

Influence of Structure Forming Components on The Viscosity of Oils

AL-Obaidi SH, Guliaeva NI, Smirnov VI

Abstract— In the oil industry almost all flow models have viscosity as an intrinsic variable. Many flow behaviours will be affected by the oil viscosity. In this work model oil systems were used to study the influence of paraffin wax and asphaltenes on the viscosity of oils. In these systems the content of paraffin wax varied in the range of 3.2–8%, and asphaltenes in the range of 1.2–5.2%. It was found that the viscosity of light oils changes slightly with increasing the content of asphaltenes or paraffin wax. It was also found that the viscosity of heavy oils increases with asphaltenes content growth and decreases almost twice with the increase of paraffin wax content.

Index Terms— Oil viscosity, Asphaltenes, Paraffin wax, FTIR, GLC, Alkane hydrocarbons, Structuring components.

1 INTRODUCTION

During production, the proportion of asphaltenes and high-molecular paraffin hydrocarbons in the reservoir oil gradually increases as a result of the preferred flow of low-molecular nonpolar components through the reservoir [1 , 2 , 3]. Asphaltenes and hard paraffin wax are structure-forming components of the dispersed oil system [4 , 5]. With an increase in their content in oils, viscous flow anomalies increase; this makes it difficult to extract them from productive layers, as well as complicates the transportation of the extracted products and technological processes of their processing. Associative interactions of oil components also contribute to the formation of highly stable oil-water emulsions [6 , 7 , 8].

Therefore, in this work, we studied the effect of increasing the content of paraffin wax and asphaltenes on the viscosity of oils. Model oil systems were used, in which the content of paraffin wax and asphaltenes was varied. We assumed that if the viscosity of the oil system increases with the addition of asphaltenes or paraffins, this will indicate their structuring effect. Conversely, a decrease in the viscosity of the system will result from the dispersing effect of these components. The oils are characterized by the data of the component composition, the structure-group composition of the components according to the data of Fourier-infrared spectroscopy (FTIR), and individual composition of alkane hydrocarbons according to the data of Gas-liquid chromatography (GLC) [9 , 10 , 11]. To assess the structuring of oils and oil systems, their viscosity was determined by the method of viscometers.

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2 RESEARCH OBJECTS

Two oils with different physical and chemical characteristics were selected. The Abdrakhmanov area oil sample from well 3297 from Carboniferous deposits is designated as oil 1, and the Sarmanov area oil sample from well 113 from Devonian deposits is designated as oil 2. The characteristics of studied oils are presented in table. 1.

2.1 Component Composition of Oils

To study the compositional composition, low-boiling hydrocarbons were removed from crude oils by distillation at 200 ° C [12 , 13 , 14]. Then, asphaltenes were separated from oil residues by precipitation with petroleum ether at 40–70 ° C. The remaining maltenic part of these oils is separated by eluent adsorption chromatography on silica gel into oil hydrocarbons, benzene and alcohol-benzene resins. Paraffin wax are extracted from oily hydrocarbons by freezing using an acetone – benzene solvent system [15 , 16 , 17].

Table 1
Composition and properties of oils

Indicators	Crude oil 1	Crude oil 2
Density, g /cm ³	0,8972	0,8764
Kinematic viscosity, mm ² /s	77,4	20,2
<u>Content, % wt. :</u>		
Sulfur	2,4	1,6
Paraffin wax components:	3,2	5,0
Hydrocarbons fraction at 200°C	19,5	20,3
Oil hydrocarbons	43,7	53,7
Benzene resins	22,3	12,9
alcohol-benzene resins	7,9	6,9
asphaltenes	3,4	1,2

3 PREPARATION OF MODEL OIL SYSTEMS

Each oil system was prepared separately. Crushed asphaltenes or paraffins isolated from the corresponding oils were added to a sample of the original oil in a certain amount. The temperature dependence of the viscosity of oil 1, which has a high content of asphaltenes resins, in contrast to oil 2, does not fit into the framework of a smoothly changing function (Fig. 1). At a temperature of 30-40°C there is an inflection, which is caused by the restructuring of the dispersed oil system 1 – its partial destruction. Therefore, the oil systems were prepared at 50°C for 2 hours in a reflux flask with stirring to facilitate the formation of a new dispersed structure. To complete its formation, the oil systems were kept for 24 hours at room temperature.

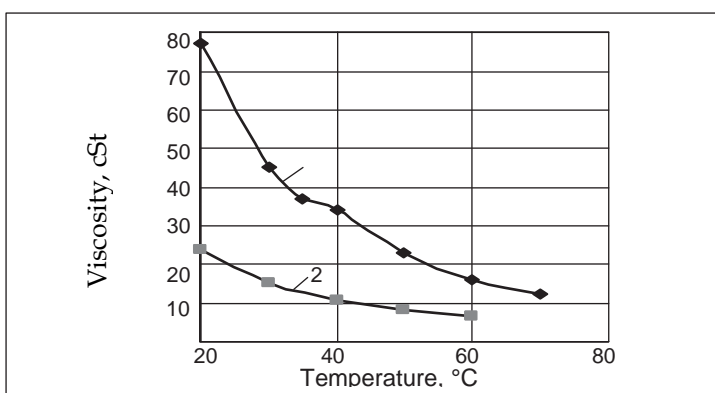


Fig.1 Dependence of oil viscosity 1 and 2 on temperature

3.1 Structural and group composition of oil components

The spectra of the components were obtained by a Perkin-Elmer "Spectrum One" FTIR spectrometer using demountable cells with sodium chloride windows [18 , 19 , 20]. The content of structural groups is calculated as the ratio of the optical density values in the maximum of the characteristic absorption bands:

1740 cm^{-1} C=O groups in the esters,

1710 cm^{-1} C=O groups in acid,

1380 cm^{-1} CH₃ groups,

1030 cm^{-1} S=O groups,

720 cm^{-1} nCH₂ groups in paraffinic structures with $n \geq 4$ and

the optical density of the reference absorption band of 1600 cm^{-1} aromatic C=C bonds.

3.2 Composition of alkane hydrocarbons

Chromatograms of oil alkane hydrocarbons were obtained using a Perkin Elmer AutoSystem XL gas-liquid chromatography. Individual alkanes were calculated using the method of internal normalization [21 , 22 , 23].

4 RESULTS AND DISCUSSION

4.1 Study of physical and chemical properties of oils, their composition and structure of components

Oil 1 from the Carboniferous deposits differs from oil 2 from the Devonian deposits (Table 1) by higher values of density, viscosity and sulphur content. According to the component composition in crude oil 1, the proportion of paraffin wax and oily components is lower. It contains more benzene and alcohol-benzene resins, as well as asphaltenes.

According to the data of the FTIR spectroscopy method, the components extracted from oils 1 and 2 are most different in structure from benzene resins (table 2).

Table 2
Structural and group composition of components

Oil sample	Content of structural groups, RU					
	CH ₂	CH ₃	Aliphaticity	SO	C=O Acids	C=O Ethers
Oily hydrocarbons						
Oil 1	1,9	5,9	7,8	-	-	-
Oil 2	2,0	5,8	7,8	-	-	-
Benzene resins						
Oil 1	0,7	4,0	4,7	0,8	0,2	-
Oil 2	0,6	2,3	2,9	0,7	0,3	-
Alcohol-benzene resins						
Oil 1	0,2	1,8	2,0	1,2	0,7	1,1
Oil 2	0,2	1,8	2,0	1,4	0,8	1,0
Asphaltenes						
Oil 1	0,1	1,5	1,6	0,8	0,4	0,5
Oil 2	0,1	1,3	1,4	0,6	0,3	0,6

Benzene resins of oil 1 contain more paraffin substituents in the polycyclic aromatic core compared to these components of oil 2. The content of sulfoxide substituents and carbonyl groups in carboxylic substituents in benzene resins of both oils is similar.

For oily hydrocarbons, along with the structural group composition, the distribution of alkanes of normal and isoprenoid structure was determined. The molecular weight distribution of n-alkanes in oils is close. Nevertheless, oil 1 has a higher total content of n-alkanes than oil 2 due to heavy homologues (table 3).

Table 3
Content of alkane fractions, %

Alkane	Oil 1	Oil 2
$n(C_{12} - C_{20})$	52,6	54,1
$n(C_{21} - C_{33})$	26,2	22,2
$\sum nP$	78,8	76,3
$i(C_{14} - C_{18})$	13,5	15,2
$i(C_{19} - C_{20})$	7,7	8,5
$\sum iP$	21,2	23,7

In the paraffin wax extracted from oil 1, the content of high-molecular homologues of n alkanes is also higher than in the paraffin wax from oil 2 (Fig. 2).

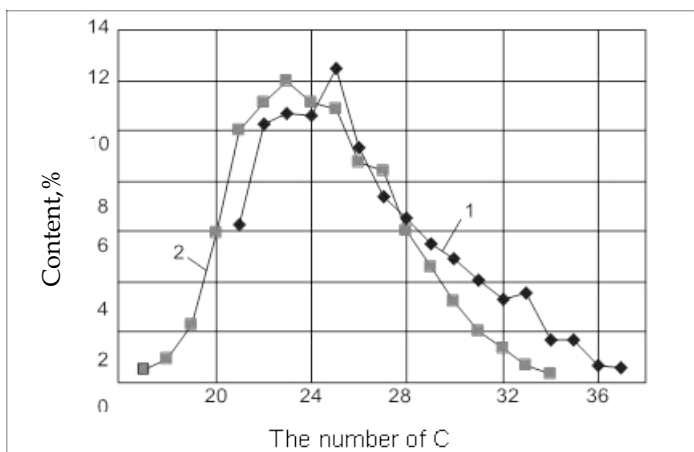


Fig. 2 Distribution of n-alkanes in paraffin wax from oil 1 and oil 2

Thus, it is shown that the studied oils of the Devonian and Carboniferous deposits differ significantly in composition and properties. It can be assumed that oil 1 from Carboniferous deposits and oil systems prepared on its basis with the addition of asphaltenes and paraffins will be more structured than, respectively, oil 2 from Devonian deposits and oil systems based on it.

4.2 Study of the viscosity of oils and oil systems

The content of structuring components in oil systems-asphaltenes or paraffin wax-is shown in Table 4.

Table 4
The content of asphaltenes and paraffin wax in crude oil and oil systems

Oil sample	Mass content, %			
	Asphaltenes			
Oil 1	3,4	4,0	4,6	5,2
Oil 2	1,2	1,8	2,4	3,0
	Paraffin wax			
Oil 1	3,2	4,0	5,0	6,0
Oil 2	5,0	6,0	7,0	8,0

To assess their structuring effect, the dependence of the viscosity of oil systems on the content of additives was studied. An increase in the asphaltene content has a different effect on the viscosity of oils (Fig. 3). If the viscosity of oil 1 increases with an increase in the asphaltene content, then the increase in the asphaltene content does not affect the viscosity of oil 2.

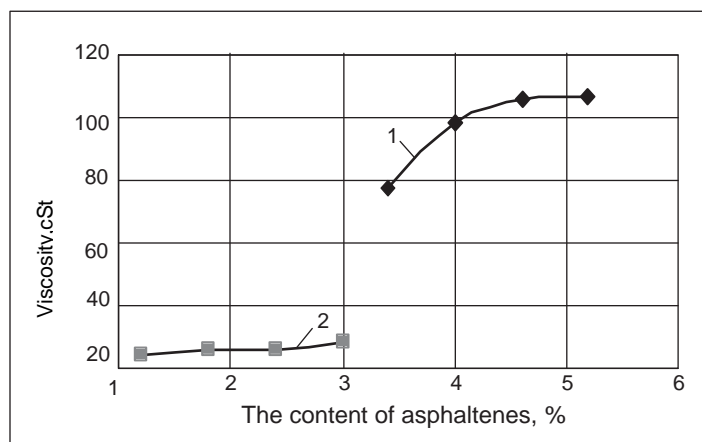


Fig. 3 dependence of the viscosity of oil systems based on oil 1 and oil 2 on the content of asphaltenes at 20°C

The viscosity of the oil system based on oil 2 with an asphaltene content of 3% is significantly lower than that of oil 1 with an initial asphaltene content of 3.4%. This is quite explainable by the difference in the ratio of the content of resinous-asphaltene components and hydrocarbons in oil systems, which reflects the proportion of complex structural units in the dispersion medium. This share in oil 2 and oil systems (based on this oil) is 0.27-0.29, and in oil 1 and oil systems (based on this oil) is 0.51-0.55.

The viscosity of oil 2 at 20°C practically does not change from the introduction of paraffin wax (Fig. 4).

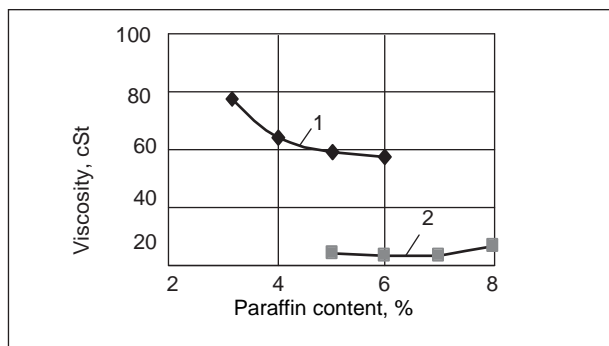


Fig. 4 Dependence of the viscosity of oil systems based on oil 1 and based on oil 2 on the content of paraffin wax at 20 ° C

With an increase in the content of paraffin wax in oil 1, a decrease in viscosity is observed, which indicates a change in its dispersed state. In accordance with the data obtained, the accumulation of paraffin wax in reservoir oil 1 will not, to some extent, degrade its viscosity. The observed decrease in viscosity when paraffin waxes are introduced into oil 1 requires an adequate explanation.

4 CONCLUSION

To study the effect of paraffin wax and asphaltenes on oil viscosity, model oil systems were used in which the content of paraffin wax varied in the range of 3.2–8%, and asphaltenes – 1.2–5.2%.

It is established that the viscosity of oils with an increase in the content of paraffin wax or asphaltenes depends on the composition of the oil. In the studied intervals of paraffin wax and asphaltene content, the viscosity of light oil changes slightly. As the asphaltene content increases, the viscosity of heavy oil increases.

Contrary to existing ideas about the negative impact on the oil viscosity of the accumulation of high-molecular paraffin as a result of lagging behind the fluid flow in the reservoir, with an increase in the content of solid paraffin (almost twice), the viscosity of heavy oil decreases.

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