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INVESTIGATING THE EFFECT OF REAGENTS USED IN THE TRANSPORTATION OF HYDROCARBONS

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The use of chemical reagents, such as paraffin inhibitors, viscosity regulators, anti-turbulence, and depressant additives, has recently been shown to significantly impact the rheological properties of oil flow. These additives function by forming asphaltene colloids through adsorption on aggregates, thereby reducing the energy of their interactions. This article describes the development, laboratory testing, and potential application in pipeline transport of the ANA-10 complex-action reagent, which combines the effects of an inhibitor of asphaltene-resin-paraffin deposits and an oil viscosity regulator. One component of the developed reagent is a synthetic carboxylic acid ester, while another group of active components includes imides of synthetic fatty acids, used as anti-wear additives for oils. The cold rod method was used to study the ability of the developed reagents to inhibit paraffin precipitation in oil. Rheological properties were analyzed at a low shear rate of 3.75 s^{-1}, corresponding to the starting loads at oil pumping stations, as well as across a range of shear rates and temperatures typical for oil collection, in-field, and main transportation processes. When the newly developed reagent was applied to a specific section of the oil pipeline without additional supply branches, it reduced pressure losses at the pump by an average of 7% and decreased the frequency of pipe cleaning operations by 2.5 times.

Keywords: reagent, oil, transportation, composition, inhibitor, viscosity, properties.

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Introduction

The increase in the operating costs of in-field and trunk oil pipelines is associated with rising expenses for transport equipment and components used in oil transportation processes. At the same time, opportunities to increase the cost of hydrocarbon transportation are limited. Therefore, cost optimization in this area should involve the introduction of new high-tech technologies, as well as the use of effective domestic alternatives to materials and components. Reducing the deposition of asphalt-resin-paraffin deposits and minimizing pressure losses are among the most costly measures required to maintain the operational efficiency of in-field and trunk oil pipelines. Traditional methods of pipeline cleaning, such as scraping and heating problematic areas, are time-consuming and expensive. Additionally, scrapers often get stuck, disrupting the technological workflow and requiring additional measures for their removal.

Several developers have proposed methods based on electromagnetic and ultrasonic processing of the oil stream using stationary devices. According to refs. [1,2], this approach reduces oil viscosity; however, in practice, the effect of such treatment is short-lived.

It is known that large molecules containing ester groups can regulate oil viscosity, as they form an external lipid layer on paraffin-asphaltene associates, similar to resins [3]. Therefore, one of the components of the reagent being developed is a synthetic carboxylic acid ester, synthesized through the etherification reaction of a tetraatomic alcohol. This process occurs at atmospheric pressure in a single stage at a temperature of 144^{0}C over 6 to 8 hours.

Another group of active components in the reagent under development consists of imides of synthetic fatty acids, which are used as anti-wear additives for oils [4,5]. These components also modify the structure of solid petroleum hydrocarbons at the molecular level, thereby preventing the formation of ASP[1]. Their synthesis is carried out similarly but involves two stages: at temperatures of 144^{0}C and 230^{0}C for 6 hours and 4 hours, respectively.

The conditions for obtaining the initial components are feasible for petrochemical enterprises, allowing the entire production process to be carried out within a single specialized technological installation. Both synthesized products are surfactants by their chemical structure.

Thus, this work focuses on the development, laboratory testing, and potential application in pipeline transport of the ANA-10 complex-action reagent, which combines the effects of an asphaltene-resin-paraffin deposit inhibitor and an oil viscosity regulator.

Experimental, results and discussion

The reagent also contains a solvent that enables dosing in the liquid phase at low temperatures and synergistically enhances the effectiveness of its active components. The selection of the solvent was based on its effect on the rheological properties of the oil and the pour point of the active components within this solvent. According to studies, aromatic hydrocarbons with various methylamine substituents (benzene, toluene, and para-, meta-, and ortho-xylene) exhibit the best ability to disperse (break down) asphaltene associates. Therefore, the solvent selection was conducted using these substances by determining the pour point of the synthesized surfactants in their solutions, as described in refs. [6,7].

It was found that additive solutions in toluene exhibit optimal low-temperature properties, which is likely due to its freezing point (−95^{0}C). The physicochemical properties of the components and the reagent are shown in Table 1.

The use of chemical reagents has recently become an optimal method for influencing the rheological properties of oil streams. These include ASF inhibitors, viscosity regulators, anti-turbulent, and depressor additives. ASF inhibitors and depressor additives interact with asphaltenes and solid petroleum hydrocarbons through adhesion and co-crystallization, preventing their aggregation into large associates. This process reduces the pour point of oils and the intensity of ASF precipitation. Viscosity regulators act similarly by forming asphaltene colloids through adsorption on aggregates, which significantly reduces their interaction energy. Essentially, these substances compensate for the lack of resins in oils [8].

Anti-turbulent additives, however, function differently: linear polymers of high molecular weight migrate to the pipeline walls, creating a liquid layer with an ordered laminar flow regime in their vicinity. This layer minimizes turbulent friction along the walls, producing the effect of a hydraulically smooth pipeline [9].

This article describes the development process, laboratory testing, and potential application of the complex-action reagent ANA-10 in pipeline transport. ANA-10 combines the effects of an asphaltene-resin-paraffin deposit inhibitor and an oil viscosity regulator, formulated using raw materials produced in Azerbaijan.

To optimize the component composition, the method of inductive dielectric studies was employed. This method involves measuring the tangent of the dielectric loss angle of the substance under investigation in a polar solvent. It is an inductive technique for measuring the dielectric parameters of objects, which records the low-frequency dispersion of permittivity and the low-frequency maximum of dielectric losses in the frequency range of 50 kHz in water and its solutions. Since the value of ΔC of the circuit after placing the liquid in the L-cell is determined by the permittivity (ε) of the liquid, the decrease in the quality factor of the circuit should be dependent on its dielectric losses. In this case, the ratio of the change in the active ΔR and the inductive $\omega\Delta L$ resistance of the measuring L-cell determines the tangent of the

Table 1

Physicochemical properties of components and reagent

Substance	Average molar mass, g/mol	Acid number, ml KOH/g	Density at 20^{0}C, kg/m^3	T, ^{0}C	Viscosity,at 20^{0}C, mm^2/s
SZHK Complex Ether	1173	13.9	925	–26	132
Image of the SZHK	952	11	914	–28	118
ANA-10	210	–	419	less than –30	less than –1

[1] Mansoori. G.A. (2009). Paraffin/wax and waxy crude oil. The role of temperature on heavy organics deposition from petroleum fluids. UIC/TRL heavy organics deposition home page. URL: http:www.uic.Edu~mansoori/Wax.and.Waxy.Crude_html.

dielectric loss angle of the liquid:

tgδ=ΔR/ωΔL.

The BI-870 device is designed for determining the dielectric constant of liquids. It measures the inductive dielectric constant of liquid media. Its simple design ensures quick measurements, reliability, and ease of use. The device offers two sensitivity ranges: from 1 to 20 and from 1 to 200. It is suitable for almost any solvents and their mixtures.

The ability of the reagent to reduce intermolecular interaction forces, which are the main component of viscous friction forces, was determined by the magnitude of the extremum of this indicator at a frequency of 50 kHz (tgδ=1.7) [10].

The dependence of the tangent of the dielectric loss angle in solutions of imide/ester surfactants in isopropanol at different volume ratios on the frequency of the electromagnetic field is shown in Fig. 1.

The effect of the obtained reagent on the rheological properties of the oil-water emulsion was studied by comparing the viscosity of the Muradkhanli oil and water emulsion from the Az field (Oil Bush 3, sle. 381c), with a density of 76% by volume, 2.06% by weight, and a density of 985 kg/m^3, both in the presence of the developed reagent at various concentrations and without it. Rheological properties were studied at a constant shear rate of 3.75 s^{-1} using a Brookfield DV-II + Pro rotary viscometer with an operating range of 0.3 to 1031 Pa·s, connected to a CRYO VT-1 cryostat that allows viscosity measurement during cooling. Rheological properties in a wide temperature range (from 70 to −10^{0}C), typical for oil transport processes, were studied using a vibrating viscometer SV-10. The shear rate in this temperature range varied from 590 to 10 s^{-1}.

The ability of the developed reagents to inhibit the deposition of asphaltene-resin-paraffin oil was studied using the cold finger test method.

To test the ANA-10 reagent, oil from the OGED Pirallakhy field was used, a combined sample with sle. 1214 plat. 5, 1342 plat. 8, and 1453 plat. 9, having similar physicochemical properties (Table 2). The inhibitor was injected into the oil at a temperature of 45^{0}C.

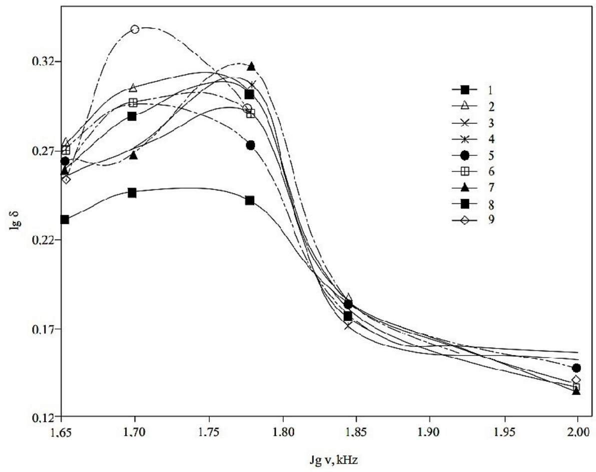

Fig. 1. Dependence of the tangent of the dielectric loss angle in solutions of imide/ester surfactants in isopropanol on the frequency of the electromagnetic field at different volume ratios (vol.%): (1) 10/90; (2) 20/80; (3) 30/70; (4) 40/60; (5) 50/50; (6) 60/40; (7) 70/30; (8) 80/20; and (9) 90/10

The ANA-10 reagent is a 12.5% by weight solution in toluene of a composition of synthesized surfactants. This concentration may vary depending on the application conditions and can reach up to 50% by weight, while maintaining the ability to function at temperatures as low as −30^{0}C without preheating.

The rheological properties were studied at a low shear rate of 3.75 s^{-1}, corresponding to the starting loads on the pumps of the NPS (Fig. 2), as well as across a range of shear rates at temperatures characteristic of the collection processes, in-field, and trunk oil transport (Fig. 3).

The diagram shows that at low shear rates within the studied temperature range, the viscosity decreases by an average of 35%, significantly reducing the starting loads on the pumps. Dynamic viscosity studies during cooling, conducted within a temperature range from 70^{0}C to −10^{0}C (Fig. 3), revealed a 6^{0}C decrease in the oil saturation temperature with paraffins when the developed reagent was used. This reduction lowers the costs associated with heating oil collectors and in-field pipelines during winter transportation.

Table 2

Physicochemical characteristics of borehole oil

Objects	Water content, vol.%	Content, wt.%			ρ_4^{20}, g/cm^3	Viscosity, MPa·s	
		asphaltenes	resins	paraffins Tpl., ^{0}C		20^{0}C	50^{0}C
Platform 5, well 1214	3	4.46	7.64	2.15(58)	0.889	62.50	13.7
Platform 8, well 1342	4	3.24	12.00	2.74 (55)	0.877	38.00	6.4
Platform 9, well 1453	4	3.41	10.9	2.65(53)	0.881	41.00	7.6

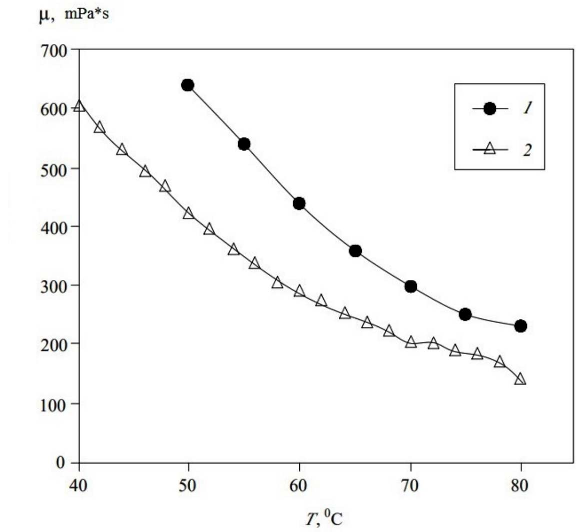

Fig. 2. Temperature dependence of the dynamic viscosity at a shear rate of 3.75 s^{-1} for the Muradkhanli oil emulsion of the field: (1) oil emulsion; (2) ANA-10 oil emulsion at a concentration of 200 g/l

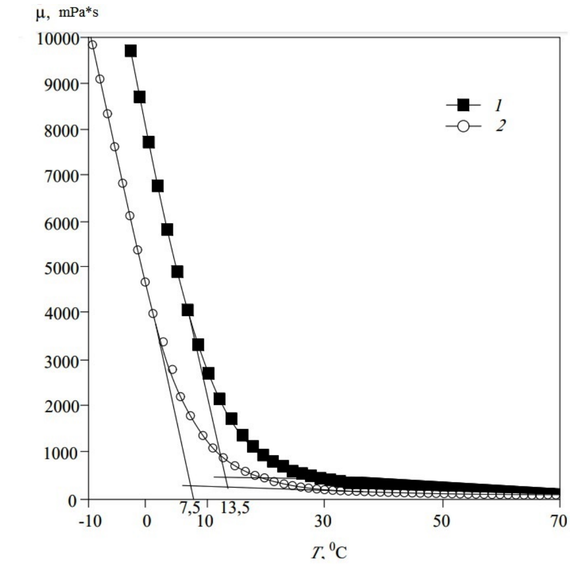

Fig. 3. Temperature dependence of dynamic viscosity for Muradkhanli oil emulsion of the field: (1) oil emulsion; (2) oil emulsion with ANA-10 at a concentration of 100 g/l

Additionally, the average decrease in viscosity of the test sample from the paraffin saturation temperature (7.5°C) to 20°C, conditions typical for in-field oil transport, was found to be 55%.

The study of the ANA-10 reagent's ability to inhibit ASF oil deposition was conducted using the «cold rod» method and compared with results from similar tests on ASF inhibitors produced by other manufacturers (Table 3).

Table 3

Results of determining the degree of inhibition of deposits of the Muradkhanli oil field by the ANA-10 reagent in comparison with analogues

Reagents	Degree of inhibition ASPO, wt.% at different content of inhibitors in oil (mg/l)		
	80	100	200
SHPX-2005	2.1	27.1	61.9
SHPX-7920	43.0	55.9	65.2
EC 5888A	45.4	57.3	63.7
Flexoil CW 288	37.3	50.6	52.1
ANA-10	51.6	54.1	60.7

According to the results (Table 3), the developed reagent effectively inhibits ASF formation in oils at economically justified concentrations of 100–200 g/m^3 and is comparable in efficiency to modern domestic and foreign counterparts. The evaluation of the reagent's applicability and effectiveness in in-field and trunk oil pipelines was performed by calculating frictional pressure losses in the pipeline. It was determined that using the developed reagent on a specific section or along the entire pipeline, in the absence of additional supply branches, reduces pressure losses at the pump by 7%. Additionally, the frequency of pipe cleaning to remove deposits can be reduced by an average of 2.5 times.

Conclusions

1. The developed reagent reduced the dynamic viscosity of oil by 55% in the temperature range typical for oil transportation processes, at a shear rate corresponding to starting loads.

2. Experimental results confirm the effectiveness of the ANA-10 reagent in preventing the formation of asphaltene-resin-paraffin deposits, comparable to industrially produced analogues.

3. The technical and economic feasibility of using the developed complex reagent for well fluid collection and oil pipeline transportation is justified by a 10–15% reduction in operating costs, considering the commercial cost of oil chemical treatment.

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ДОСЛІДЖЕННЯ ВПЛИВУ РЕАГЕНТІВ, ЩО ВИКОРИСТОВУЮТЬСЯ ПРИ ТРАНСПОРТУВАННІ ВУГЛЕВОДНІВ

А.Н. Гурбанов, І.З. Сардарова

Використання хімічних реагентів, таких як інгібітори парафіну, регулятори в'язкості, анти-турбулентні та депресорні добавки, останнім часом показало значний вплив на реологічні властивості нафтопотоку. Ці добавки діють шляхом утворення асфальтенових колоїдів в результаті адсорбції на агрегатах, що значно знижує енергію їх взаємодії. У статті описано процес розробки, лабораторні випробування та потенційне застосування в трубопровідному транспорті багатофункціонального реагенту ANA-10, який поєднує в собі ефекти інгібітора асфальтено-смолисто-парафінових відкладень та регулятора в'язкості нафти. Одним із компонентів розробленого реагенту є ефір синтетичної карбонової кислоти, а іншою групою активних компонентів є іміди синтетичних жирних кислот, які використовуються як протизносні добавки до нафтопродуктів. Здатність розроблених реагентів інгібувати осадження парафінів у нафті досліджували методом холодного стрижня. Реологічні властивості аналізували при низькій швидкості зсуву 3,75 $с^{-1}$, що відповідає пусковим навантаженням на нафтових насосних станціях, а також у діапазоні швидкостей зсуву при температурах, характерних для процесів збору, внутрішньопромислового та магістрального транспортування нафти. Застосування нового реагенту на окремій ділянці нафтопроводу без додаткових гілок живлення дозволило знизити втрати тиску на насосі в середньому на 7% і зменшити частоту очищення трубопроводу в 2,5 рази.

Ключові слова: реагент, нафта, транспортування, композиція, інгібітор, в'язкість, властивості.

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