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ANALYSIS OF TRANSPORTING HIGH-VISCOSITY CRUDE OIL THROUGH PIPELINES

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Annotation. In Uzbekistan, oils are mainly highly resinous and contain many substances that adversely affect their transportation. Thus, the conducted research of local oils allows them to be classified according to the content of resins, asphaltenes and paraffins, the main components reflecting their viscosity. The results of this study were used when choosing the nature and amount of viscosity reducers of local oils before their transportation through pipelines

Keywords: transportation, oil, high viscosity, pipeline, asphaltene, paraffin, resin, solvent, surfactants, fluidity, efficiency index, shear rate.

I. Introduction

The oils extracted in Uzbekistan are primarily high-resin oils and contain numerous substances that negatively affect their transportation. Sulfur compounds significantly influence the viscosity and rheological properties of high-resin oils. Therefore, to transport them through pipelines, linear heating is often used, which significantly increases the cost of transporting these oils.

Additionally, the structural-mechanical properties and viscosity of high-resin oils are greatly affected by solid paraffins and ceresins. The latter are white crystalline masses that are insoluble in water but highly soluble in benzene. Their melting point ranges from 22 to 85°C, while ceresins can reach up to 90°C. All of them dissolve well in oils, forming true molecular solutions. As the melting point decreases, their solubility in oils increases.

Asphalt-resin substances in oils possess specific properties, being highly polar and surface-active compounds with molecular weights ranging from 500 to 1200 and higher. Consequently, as the molecular weight of resins increases, their consistency changes significantly from a viscous, sticky mass to a solid state. This is explained by the presence of oxygen, sulfur, and nitrogen compounds in various proportions within the resins.

II. Methods

The substances most closely related to petroleum resins are high-molecular-weight asphaltenes, which have a molecular weight 2-3 times greater than that of resins. Typically, asphaltenes are solid, amorphous, dark-colored substances that first swell in solvents and then dissolve into a solution.

As seen from the above-mentioned oil components, their influence on viscosity—that is, the rheological properties of oil—can vary significantly. This is due to differences in their concentration, compatibility with other components, and other factors.

Resin-containing crude oils are divided into three categories:

- Low-resin oils, in which the content of asphaltene-resinous substances is less than or equal to 10%;
- Medium-resin oils, where the asphaltene-resin content ranges from 10% to 20%;

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- High-resin oils, in which the content of asphaltene-resinous substances ranges from 20% to 35%.

It is well established that viscosity, along with the pour point, is one of the key parameters determining the flowability of crude oil. Since oil is not a pure chemical compound but a complex mixture, gradual aggregative transitions occur with changes in temperature. The transition from a liquid to a solid state is preceded by gelation, while the transition from solid to liquid is characterized by melting (softening). In this process, the color of crude oil mainly depends on the presence of asphaltene-resinous compounds, as other components tend to be more colorless.

From the above, it can be concluded that crude oil is a multicomponent liquid that undergoes temperature-dependent structural changes and exhibits non-Newtonian behavior, which significantly affects its transportation through pipelines.

III. Results

Among the main challenges in transporting resinous crude oils is the phase transformation of components such as asphaltenes, paraffins, and similar substances. These compounds tend to adhere to the inner walls of pipelines, reducing the cross-sectional area available for flow and increasing the internal pressure. This elevated pressure may result in pipeline seam rupture, emergency shutdown of power supply to pumps, and in some cases, even engine failure or combustion [1].

Given these potential risks, we conducted a study on the composition of crude oils from industrially significant oil fields in Uzbekistan, with the results presented in Table 1.

Oil fields	Content of Components in Crude Oil, %				
	Resins	Asphaltenes	Paraffins	Sulfur	Coke
Low-resin crude oils oils (AR ≤ 10%):					
Kruk	9,5	0,3	8,5	1,3	3,75
Andijan	8,8	1,7	13,5	0,3	4,45
Southern Alamushuk	9,7	0,8	22	0,2	3,10
Nothern O'rtabulak	9,9	2,5	6,1	3,5	5,25
Ko'kdumalak	5,4	3,1	4,3	2,3	7,80
Medium-resin crude oils (10<AS≤20%):					
Varik	14,5	1,15	13,4	0,3	3,55
Nothern Sox	13,9	0,85	5,1	0,2	5,44
Hankiz	18,2	2,54	12,5	0,4	6,13
High-resin crude oils (20<AS≤35%):					
Koshtar	24,5	5,1	6,5	9,1	5,65
Lyarmikor	28,4	10,2	3,1	4,3	3,53
Amudarya	29,8	5,4	7,2	10,1	9,14
Kokayti	31,5	9,3	2,9	5,2	5,25
Mirshadi	35,4	9,5	8,4	4,8	13,6

As can be seen from Table 1, the content of each component in low-resin, medium-resin, and high-resin crude oils does not exhibit a clear correlation with other compounds. This can be explained by the differences in conditions, time, and location of their formation, which necessitates an individual

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approach when developing and applying surfactants (SAA) to ensure their efficient transportation through pipelines.

The role of paraffins and ceresins in forming the rheological properties of crude oil is more complex compared to other components, as they are the first to undergo phase transitions. The formation of paraffin and ceresin crystals significantly reduces pipeline conductivity. Therefore, known crude oils are classified as low-paraffinic, paraffinic, and highly paraffinic [2,3].

Taking this into account, we grouped the known local crude oils into the three aforementioned categories.

In doing so, we recorded the data by analyzing their densities and pour points using standardized methods [4,5]. The results obtained are presented in Table 2.

Table 2 Changes in density and pour point depending on the paraffin content in local crude oils

Oil field	Paraffin content %	Paraffin indicators	
		Density, kg/m^3	Temperature point ^{0}C
"Low-paraffin(P≤5%) crude oils"			
Kokayti	2,9	956	+16
Lyalmikor	3,1	960	+17
Nothern Sox	5,1	851	+7
Kukdumaloq (control)	4,3	871	-11
Paraffinic (5<P≤10%) oils:			
Kruk	8,5	871	-20
Nothern Urtabuloq	6,1	880	-19
Koshtar	6,5	940	+27
Amudarya	7,2	992	+26
Mirshadi	8,4	958	+6
High-paraffinic (P>10) oils:			
Andijan	13,5	860	+9
Southern Almashik	22	851	+8
Varik	13,4	873	+11
Xanqiz	12,5	896	+18

From Table 2, it can be seen that as the density of local crude oils increases, their pour point temperature also rises. In this case, the role of paraffin is minimal, especially in highly resinous oils. Notably, highly paraffinic oils are mainly produced in the Fergana Valley, while paraffinic oils are found predominantly in the Surkhandarya region. The obtained data make it possible to determine the necessity of increasing the temperature and using depressants during their transportation through pipelines.

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It is well known that viscosity, along with density and pour point, is one of the main parameters characterizing the flowability of oil. Based on flow properties, oils are classified into the following groups:

- **Light oil** — containing more than 40% gasoline fractions with low paraffin and resin content;
- **Paraffinic oil** — characterized by a high pour point (5–20°C and above);
- **Resinous oil** — characterized by high viscosity.

For the first group, pipeline transportation does not present any challenges. However, for the second and third groups, special methods must be used to pump highly viscous oils [6,7].

There is also another method of classifying oils according to the following indicator: , with the values for local crude oils presented in Table 3.

Table 3 Types of Local Crude Oils and Their Values

Oil fields	Values $\frac{a+c}{П}$	Type of oil
Southern Almashik	0,4773	Mixed
Andijan	0,7778	Mixed
Varik	1,1679	Mixed
Xankiz	1,6592	Mixed
Kruk	1,1529	Mixed
Mirshadi	5,3452	High-resin
Amudarya	4,8888	High-resin
Koshtar	4,5539	resinous
Nothern Ortabuloq	2,0328	resinous
Nothern Sox	2,8922	resinous
Lyalmikor	12,4516	High-resin
Kokayti	14,0690	High-resin
Kokdumalak (control)	1,9767	Mixed

From Table 3, it can be seen that the low-asphaltene and resinous oils of Southern Alamyshik, Andijan, Varyk, Khankyza, Kruk, and Mingbulak (control samples) are classified as mixed types, since their values fall within the range of 0.91–1.400.

IV. Discussions

The oils of the Koshtar, Northern Urtabulak, and Northern Sokh fields are considered resinous, as their values lie within the range of 2.79–3.888, while the oils from the Mirshodi, Amudarya, Lyalmikor, and Kokayty fields are classified as highly resinous, since their values exceed 4.774.

As can be seen, there are discrepancies between the considered methods of oil classification, which affect the determination of oil types. This is due to the fact that the first method does not take into account the asphaltene content when identifying oil types and relies solely on the resin content analysis, which, in our opinion, is not sufficiently objective. Thus, the conducted research on local oils has made it possible to classify them based on the content of resins, asphaltenes, and paraffins — the main components that determine their viscosity.

V. Conclusions

The results of this study can be used to select the nature and quantity of viscosity reducers for local oils prior to their transportation through pipelines. Moreover, in terms of reliability, the second method of classifying local oils is considered more objective than the first one, which is based only on laboratory analysis of resin content for each individual oil field.

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