Determination of optimal oil pumping plans

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ABSTRACT

This paper presents the results of determining the optimal plans for pumping oil through the main oil pipelines of Kazakhstan. The calculation methodology is based on determining the minimum unit cost of pumping depending on oil flow rate. Oil pumping energy-saving modes are determined under optimal operating conditions of pumping units and heating furnaces at stations. Determination of the optimal pumping plan is implemented as a separate module of the SmartTranPro software. Pumped oil volumes on the oil pipeline sections were determined on the basis of the automated system of control and metering of electrical energy data of KazTransOil JSC. Optimal pumping plans for monthly oil volumes in the Kalamkas – Karazhanbas and Dzhumagaliev – Atasu pipeline sections for cold and warm periods were calculated on the basis of the found dependence of the pumping unit cost. For each range of oil mass flow rate, specific costs for oil pumping and a list of operating pumps at oil pumping stations located along the pipeline section are indicated.

Keywords: oil pipeline, flow rate, optimal pumping plan, energy-saving mode, unit cost.

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Introduction

Increasing energy consumption efficiency when transporting oil by main pipelines mostly depends on the system of organization and management of technological modes of oil pipeline operation and is achieved by modeling optimal conditions of its operation [[1], [2], [3], [4]].

Optimizing the process of pipeline transportation of oil is of great practical importance, and a number of works are devoted to the problem of optimizing distribution of cargo flows through the system of main pipelines [[5], [6], [7], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17]].

When considering this problem, the question of choosing rational volumes of pumped oil naturally arises. Pumping units must be able to pump the amount of oil that is required according to optimal operation of the oil pipeline. Therefore, associated with the problem of choosing rational oil volumes along oil pipeline routes is the problem of choosing the most effective modes of operation of pumping and power equipment for reliable operation of the main oil pipeline.

Management of energy-saving modes is determined under optimal operating conditions of equipment of oil pumping stations and technological modes of oil pumping through main oil pipelines. Determination of energy-saving modes of pumping is important for estimating the efficiency of operation of main oil pipelines.

Methodology for finding the optimal oil pumping plan

The optimal pumping mode is considered to be such the mode in which the least amount of financial costs is consumed for given performance. Oil pumping costs are the sum of electricity expenses consumed by pumps and fuel for operation of heating furnaces.

The problem of finding the optimal pumping mode of a given volume of oil is as follows: G is the total volume of oil (in tons), which must be pumped optimally over a period of time T; Q_i is the capacity (in t/h) of the pipeline at the mode No. i without using a pressure regulator (PR) or a variable frequency drive (VFD); t_i is the total operating time of the pipeline in the mode No. i during the period T; E_i is the unit costs per unit of time (in tenge/h) when pumping oil in the mode No. i; Q_i^{min} is the minimum specified capacity (in t/h) of the pipeline at the mode No. i, which can be achieved using a PR or a VFD.

Each optimal plan is represented by one of the following three cases:

1) The mode No. i with shutdowns, i.e. the plan consists of alternating states: pumping in the mode with the capacity Q_i (total t_i hours) and stopping pumping (total $(T - t_i)$) hours):

$$Q_i t_i = G, \quad t_i \le T$$

2) The combination of modes No. i and No. j, i.e. the plan consists of alternating states: pumping in the mode with the capacity Q_i (total t_i hours) and in the mode with the capacity Q_j (total t_j hours):

$$Q_i t_i + Q_j t_j = G, \quad t_i + t_j = T,$$
$$E_i t_i + E_j t_j \to min$$

3) The mode No. i with the selection of rotor speed:

$$Q_{VFD} = \frac{G}{T}, \quad Q_i^{min} \le Q_{VFD} \le Q_i$$

In this case, the pumping plan consists of one mode with the constant capacity Q_{VFD}. Required pump rotor speed is determined based on the value of Q_{VFD}.

The energy efficiency of oil transportation can be estimated by specific electric energy consumption according to the work performed [18]:

$$E_p = \frac{W}{G \cdot H_{loss}} \qquad (1)$$

where W is the amount of consumed electricity, kWh; G is the volume of pumped oil, t; H_{loss} is the required head for pumping the volume of oil G through the pipeline, m.

In practice, in addition to specific electric energy consumption E_p, specific electric energy consumption by pipeline capacity is used:

$$E_{cap} = \frac{W}{G \cdot L} \qquad (2)$$

where L is the oil pipeline length, km; E_{cap} has the dimension of kWh/(thousand tons$\cdot$km).

The energy-saving mode of main oil pipeline operation is estimated by specific electric energy consumption for pumping one ton of oil. Specific electric energy consumption in kWh/t is found by the formula [[18], [19]]:

$$E_{spj} = \frac{1}{\rho Q_j}\left(N_{consjn} + \sum_{i=1}^{n_{Hj}} N_{consij}\right) \qquad (3)$$

where N_{consjn} is the power consumed by electric motors of booster pumps of the head pumping station (PS) when operating in the j-th mode; N_{consij} is the same for electric motors of mainline pumps of the i-th PS; n_{Hj} is the total number of mainline pumps at stations in the j-th mode.

Power consumed by the pumping unit when operating in the j-th mode is found from the expression [[18], [19], [20]]:

$$N_{consj} = \frac{\rho g H_j Q_j}{\eta_{1j}\eta_{2j}\eta_{3j}} \qquad (4)$$

where H_j, Q_j, η_{3j} are the head, the flow rate and the efficiency of the pump, respectively, when operating in the j-th mode, η_{1j} is the efficiency of the electric motor in the j-th mode, η_{2j} is the efficiency of the mechanical transmission, for the mechanical clutch can be taken η_{2j} = 0.99.

Pump efficiency is calculated by the formula [[18], [19]]:

$$\eta_{3j} = c_0 + c_1 Q_j + c_2 Q_j^2 + c_3 Q_j^3$$

where c_0, c_1, c_2, c_3 are the empirical coefficients, which are determined for each type of rotor.

The efficiency of an electric motor is expressed by the formula [19]:

$$\eta_{1j} = \left[1 + \frac{1 - \eta_{nom}}{2\eta_{nom}k_{load}}(1 + k_{load}^2)\right]^{-1}$$

where η_{nom} is the efficiency of an electric motor at nominal loading, k_{load} is the operation factor of an electric motor.

Thus, to assess the efficiency of energy-saving modes of pumping oil blends along oil pipeline routes, it is possible to use specific electric energy consumption (3), specific electric energy consumption for the work performed (1) or specific electric energy consumption for cargo turnover (2).

Calculation results

Determination of the optimal pumping plan is implemented as a separate module for the SmartTranPro software package [21]. The software module selects the most optimal combination of pumps for each flow rate Q in the interval (10, Q_{max}) with a step of 0.5 t/h and calculates specific energy consumption E(Q).

Using this module for the Kalamkas – Karazhanbas and the Dzhumagaliev – Atasu oil pipeline sections, optimal modes of pumping oil and oil blends were calculated. According to production data, the lowest ground temperature value is observed in March, and the highest – in September, therefore calculations were carried out for these two months.

To calculate financial costs, tariffs for electricity and fuel in respective regions for 2020 were used. Pumped oil volumes on considered sections of oil pipelines were determined on the basis of the ASCAPC (Automatic System for Commercial Accounting of Power Consumption) system data of KazTransOil JSC.

The following data were used as initial parameters:

- average monthly values of soil temperature along the pipeline;

- an actual value of the pumped oil volume during the month.

When carrying out optimization calculations, the following restrictions are taken into account, which are necessary for safe operation of oil pipelines:

- maximum allowable pressure at the station outlet;

- maximum allowable pressure at the oil pumping station outlet (up to the PR);

- minimum allowable pressure at the pump inlet;
- a safe range of pump flow rate;
- minimum allowable rotor speed.

For listed sections of oil pipelines, dependences of the minimum unit cost of pumping on capacity were plotted. Based on the found dependence, optimal pumping plans were calculated for various values of monthly planned volumes.

Optimal pumping plans are presented in a tabular form, which displays a list of ranges of monthly planned volumes with corresponding optimal pumping modes.

Tables show lists of pump operating modes in ascending order of obtained performance. A performance range corresponds to each individual table mode. If, opposite to the performance range in the list of operating pumps, any pump is indicated "with a VFD" (for example, "mainline pumping unit (MPU) No. 1 with a VFD"), it is assumed that any performance value from the corresponding range can be obtained by adjusting rotor speed of the specified pump. If, opposite to the performance range in the list of operating pumps, no pump is indicated "with a VFD", it is assumed that any performance value from the corresponding range can be obtained using a VFD at the starting station, or by creating backpressure at the inlet to the terminal station. In addition, if names of pumps are indicated in a cell on one line, then this means that given pumps operate in parallel, if on different lines of one cell, then sequentially.

The Kalamkas - Karazhanbas oil pipeline

At the Kalamkas – Karazhanbas section (Fig. 1) of the Kalamkas – Karazhanbas – Aktau main oil pipeline, Buzachi oil with constant physical and chemical composition is pumped [22]. Optimization calculations were carried out using the actual data of the SCADA system [23].

Initial parameters for performing optimization calculations are given in Table 1. At 0.6 km and 23 km of the Kalamkas - Karazhanbas pipeline, there are associated oil pumping points of Buzachi neft LLP and Arman JV. Based on the archival data of the SmartTranPro database for 2019, monthly pumping volumes from Buzachi neft LLP and Arman JV are 15-16 thousand m^3 and 10-12 thousand m^3, respectively. Therefore, in order to take this fact into account, monthly average values of pumping flow rate were used as the initial calculation parameter.

Figure 2 shows the dependency curve of unit costs for pumping oil for the Kalamkas –

Karazhanbas oil pipeline section from performance obtained for the cold period. Tables 2 and 3 show optimal pump operation modes for different performances and optimal pumping plans for different monthly volumes for the Kalamkas – Karazhanbas oil pipeline.

As a result of the calculation, two optimal pump operation modes were selected for this section: in the range of mass flow rate values 100 – 231 t/h, the pipeline can operate in the mode No. 1 with shutdowns, in the range of flow rates 232 – 740 t/h – in the mode No. 2 with the selection of required rotor speed.

Figure 1 – Diagram and profile of the Kalamkas - Karazhanbas pipeline section

Table 1 – Initial parameters for calculating unit costs in the section of the Kalamkas – the Karazhanbas

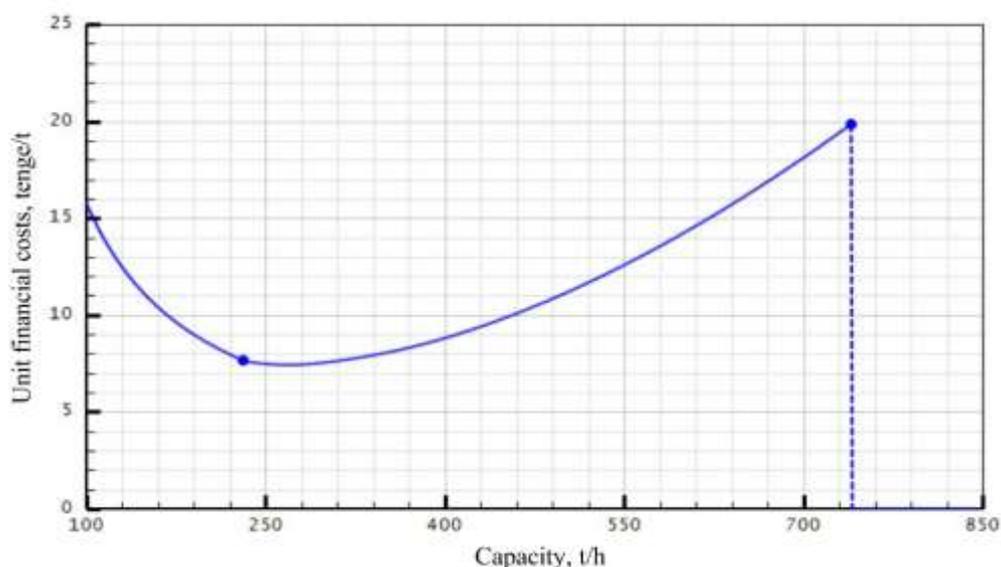| Parameter names	Parameter value	
	March	September
Initial oil temperature, °C	+52.5	+54
Initial pressure, bar	0.5	0.5
Flow rate of pumping from "Buzachi neft" LLP, t/h	20	20
Flow rate of pumping from "Arman" JV, t/h	14	14
Residual pressure at the inlet of the terminal station, bar	1.2	1.2
Soil temperatures, °C	+9.2 (0 km) +10.6 (62 km)	+24.8 (0 km) +25.5 (62 km)
Electricity tariff, kWh/tenge	19.49	19.49

Figure 2 – Dependence of unit costs on capacity in the Kalamkas – Karazhanbas section for March

Table 2 – Optimal operating modes of pumps for various performance values of the Kalamkas – Karazhanbas section

Mode No.	Flow rate, t/h	Costs, thousand tenge/h	Unit costs, tenge/t	Operating pumps
1	100 - 231 (March) 100 - 242 (September)	1.6 - 1.8 (March) 1.6 - 1.8 (September)	15.8 - 7.7 (March) 15.8 - 7.4 (September)	booster pump unit (BPU) No. 1
2	232 - 740 (March) 243 - 750 (September)	1.8 - 14.7 (March) 1.8 - 14.9 (September)	7.6 - 19.8 (March) 7.4 - 19.8 (September)	BPU No. 1 MPU No. 3 with a VFD

Table 3 – Optimal pumping plans at different monthly volumes for the Kalamkas – Karazhanbas section

Pumping volume, t	Required modes
0 – 171000 (March) 0 – 174000 (September)	Mode No. 1 with shutdowns
171000 – 550000 (March) 174000 – 540000 (September)	Mode No. 2 with the selection of required rotor speed

Table 4 – Initial parameters for calculating unit costs in the Dzhumagaliev – Atasu oil pipeline section

Parameter names	Parameter value	
	March	September
Initial oil temperature, °C	+10	+24
Initial pressure, bar	0.6	0.6
Residual pressure at the inlet of the terminal station, bar	1	1
Soil temperature, °C	+ 4.3 (0 km) +1.4 (175.7 km) +3.3 (267.6 km) +2.7 (427.3 km)	+ 22.1 (0 km) +18 (175.7 km) +19.2 (267.6km) +16.4 (427.3km)
Electricity rate, kWh/tenge	15.49	15.49

The Dzhumagaliev – Atasu oil pipeline

For optimization calculations of the Dzhumagaliev – Atasu section (Fig. 3) of the Pavlodar – Atasu main oil pipeline, parameters of Aktobe oil at the outlet of the Pavlodar - head oil pumping station (HOPS) were used.

Initial data for optimization calculations are given in Table 4: initial oil temperature, pressure at the inlet of the booster pump at the Dzhumagaliev HOPS, residual pressure at the inlet of the Atasu – oil pumping station (OPS), soil temperature values at main points and electricity tariffs.


Figure 3 – Diagram and profile of the Dzhumagaliev – Atasu pipeline section

Figure 4 shows the dependency curve of unit costs on performance obtained for cold and warm periods of Dzhumagaliev – Atasu pipeline section operation. The zigzag change in specific energy consumption on the graph is explained by switching to another pump or a group of pumps.

Table 5 shows found optimal operating modes of pumps for various performance values of the Dzhumagaliev – Atasu section for the cold period. For each range of oil mass flow rate, specific pumping costs and lists of pumps that operated at oil pumping stations of the considered section

(Dzhumagaliev HOPS and Barsengir OPS) are indicated. If the cell is empty, then this pumping station is not turned on.In accordance with obtained modes for the Dzhumagaliev – Atasu pipeline section, optimal plans for pumping oil were found at various monthly volumes.

Table 6 shows data on optimal pumping plans for the cold period. For example, in the range of monthly oil flow rates from 738,000 to 1,066,000 tons, the most optimal for energy saving is the use of a combination of modes No. 4 and No. 13 when pumping oil in this section.

a)　　　　　　　　　　　　　　　　　　　　　　　b)
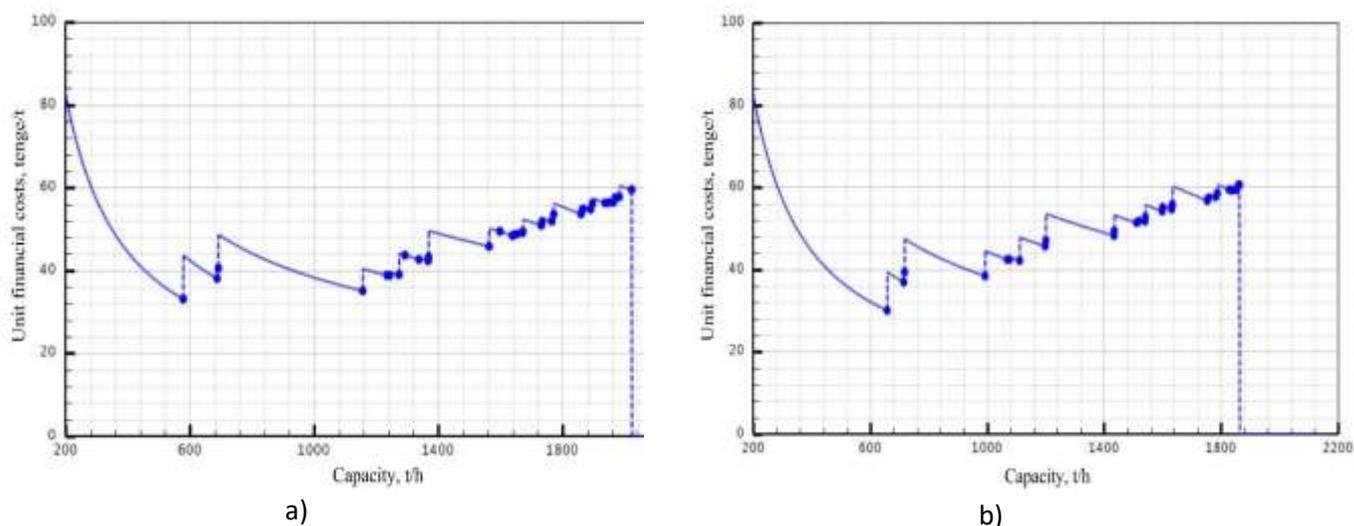
Figure 4 – Dependence of unit costs on performance at the Dzhumagaliev – Atasu pipeline section: a) cold period (March); b) warm period (September)

Table 5 – Optimal operating modes of pumps for various performance values of the Dzhumagaliev – Atasu oil pipeline section in the cold season

Mode No.	Flow rate, t/h	Unit costs, tenge/t	Operating pumps	
			Dzhumagalieva HOPS	Barsengir OPS
1	2	3	4	5
1	200 - 658	82.6 - 30.1	BPU No. 1 MPU No. 1 (Q=0.5)	
2	659 - 715	39.4 - 36.9	BPU No. 1 MPU No. 3	
3	716 - 718	39.5 - 39.4	BPU No. 1 MPU No. 4 (D=465mm)	
4	719 - 993	47.4 - 38.5	BPU No. 1 MPU No. 1 (Q=0.5)	MPU No. 3 (Q=0.5)
5	994 - 1069	44.5 - 42.5	BPU No. 1 MPU No. 1 (Q=0.5) MPU No. 3	
6	1070 - 1076	42.6 - 42.5	BPU No. 1 MPU No. 3	MPU No. 3 (Q=0.5)
7	1077 - 1078	44.0 - 44.0	BPU No. 1 MPU No. 4 (D=465mm)	MPU No. 3 (Q=0.5)
8	1079 - 1086	44.1 - 43.9	BPU No. 1 MPU No. 1 (Q=0.5)	MPU No. 1
9	1087 - 1128	49.4 - 48.2	BPU No. 1 MPU No. 3 MPU No. 4 (D=465mm)	
10	1129 - 1172	48.3 - 46.9	BPU No. 1 MPU No. 3	MPU No. 1
11	1173 - 1174	48.4 - 48.3	BPU No. 1 MPU No. 4 (D=465mm)	MPU No. 1
12	1175 - 1187	49.0 - 48.8	BPU No. 1	MPU No. 3 (Q=0.5)

			MPU No. 1 (Q=0.5)	MPU No. 4
13	1188 - 1434	54.0 - 48.3	BPU No. 1 MPU No. 1 (Q=0.5) MPU No. 3	MPU No. 3 (Q=0.5)
14	1435 - 1435	49.4 - 49.4	BPU No. 1 MPU No. 1 (Q=0.5) MPU No. 4 (D=465mm)	MPU No. 3 (Q=0.5)
15	1436 - 1511	53.2 - 51.4	BPU No. 1 MPU No. 1 (Q=0.5) MPU No. 3	MPU No. 1
16	1512 - 1518	51.9 - 51.8	BPU No. 1 MPU No. 2 MPU No. 3	MPU No. 3 (Q=0.5)
17	1519 - 1519	52.5 - 52.5	BPU No. 1 MPU No. 3 MPU No. 4 (D=465mm)	MPU No. 3 (Q=0.5)
18	1520 - 1599	56.3 - 54.2	BPU No. 1 MPU No. 2 MPU No. 3	MPU No. 1
19	1600 - 1600	55.0 - 55.0	BPU No. 1 MPU No. 2 MPU No. 3	MPU No. 2
20	1601 - 1601	55.2 - 55.2	BPU No. 1 MPU No. 3 MPU No. 4 (D=465mm)	MPU No. 1
21	1602 - 1602	56.0 - 56.0	BPU No. 1 MPU No. 3 MPU No. 4 (D=465mm)	MPU No. 2
22	1603 - 1685	57.0 - 54.8	BPU No. 1 MPU No. 1 (Q=0.5) BPU No. 2	MPU No. 3 (Q=0.5) MPU No. 4
23	1686 - 1688	55.2 - 55.1	BPU No. 1 MPU No. 1 (Q=0.5) MPU No. 3	MPU No. 3 (Q=0.5) MPU No. 4
24	1689 - 1753	58.6 - 56.8	BPU No. 1 MPU No. 1 (Q=0.5) MPU No. 2	MPU No. 1 MPU No. 3 (Q=0.5)
25	1754 - 1757	57.5 - 57.4	BPU No. 1 MPU No. 1 (Q=0.5) MPU No. 3	MPU No. 1 MPU No. 3 (Q=0.5)
26	1758 - 1766	57.7 - 57.5	BPU No. 1 MPU No. 2 MPU No. 3	MPU No. 3 (Q=0.5) MPU No. 4
27	1767 - 1770	59.2 - 59.2	BPU No. 1 MPU No. 3 MPU No. 4 (D=465mm)	MPU No. 3 (Q=0.5) MPU No. 4
28	1771 - 1828	61.1 - 59.4	BPU No. 1 MPU No. 1 (Q=0.5) MPU No. 2	MPU No. 1 MPU No. 2
29	1829 - 1839	59.6 - 59.3	BPU No. 1 MPU No. 2 MPU No. 3	MPU No. 1 MPU No. 3 (Q=0.5)
30	1840 - 1843	60.4 - 60.4	BPU No. 1 MPU No. 2 MPU No. 3	MPU No. 2 MPU No. 3 (Q=0.5)
31	1844 - 1844	61.4 - 61.4	BPU No. 1 MPU No. 3 MPU No. 4 (D=465mm)	MPU No. 1 MPU No. 3 (Q=0.5)
32	1845 - 1848	62.5 - 62.5	BPU No. 1 MPU No. 3 MPU No. 4 (D=465mm)	MPU No. 2 MPU No. 3 (Q=0.5)
33	1849 - 1863	63.9 - 63.5	BPU No. 1 MPU No. 2 MPU No. 3	MPU No. 1 MPU No. 2

Table 6 – Optimal pumping plans at different values of monthly volumes for the Dzhumagaliev – Atasu section for March

Pumping volume, thousand tons	Required modes
0 – 489000	Mode No. 1 with shutdowns
489000 - 738000	a combination of mode No. 1 and mode No. 4
738000 – 1066000	a combination of mode No. 4 and mode No. 13
1066000 - 1304000	a combination of mode No. 13 and mode No. 24
1304000 – 1368000	a combination of mode No. 24 and mode No. 29
1368000 - 1386000	a combination of mode No. 29 and mode No. 33

Thus, for each range of monthly flow rates, the most optimal pump operating modes were determined for the coldest and warmest periods of time for the Dzhumagaliev – Atasu oil pipeline section.

Conclusions

With the use of the control module of optimal oil pumping modes of SmartTranPro SP for the Kalamkas – Karazhanbas and the Dzhumagaliev – Atasu oil pipeline sections:

- dependences of the minimum unit cost of pumping on performance for warm and cold periods were plotted;

- on the basis of the found dependence of the unit cost, optimal pumping plans were calculated for various values of monthly planned volumes for warm and cold periods of time.

Мұнай айдаудың оңтайлы жоспарларын анықтау

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ТҮЙІНДЕМЕ

Бұл мақалада Қазақстанның магистральдық мұнай құбырлары арқылы мұнай айдаудың оңтайлы жоспарларын анықтау нәтижелері келтірілген. Есептеу әдістемесі мұнай шығынына байланысты айдау бірлігінің минималды меншікті құнын анықтауға негізделген. Мұнай айдаудың энергия үнемдеу режимдері станциялардағы сорғы қондырғылары мен жылыту пештерінің оңтайлы жұмыс жағдайларында анықталды. Айдаудың оңтайлы жоспарын анықтау SmartTranPro бағдарламалық пакеті үшін жеке модуль ретінде жүзеге асырылды. Мұнай құбырларының учаскелері арқылы айдалатын мұнай көлемі «ҚазТрансОйл» АҚ ASKUE жүйесінің деректері бойынша анықталды. Анықталған бірлік құнының ағын жылдамдығына тәуелділігі негізінде «Қаламқас – Қаражанбас» және «Жұмағалиев – Атасу» учаскелеріндегі суық (наурыз) және жылы (қыркүйек) уақыт аралығындағы мұнайдың айлық көлеміне айдаудың оңтайлы жоспарлары есептелді. Әрбір шығын диапазоны үшін мұнай айдауға арналған нақты шығындар және құбыр учаскесінің бойында орналасқан мұнай айдау станцияларындағы жұмыс істейтін сорғылардың тізімі көрсетілді.

Түйін сөздер: мұнай құбыры, массалық шығын, оңтайлы айдау жоспары, энергияны үнемдеу режимі, меншікті шығындар.

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Определение планов оптимальной перекачки нефти

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АННОТАЦИЯ

В данной статье приведены результаты определения оптимальных планов перекачки нефти по магистральным нефтепроводам Казахстана. Методика расчета основана на определении минимальной удельной стоимости перекачки в зависимости от расхода нефти. Энергосберегающие режимы перекачки нефти определяются при оптимальных условиях работы насосных агрегатов и печей подогрева на станциях. Определение оптимального плана перекачки реализовано в виде отдельного модуля для программного комплекса SmartTranPro. Объемы перекачиваемой нефти по участкам нефтепроводов были определены по данным системы АСКУЭ АО «КазТрансОйл». На основании найденной зависимости удельной стоимости от расхода были рассчитаны оптимальные планы перекачки для месячных объемов нефти на участках «Каламкас – Каражанбас» и «Джумагалиева – Атасу» для холодного (март) и теплого (сентябрь) периодов времени. Для каждого диапазона расхода указаны удельные затраты на перекачку нефти и перечень работающих насосов на нефтеперекачивающих станциях, расположенных вдоль участка нефтепровода.

Ключевые слова: нефтепровод, массовый расход, оптимальный план перекачки, энергосберегающий режим, удельные затраты.

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[1] Abramzon LS. Optimal'nyye parametry raboty goryachikh truboprovodov [Optimal parameters of operation of hot pipelines]. Neftyanoe khozyaistvo = Oil industry. 1979;2:53-54 (In Russ.).

[2] Maron VI. Gidrodinamika i odnofaznykh i mnogofaznykh potokov v truboprovode [Hydrodynamics and single-phase and multiphase flows in a pipeline]. Moscow: MAKS Press. 2009, 344. (In Russ.).

[3] Agapkin VM, Krivoshein BL, Yufin VA. Teplovyye i gidrodinamicheskiye raschety truboprovodov dlya nefti i nefteproduktov [Thermal and hydrodynamic calculations of pipelines for oil and oil products]. Moscow: Nedra. 1981, 256. (In Russ.).

[4] Yablonsky VS, Novoselov VF, Galeev VV, Zakirov GZ. Proyektirovaniye, ekspluatatsiya i remont nefteproduktoprovodov.

[Design, operation and repair of oil product pipelines]. Moscow: Nedra. 1965, 410. (In Russ.).

[5] Shchepetkov LG. Optimizatsiya plana perekachki mnogonitochnogo nefteprovoda [Optimization of a pumping plan for a multi-line oil pipeline]. Transport i khranenie nefti i nefteproduktov = Transport and storage of oil and petroleum products. 1971;3:15-18. (In Russ).

[6] Tumansky AP. Optimizatsiya rezhimov transportirovki uglevodorodnykh zhidkostey po truboprovodam s promezhutochnymi nasosnymi stantsiyami, oborudovannymi chastotno-reguliruyemym privodom [Optimization of transportation modes of hydrocarbon liquids through pipelines with intermediate pumping stations equipped with a frequency-controlled drive]. Dissertation of the Candidate of Technical Sciences: 25.00.19. Tumanskiy Aleksandr Petrovich. Moscow, 2008. 137 (In Russ).

[7] Gopal VN. Optimizing pipeline operations. Journal of Petroleum Technology. 1980;11(3):2063-2067.

[8] Jokic A, Zavargo Z. Optimization of pipeline network for oil transport. Hungarian Journal of Industrial Chemistry. 2001;29(2):113-118.

[9] Liu EB, Li CJ, Yang LT, Liu S, Wu MC, Wang D. Research on the optimal energy consumption of oil pipeline. Journal of Environmental Biology. 2015;36:703-711.

[10] Wang Y, Liu Y, Zhao J, Wei LX. Energy Consumption Analysis and Comprehensive Optimization in Oil Pipeline System. Advanced Materials Research. 2013;648:251-254.

[11] Wang Y, Tian CH, Yan JC, Huang J. A survey on oil/gas pipeline optimization: Problems, methods and challenges. Proceedings of 2012 IEEE International Conference on Service Operations and Logistics, and Informatics. 2012. 150–155.

[12] Meng ZH, Chen YZ. Optimization analysis of oil transport scheme for long distance pipeline. Oil and Gas Storage and Transportation. 2002. 4.

[13] Wu CC, Yan DF. A two-level hierarchical model for optimizing steady operation of hot oil pipelines. Acta Petrolei Sinica. 1989;10:109-117.

[14] Wu CC, Yan DF. Introduction of HOPOPT software pack for the optimization of thermal oil pipeline operation. Oil and Gas Storage and Transportation. 1992;11(2):5-10.

[15] Li CJ, Wang J, Wu X, Jia WL. Operation optimization of heated oil transportation pipeline. International Conference on Pipelines and Trenchless Technology. 2011. 733–743.

[16] Zhou M, Zhang Y, Jin SJ. Dynamic optimization of heated oil pipeline operation using PSO-DE algorithm. Measurement. 2015;59:344–351.

[17] Zhang Y, Wang B, Huang X. Online Optimization of Heated-Oil Pipeline Operation Based on Neural Network System Identification. Journal of Pipeline Systems Engineering and Practice. 2020. 11(1).

[18] Tugunov PI, Novoselov VF, Korshak AA, Shammazov AM. Tipovyye raschety pri proyektirovanii i ekspluatatsii gazonefteprovodov [Typical calculations for the design and operation of gas and oil pipelines]. Ufa: Design-Polygraphservice. 2002. 658. (In Russ).

[19] Beysembetov IK, Bekibayev TT, Zhapbasbayev UK, Kenzhaliev BK. Upravleniye energosberegayushchimi rezhimami transportirovki neftesmesey [Management of energy-saving modes of transportation of oil blends]. Almaty. 2016. 215. (In Russ).

[20] Bekibayev TT, Zhapbasbayev UK, Ramazanova GI, Minghat AD, Bossinov DZh. Simulation of oil pipeline shutdown and restart modes. Kompleksnoe Ispol'zovanie Mineral'nogo Syr'a = Complex Use of Mineral Resources. 2021;316(1):15-23. https://doi.org/10.31643/2021/6445.02

[21] Certificate of registration of rights to the computer program No. 2691 dated April 8, 2019. Programmnyy kompleks "SmartTranPro" [SmartTranPro software package]. (In Russ.).

[22] Aldyyarov TK, Makhmotov YeS, Didukh AG, Gabsattarova GA, Boranbaeva LYe. Reologiya neftey i neftesmesey transportiruyemykh AO "KazTransOyl" [Rheology of oils and oil blends transported by "KazTransOil" JSC]. Almaty: Dala. 2012. 417. (In Russ).

[23] Zhapbasbayev UK, Ramazanova GI, Bossinov DZh, Kenzhaliyev BK. Flow and heat exchange calculation of waxy oil in the industrial pipeline. Case Studies in Thermal Engineering. 2021. 26 (101007). https://doi.org/10.1016/j.csite.2021.101007