-th and $(k-1)$-rh points of the oil pipeline route in accordance.

Next, the linear coordinates of the location of the end of the first oil grade batches, and the beginning and the end of all other oil grade batches are determined. The geodetic marks of the indicated points of the oil pipeline route are calculated according to the formula (29). The following formulas are used to find the difference in geodetic marks for batches of each grade depending on their location on the oil pipeline route.

If the condition is met

$$x \leq l_1, \tag{30}$$

than

$$\Delta z_b = z_n - z_x; \Delta z_1 = z_x - z_0; \Delta z_2 = 0; \Delta z_3 = 0. \tag{31}$$

Upon fulfilment of the condition

$$l_1 < x \leq (l_1 + l_2), \tag{32}$$

than

$$\Delta z_b = z_n - z_x; \Delta z_1 = z_x - z_{x-l_1}; \Delta z_2 = z_{x-l_1} - z_0; \Delta z_3 = 0. \tag{33}$$

Upon fulfilment of the condition

$$(l_1 + l_2) < x \leq (l_1 + l_2 + l_3), \tag{34}$$

than

$$\Delta z_b = z_n - z_x; \Delta z_1 = z_x - z_{x-l_1}; \Delta z_2 = z_{x-l_1} - z_{x-l_1-l_2};$$
$$\Delta z_3 = z_{x-l_1-l_2} - z_0. \tag{35}$$

If the condition is met

$$(l_1 + l_2 + l_3) < x \leq L, \tag{36}$$

than

$$\Delta z_{b1} = z_n - z_x; \Delta z_1 = z_x - z_{x-l_1}; \Delta z_2 = z_{x-l_1} - z_{x-l_1-l_2}; \Delta z_3 = z_{x-l_1-l_2} - z_{x-l_1-l_2-l_3}; \Delta z_{b2} = z_{L-l_1-l_2-l_3} - z_0; \Delta z_b = \Delta z_{b1} + \Delta z_{b2}. \tag{37}$$

If the condition is met

$$L < x \leq (L + l_1), \tag{38}$$

than

$$\Delta z_1 = z_n - z_{L-l_{c1}}; \quad \Delta z_2 = z_{L-l_{c_1}} - z_{L-l_{c_1}-l_2}; \quad \Delta z_3 = z_{L-l_{c_1}-l_2} - z_{L-l_{c_1}-l_2-l_3}; \Delta z_b = z_{L-l_{c_1}-l_2-l_3} - z_0. \tag{39}$$

Upon fulfilment of the condition

$$(L + l_1) < x \leq (L + l_1 + l_2), \tag{40}$$

than

$$\Delta z_1 = 0; \Delta z_2 = z_n - z_{L-l_{c_2}}; \Delta z_3 = z_{L-l_{c_2}} - z_{L-l_{c_2}-l_3};$$
$$\Delta z_b = z_{L-l_{c_2}-l_3} - z_0. \tag{41}$$

If the condition is met

$$(L + l_1 + l_2) < x \leq (L + l_1 + l_2 + l_3), \tag{42}$$

than

$$\Delta z_1 = 0; \Delta z_2 = 0; \Delta z_3 = z_n - z_{L-l_{c_3}}; \Delta z_{\delta} = z_{L-l_{c_3}} - z_0. \tag{43}$$

The total pressure losses in the oil pipeline for any moment of different oil grades sequential pumping are found by the formula

$$P_{sum} = 1.02\left(P_{\tau_b} + P_{\tau_1} + P_{\tau_2} + P_{\tau_3}\right) + \left(\Delta z_b \rho_b + \Delta z_1 \rho_1 + \Delta z_2 \rho_2 + \Delta z_3 \rho_3\right)g + P_{end} + m\Delta P_{sep}, \tag{44}$$

where P_{end} – technologically necessary oil pressure at the end of the oil pipeline; m – the number of dividers on the oil pipeline route; ΔP_{sep} – ressure loss on the mechanical separator.

The calculated energy losses in the oil pipeline should be compensated by the energy provided to the transported oil by the pumping units of the main oil pumping station.

The pressure characteristic of the j-th main pump is described by a third-order polynomial mathematical model

$$H_j = a_{0_j} + a_{1_j}Q_h + a_{2_j}Q_h^2 + a_{3_j}Q_h^3, \tag{45}$$

where $a_{0_j}, a_{1_j}, a_{2_j}, a_{3_j}$ – the coefficients of the j-th main pump pressure characteristic mathematical model.

The following mathematical model is used to describe the characteristics of the main pump efficiency:

$$\eta_j = b_{1_j}Q_h + b_{2_j}Q_h^2 + b_{3_j}Q_h^3, \tag{46}$$

where $b_{1_j}, b_{2_j}, b_{3_j}$ – coefficients of the j-th main pump efficiency curve mathematical model; Q_h – hourly supply of the j-th main pump, which corresponds to the consumption of transported oil in the oil pipeline.

Similar expressions are used to describe the pressure characteristic and booster pump efficiency curve

$$H_{sup} = a_{0_{sup}} + a_{1_{sup}}Q_h + a_{2_{sup}}Q_h^2 + a_{3_{sup}}Q_h^3, \tag{47}$$

$$\eta_{sup} = b_{1_{sup}}Q_h + b_{2_{sup}}Q_h^2 + b_{3_{sup}}Q_h^3, \tag{48}$$

where $a_{0_{sup}}, a_{1_{sup}}, a_{2_{sup}}, a_{3_{sup}}$ – coefficients of the sub-prime pump pressure characteristics polynomial mathematical model; $b_{1_{sup}}, b_{2_{sup}}, b_{3_{sup}}$ – coefficients of the booster pump efficiency curve polynomial mathematical model.

It is assumed that in the gas and oil pumping station, the support and r main pumps work in sequence, then the pressure created by the pumps of the oil pumping station is equal to

$$H_{ps} = H_{sup} + \sum_{j=1}^{r} H_j. \tag{49}$$

The pressure created by the pump at a certain supply depends on the density of the oil filling its cavity during the sequential pumping cycle; the oil density changes periodically. The following formulas find the calculated density of oil passing through the pump cavity.

Upon fulfilment of the condition

$$x \leq l_1, \tag{50}$$

$$\rho_{ps} = \rho_1. \tag{51}$$

If the condition is met

$$l_1 < x \leq (l_1 + l_2), \tag{52}$$

$$\rho_{ps} = \rho_2. \tag{53}$$

Upon fulfilment of the condition

$$(l_1 + l_2) < x \leq (l_1 + l_2 + l_3), \tag{54}$$

$$\rho_{ps} = \rho_3. \tag{55}$$

If the condition is met

$$x > (l_1 + l_2 + l_3), \tag{56}$$

$$\rho_{ps} = \rho_b. \tag{57}$$

The pressure created by the pipe-end oil-pumping station pumps at the assumed oil consumption is calculated

$$P_{ps} = H_{ps}\rho_{ps}g, \tag{58}$$

where g – acceleration of gravity.

Let us check the fulfilment of the technological limitation regarding the maximum pressure at the output of the pipe-end oil-pumping station.

If the condition is met

$$P_{ps} > P_{max}, \tag{59}$$

then the oil pressure at the beginning of the pipeline section (after the pipe-end oil-pumping station pressure regulators) is taken to be equal to the maximum allowable pressure

$$P_{beg} = P_{max}. \tag{60}$$

If the condition is satisfied

$$P_{ps} < P_{max}, \tag{61}$$

then the oil pressure at the beginning of the oil pipeline section (after the pipe-end oil-pumping station pressure regulators) is assumed to be equal to the pressure at the pump outlet

$$P_{beg} = P_{ps}. \tag{62}$$

The fulfilment of the pressure balance equation for the accepted value of liquid consumption in the pipeline is checked. To do this, the oil pressure at the beginning of the oil pipeline P_{beg} and total pressure losses P_{sum} was compared. Upon fulfilment of the condition

$$P_{beg} - P_{sum} > \varepsilon_c \tag{63}$$

we increase the oil flow in the oil pipeline with a certain step.

When billing accuracy is achieved ε_c the oil pipeline throughput capacity corresponding to the given value of the different grades of oil batches location on the route was obtained.

Using formulas (45) and (47), the pressure created by the main and support pump during the oil supply corresponding to the throughput of the system was found. Using formulas (46) and (48), the efficiency of the main η_j and booster η_{sup} pump was found. Next, the total consumed power of the pumps N_{sum} for the implementation of the sequential pumping mode with a flow that corresponds to the throughput capacity of the oil pipeline was determined

The weighted average value of the density of sequentially transported oils on the pipeline route was calculated

$$\rho_m = \frac{\left(\rho_b l c_b + \rho_1 l c_1 + \rho_2 l c_2 + \rho_3 l c_3\right)}{L}, \tag{64}$$

The specific electricity consumption for the implementation of different oil types of sequential pumping could be found using the formula

$$W_e = \frac{N_{sum}}{\rho_m Q_h L}. \tag{65}$$

Table 1.
The physical and chemical properties of oil calculated values

Name of the parameter	Basic oil	Grade oil 1	Grade oil 2	Grade oil 3
Oil density, kg/m^3	878.0	845.8	820.4	826.2
Kinematic viscosity, cSt	55.7	12.8	5.1	6.5

Table 2.
The oil pipeline route profile characteristics

l_{s_j}, km	0	40	30	32	36	32	28	27	45	25	36	51	12
z_{s_j}, m	159	182	143	165	221	175	206	222	176	225	228	192	233

When implementing sequential pumping of oil of various grades, it is necessary to know the location of oil batches in the oil pipeline cavity and the patterns of changes in throughput and energy efficiency as a function of time.

To solve the specified task, calculations for different values x of the coordinates with a certain step would be performed. For the k-th value of x, the time from the beginning of the sequential pumping cycle is found by the formula

$$\tau_x = \sum_{j=1}^{k} 2\frac{(x_j - x_{j-1})}{(w_j + w_{j-1})}. \tag{66}$$

The above calculation method is implemented in a computer program that makes it possible to perform a hydrodynamic calculation of the sequential pumping of an arbitrary number of oil batches in small batches through the oil pipeline.

3. Regime parameters of the oil pipeline during sequential pumping of four types of oil

The hydrodynamic calculation method was tested by determining one of the oil pipelines' operational section throughput capacity. The length of the section is 394 km, and the internal diameter is 0.702 m. The maximum allowable pressure, based on the strength of the pipe, is 45 bar. The oil batches volumes for transportation by oil pipeline are as follows: grade oil 1 35000 m^3, grade oil 2 40000 m^3, grade oil 3 31000 m^3.

The density and kinematic viscosity of the oil grades transported by the pipeline at the pumping temperature are given in Table 1, and the characteristics of the pipeline route are given in Table 2.

The various oil sequential pumping hydrodynamic proces through the oil pipeline, and multivariate calculations were performed using the developed computer program. Figure 1 shows the obtained dependence between the value

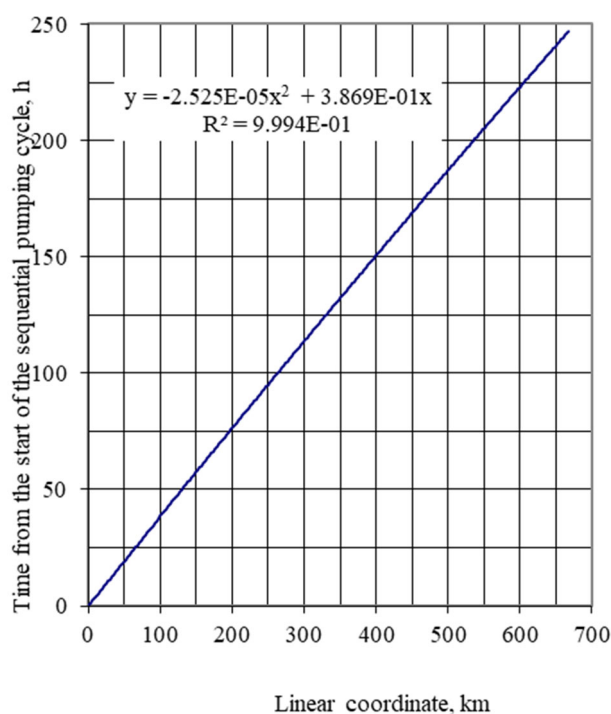of the linear coordinate and the time counted from the beginning of the sequential pumping cycle.

Fig. 1. Dependence between the coordinate value and the time counted from the beginning of the sequential pumping cycle

As shown in Figure 1, the dependence between the value of the linear coordinate x and the duration of various oil sequential pumping with an approximation probability of more than 99% could be described by a second-order polynomial function.

Figures 2 and 3 show the dynamics of changes over time in the oil batch length in the oil pipeline cavity, respectively, during the first and second periods of the sequential pumping cycle.
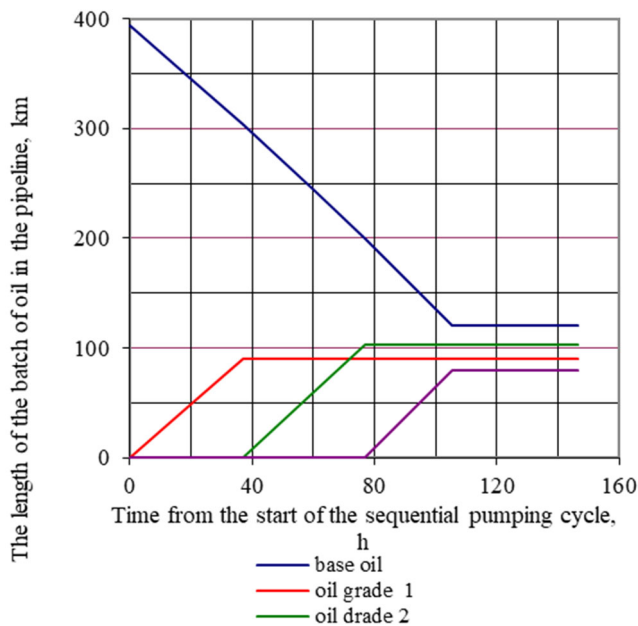
Fig. 2. Dynamics of changes in the oil batches length in the oil pipeline cavity during the first period of the sequential pumping cycle
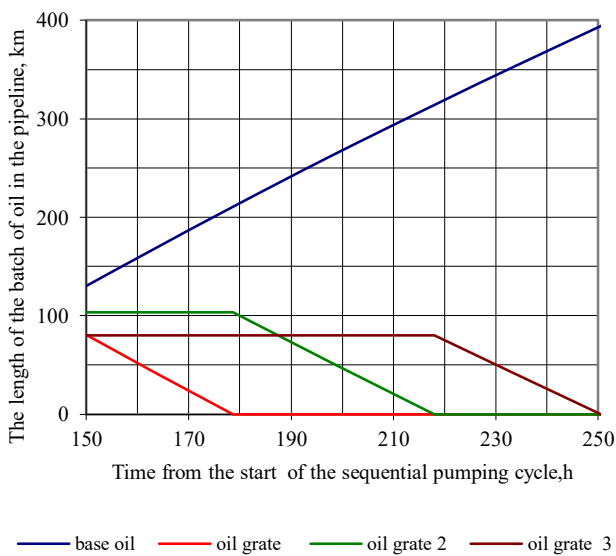

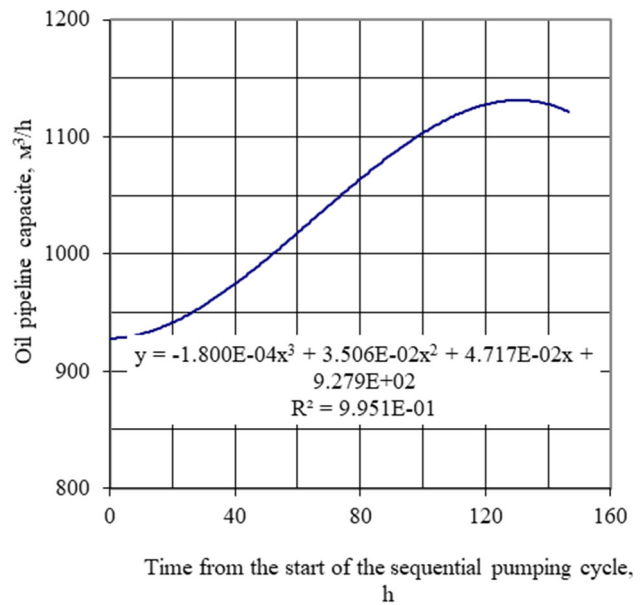Fig. 4. Results of mathematical modelling of bandwidth dependence pipeline capacity over time (first period of the cycle)

Fig. 3. Dynamics of changes in the oil batches length in the oil pipeline cavity during the second period of the sequential pumping cycle
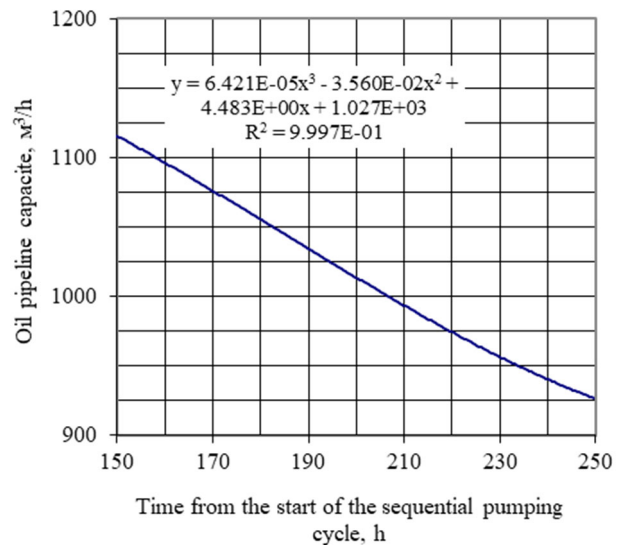

Fig. 5. Results of mathematical modelling of the oil pipeline throughput capacity dependence on time (the second period of the cycle)

Figures 4 and 5 show the results of mathematical modelling of the oil pipeline throughput capacity dependence on the time of various oils' sequential pumping, respectively, for the first and second cycle periods.

As shown in Figures 4 and 5, in the process of three oil types pumping, which properties differed significantly from the base oil characteristics as a result of the change in the oil pipeline hydraulic resistance, the system throughput and the specific consumption of electricity change according to a

complex law. In addition to changes in pressure losses due to friction, the results of the hydrodynamic calculation are affected by the change in pressure created by the pumps due to changes in the oil type filling its cavity, as well as gravitational losses caused by the profile of the oil pipeline route.

The bandwidth dependence on the duration of the sequential pumping cycle for the first and second periods with an approximation probability of more than 99% is described by a third order polynomial function.

Figures 6 and 7 illustrate the change in specific electricity consumption during the first and second periods of the sequential pumping cycle. It could be seen from Figure 6 that during the implementation of the various oil in small batches sequantial pumping cycle first period, the energy efficiency of the oil pipeline operation would change according to a complex law in the range from 8.1 kWh/(thousand tons km) to 7.4 kWh/(thousand t km). During the second period of the various oil sequential pumping cycle, the electricity specific consumption would be monotonically increase from the value of 7.7 kWh/(thousand tons km) to 8.4 kWh/(thousand tons km).
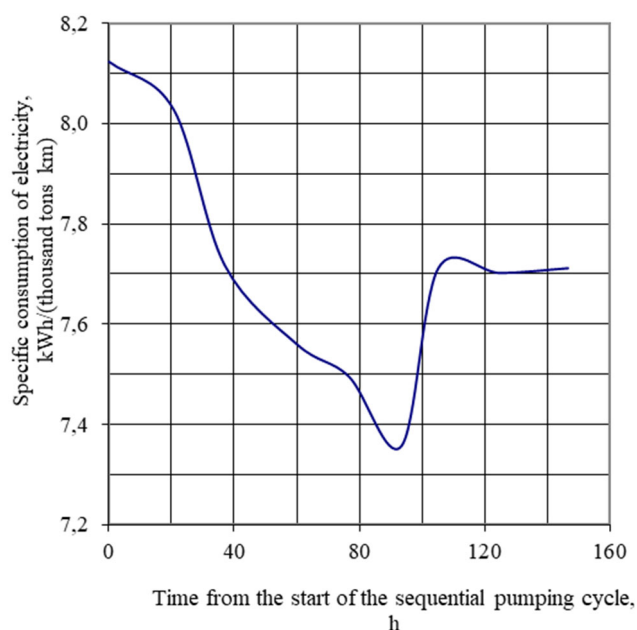

Fig. 6. Change in electricity-specific consumption during the first-period cycle of various oils sequential pumping

It can be seen from Figure 6 that during the implementation of the various oil in small batches sequential pumping cycle first period, the energy efficiency of the oil pipeline operation would change according to a complex law

in the range from 8.1 kWh/(thousand tons km) to 7.4 kWh/(thousand tons km). During the second period of the various oil sequential pumping cycle, the electricity-specific consumption would be monotonically increased from the value of 7.7 kWh/(thousand tons km) to 8.4 kWh/(thousand tons km) (Fig. 7).
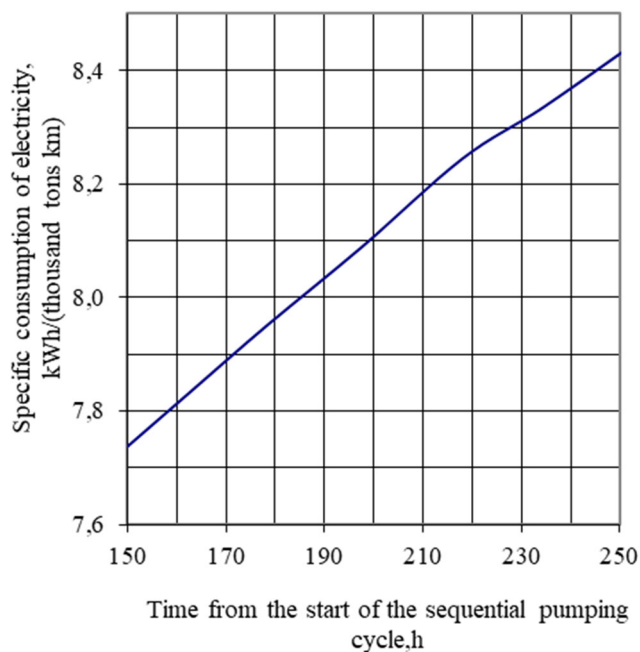

Fig. 7. Changes in specific electricity consumption during the second period cycle of various oils sequential pumping

4. Conclusions

1. The hydrodynamic process of various oil sequential pumping through the oil pipeline, which is pumped in small batches and is characterized by a noticeable difference in physical and chemical properties, has a number of features that must be taken into account during design and operational calculations.
2. Within the framework of the hydrodynamic model of the steady liquid movement in the pipeline, a method for determining the throughput and energy oil pipeline operation efficiency is proposed for the arbitrary case of the small oil batches location in the pipeline and the corresponding value of the time for the sequential pumping cycle implementation. The method considers the peculiarities of the oil pipeline route profile and the change in pump pressure when the liquid that fills their changes.

3. The method was tested by performing hydrodynamic calculations of a domestic oil pipeline section with four oil types of sequential pumping, three of which are transported in small batches. It was established that during the cycle of sequential pumping, the relative change in the throughput of the oil pipeline reaches 21%, and the relative change in specific electricity consumption could be 13%.

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