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Possibility of Obtaining Lubricant Base Oil from Talakan Crude Oil Suitable for Exploitation in Extremely Cold Conditions in the Republic of Sakha (Yakutia)

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Abstract – This paper addresses the problems of using anti-freeze lubricants for different machines that must function at extremely low temperatures during winter operation in the Republic of Sakha (Yakutia). We discuss the possibility of obtaining anti-freeze base oils from Talakan crude oil, an area with major oil and gas deposits of the Republic of Sakha, and also provide the trade and technological classification of Talakan crude oil. We propose two different schemes for processing Talakan crude oil: the fuel scheme (obtaining light and heavy fractions as a fuel oil) and the base oil scheme (obtaining light fractions and base oils). We investigate the influence of pour point depressants on alkyl-methacrylate base on the low-temperature properties of the fractions obtained from Talakan crude oil and Korean base oils, and establish the optimal concentration of pour point depressants. We compare the properties of these fractions with the low-temperature properties of Korean base oils and find that the commercial oil "Ravenol 0W–40" provides optimistic results. We obtain oil with a pour point of minus 50°C and a viscosity index greater than 100. The Design of Experiment was used to establish the optimum composition of the pour point depressants and the base oil S-8 to obtain lubricant oil with a kinematic viscosity of 17 cSt, viscosity index of 208, and a pour point of minus 64°C.

Keywords – talakan, anti-freeze, viscosity index, base oil, pour point

Nomenclature

AP : Aniline Point
BP : Boiling Point
FP : Flash Point
KV : Kinematic Viscosity
PP : Pour Point
PPD : Pour Point Depressant
SG : Specific Gravity
TAN : Total Acid Number
VI : Viscosity Index

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1. Introduction

At present, the Republic of Sakha faces the task of developing the oil refining industry for production of high-quality motor fuels, lubricants, and raw materials for the chemical industry to develop its national economy [1, 2].

Creating anti-freeze lubricants from local raw materials is an important task, since the use of these lubricants would help resolve the problem of improving the reliability and durability of machines and mechanical devices in the extremely cold climates of the Republic of Sakha [3]. This republic needs to develop targeted technologies that are adapted to the chemical composition of Sakha crude oils for producing anti-freeze lubricants that are efficient at temperatures as low as -60°C.

Talakan oil and gas deposits were discovered in the

Lensky region in 1984, and they are now the largest deposits in the Republic of Sakha (Yakutia). The deposit, which is 60 by 120 km in size, lies on the Talakan uplift in the most elevated domal part of the Nepa-Botuobiya Anteclise [4]. Oil from the Talakan field (in combination with other oils from Eastern Siberia) is served on the Eastern Siberia–Pacific Ocean (ESPO) pipeline [5], and is then exported from the port of Kozmino in the Asia-Pacific Region and the United States under the new brand, ESPO [6].

In 1967, technological classification of crude oil was introduced in Russia [7]. The classification of oils based on their technological features allows us to take the physicochemical properties of crude oil and its fractions into account when determining the version of the processing flow sheet to be used. Crude is divided into classes (class 1 crude is called "Low-sulfur crude," class 2 is called "Sulfur crude," and class 3 is called "Sour crude") based on the sulfur content of the crude, gasoline, jet, and diesel fuel. The classification also includes types based on the output fractions up to 350°C, groups based on the potential base oil content, subgroups based on the viscosity index of the base oils, and sorts (1: Low-wax, 2: Waxy, 3: Highly waxy) based on the content of paraffin wax in wt.% (Table 1).

If distillate fuels from sour crude oil contain sulfur in relatively low quantities and the sulfur content meets the requirements for fuels of class 3 (sour crude), even if the sulfur content of the oil is more than 2%, this oil should be categorized as class 2. If diesel oil can only be obtained after dewaxing, the crude should be classified as sort 3. Conversely, if diesel fuel produced from the crude contains more than 6 wt.% paraffin but dewaxing is not required, this oil is categorized as sort 2 [7].

The crude oil code is its technological passport and determines the processing direction (for fuel or for base oil), the processes to which it is subjected (desulfurization, dewaxing), and the range of possible end products.

In 1921, the American Petroleum Institute developed a unit of measurement for the density of oil, termed API Gravity, which is presently used. The API Gravity at a temperature of 15.6°C (60°F) and the Specific Gravity (SG) measured at 15.6°C (60°F) are clearly linked via arithmetic equation (1) and can be readily interconverted:

$$\text{API Gravity} = 141.5/\text{SG} - 131.5 \quad (1)$$

Crude oil with an API Gravity above 31.1° API is called "light". Crude with an API Gravity between 22.3-31.1° API is called "medium", and oil with an API Gravity below 22.3° API is called "heavy" [8]. "Light" crude oil with 40-45° API Gravity is highly valued, because a high yield of gasoline, jet, and diesel fuel can be obtained from it.

2. Experimental

Base oil fractions were obtained by using the Russian Government Standard method, GOST 11011-85 [9], by rectification on an ARN-2 apparatus from Company Chromatec [10] using boiling range temperatures of 300-350, 350-400, 400-450, and 450-500°C.

At the Buhmwoo Institute of Technology (BIT), vacuum distillation was performed to obtain two fractions: 350-377°C and 378-400°C. Furthermore, to reduce the pour points, the dewaxing process was conducted with a mixture of MEK:toluene (60:40 vol.%) in an oil and dewaxing mixture with a component ratio of 1:1.8 by means of freezing at -50°C. The physical properties of the obtained fractions of the base oils from the Talakan crude and base oils of Korean origin, Yubase-3, Yubase-4 (Group III base oils, Company SK-Lubricant) [11], and S-8 (Company S-Oil) [12], were measured using ASTM (American Society for Testing and Materials) methods.

3. Results and Consideration

Table 2 shows the physical characteristics of Talakan crude oil. By comparing the data in Table 3 with that in Table 1, it can be seen that the code for the technological classification of Talakan crude oil is 1.2.1.2.1. This crude oil is Class 1 because the light fraction has a low content of sulfur that complies with the require-

Table 1. Technological classification of crude in Russia [7]

Class	Content of Sulfur, wt.%				Type	Fraction to 350℃, wt.%	Group	Base oil content, wt.%		Subgroup	VI of Base oil	Sort	Content of wax in crude, wt.%	De-waxing	
	In crude	BP - 180℃	120 - 240℃	240 - 350℃				In crude	In fuel oil					Required	Not required
1	< 0.50	< 0.10	< 0.10	< 0.20	1	> 55.0	1	> 25.0	> 45.0	1	> 95.0	1	< 1.50	obtaining jet and diesel fuels, distillate oils	-
							2	15.0 – 24.9	< 45.0	2	90.0 – 95.0				
2	0.51 – 2.00	< 0.10	< 0.25	< 1.00	2	45.0 – 54.9	3	15.0 – 24.9	30 - 44.9	3	85.0 – 89.9	2	1.51 – 6.00	obtaining jet and diesel fuels	obtaining winter diesel fuel and distillate base oils
3	> 2.00	> 0.10	> 0.25	> 1.00	3	< 45.0	4	< 15.0	< 30	4	< 85	3	> 6.00	-	obtaining jet and diesel fuels, distillate base oil

Table 2. Physical characteristics and hydrocarbon composition of Talakan crude oil

Parameters	Values
SG@60/60^{0}F	0.8481
KV@20°C, cSt	17.68
VI	90
Content of paraffin, wt.% in crude	0.65
Sulfur content, wt.% in crude	0.53
Fractional composition, %vol:	
BP, °C	60
Output fractions:	
Up to 200°C	20.0
200-350°C	25.0
350-500°C	29.0
Residue > 500°C	26.0
Component composition, wt%:	
Oils	84.6
Benzene resins	8.8
Alcohol-benzene resins	4.8
Total resins	13.6
Asphaltenes	1.8
Hydrocarbon composition of crude, total wt.%:	
Methane-naphthenic	73.2
Naphthenic-aromatic	26.8

ments for Class 1. Based on this code, Talakan crude oil is "sweet crude oil" with an average grade of light and dark factions; it has a high potential output of base oils (fuel oil) with a good viscosity index and low wax content. Therefore, Talakan crude oil can be processed via two schemes: the fuel scheme (obtaining light fractions and heavy fractions as fuel oil) [13] or the base oil scheme (obtaining light fractions and base oils). The hydrocarbon composition of Talakan crude is methane-naphthenic.

Table 3 shows the physicochemical properties of oil fractions from Talakan crude and Korean base oils. The base oil fractions from Talakan crude oil are characterized by lower Viscosity Index values and higher TAN and Aniline Point (aromatic content) values. This is not surprising, because the base oil fractions from Talakan crude oil are not subjected to the processes of hydrocracking and hydrotreatment. Due to the low sulfur content of Talakan crude, its Copper Corrosion test value is 1A.

In order to improve the low temperature properties of Talakan base oils and Yubase-4, pour point depressants (PPDs) based on polymethacrylate with different molecular weights were used as additives; these are

Table 3. Physicochemical properties of base oil fractions from Talakan crude and Korean base oils

Parameters	ASTM	Yubase-3	Yubase-4	S-8	Fraction 350-377°C	Fraction 378-400°C
SG@ 60/60^{0}F	D 1298	0.829	0.834	0.872	0.874	0.888
KV@40°C, cSt	D 445	12.43	19.50	8.186	11.57	24.16
KV@100°C, cSt	D 445	3.12	4.22	2.244	2.797	4.228
VI	D 2270	112	122	72	75	59
PP, °C	D 97	-25	-12.5	-40	-17.5	-15
FP, °C	D 92	204	230	158	182	210
AP	D 611	100.7	105.7	84.5	74	77
TAN, KOH mg/g	D 664	0.012	< 0.01	< 0.01	0.086	0.145
Copper Corrosion, 100°C, 3 h	D130	1B	1B	1A	1A	1a
Hydrocarbon composition:	D 2140					
Aromatic		-	-	1.6	15.4	16.0
Naphthenic		-	-	39.4	23.7	25.1
Paraffinic		-	-	59.0	60.9	58.9

Table 4. The influence of depressant additive amount on pour point and Viscosity Index of base oils

Base oil and amount of PPD	Characteristics			
	KV@40℃, cSt	KV@100℃, cSt	VI	PP, ℃
Yubase-4 + 1% L PPD	20.65	4.664	150	-47.5
Yubase-4 + 1% M PPD	20.81	4.518	134	-45
Yubase4 + 1% L PPD + 1% M PPD	21.96	4.943	158	-47.5
Yubase-4 + 0,5% H PPD	19.4	4.372	139	-42.5
Yubase-4 + 2% L PPD	22.53	5.080	163	-47.5
Yubase-4 + 2% M PPD	21.81	4.805	147	-37.5
Yubase-4 + 3,85% L PPD	28.26	5.972	164	-37.5
Fraction 350-377℃ + 1% L PPD + 1% M PPD	14.51	3.417	110	-50
Fraction 378-400℃ + 1% L PPD + 1% M PPD	29.40	5.160	107	-42.5
Ravenol SSL 0W–40	84.97	14.480	178	-52.5

conventionally termed L PPD (Low), M PPD (Medium), and H PPD (High). The additives were dissolved in the base oil at 50°C in quantities ranging from 0.5 to 4.0% by weight. Their pour points and kinematic viscosity at 40°C and 100°C were then determined, followed by determination of the viscosity index. The influence of the additives on the properties of the Talakan base oil and Yubase-4 is summarized in Table 4.

The data in Table 4 show that addition of the pour point depressant in an amount greater than 1 wt.% did not lead to further reduction of the pour point, but when we added two different brands of additives, L PPD and M PPD, a reduction in the pour point and a maximum increase in the Viscosity Index were observed.

Thus, we have established the following optimal amount of depressant to be added to the base oil: 1 wt.% of L PPD and 1 wt.% of M PPD.

The established optimum combination of depressants was added to the Talakan base oils. The resulting viscosity-temperature properties are also summarized in Table 4. For comparative purposes, the viscosity-temperature properties of the fully synthetic engine oil Ravenol SSL 0W–40 are also presented in Table 4.

Thus, due to the high pour point of Talakan base oil (only -17°C) the addition of the pour point depressant additives did not lead to a reduction of the pour point below -50°C. However, for anti-freeze lubricants that are efficient at temperatures as low as -60°C, the pour

Table 5. Design of experiment for maximum depression of pour point of the base oil S-8 as a function of content of pour point depressant additives

No.	Content of PPDs in S-8, wt.%			
	L PPD	M PPD	H PPD	S-8
1	5.00	0	0	95.00
2	1.07	3.57	1.07	94.29
3	1.07	1.07	1.07	96.79
4	3.57	3.57	1.07	91.79
5	3.57	1.07	3.57	91.79
6	0	5.00	0	95.00
7	3.57	1.07	1.07	94.29
8	1.07	1.07	3.57	94.29
9	0	5.00	5.00	90.00
10	5.00	5.00	0	90.00
11	5.00	0	5.00	90.00
12	1.07	3.57	3.57	91.79
13	2.14	2.14	2.14	93.57
14	0	0	0	100
15	0	0	5.00	95.00

Table 6. Physical characteristics of the samples

No.	PP, °C	KV@40°C, cSt	KV@100°C, cSt	VI
1	-60.0	13.97	3.962	199
2	-57.5	13.41	3.608	163
3	-62.0	11.10	3.007	131
4	-52.5	17.23	4.620	203
5	-60.0	16.76	4.546	205
6	-55.0	12.47	3.317	143
7	-60.0	14.47	3.928	181
8	-62.5	12.96	3.536	164
9	-57.5	17.15	4.580	201
10	-47.5	19.96	5.441	234
11	-60.0	19.50	5.291	229
12	-57.5	15.76	4.229	189
13	-59.5	14.35	3.889	179
14	-55.0	8.328	2.259	70
15	-55.0	11.29	3.200	160

point must be at least -60°C.

To obtain oil with a pour point below -60°C as a base oil, the S-8 production of Company S-Oil with the lowest pour point was used.

To determine the composition and concentration of additives to achieve the greatest depression, the program Minitab was used to design an experiment based on the maximum content of a mixture of three different additives of up to 10 wt.% in the base oil. Fifteen samples were prepared, as shown in Table 5.

For each sample, the pour point, Kinematic Viscosity at 40°C and 100°C, and the Viscosity Index were determined. The corresponding data are presented in Table 6.

Using the experimental means of the factor analysis in Minitab (data from Table 6), we constructed a mathematical model based on the optimal ratio of depressant additives (5.0% L PPD and 2.13% H PPD) for oil with a predicted pour point equal to -75°C. Unfortunately, due to unavailability of equipment for measuring the pour point at such a low temperature, we could not perform this test. Additionally, the ratio of additives for oil with a predicted pour point of below -62.5°C, a Viscosity Index greater than 200, and an expected viscosity at 40°C equal to 17 cSt was calculated. Samples were prepared in accordance with the calculated data, the measured viscosity at 40 and 100°C, and the Viscosity Index. The obtained kinematic viscosity and Viscosity Index (VI data) correlated well with the predicted results. However, the pour point of samples 16 and 17 were only -62.5°C. This was perhaps due to the low temperature limit of the device for determining the pour point (Table 7).

Table 7. Physical characteristics of the oil samples with predicted pour points

	Calculated content of PPDs in S-8, wt. %			
No.	L PPD	M PPD	H PPD	S-8
16	5.00	0	2.13	92.87
17	3.96	0	4.28	91.76

No.	PP, °C measured/ (predicted)	KV@40°C, cSt	KV@100°C, cSt	VI
16	-62.5/(-75)	16.45	4.477	204
17	-62.5/(-64)	16.89	4.599	208

4. Conclusions

This study demonstrated that Talakan crude oil has a low sulfur and low paraffinic content (Table 2). The API Gravity of Talakan crude oil is approximately 35.3° (Eq. 1), and thus this oil can be classified as "light crude oil". Due to its low sulfur content, Talakan crude oil can be processed via two schemes: the fuel scheme (obtaining light fractions and heavy fractions as fuel oil) or the base oil scheme (obtaining light fractions and base oils).

Lubricating oils with a pour point of -50°C and a Viscosity Index of above 100 can be obtained from Talakan crude oil using the depressant additives L PPD and M PPD. The Viscosity Index may be increased after the removal of aromatic hydrocarbons through selective solvent purification or the hydrotreatment process.

It was also shown that lubricating oils with a pour point of below -60°C can be obtained from the base oil S-8. Using the Design of Experiments method, the optimum composition for oil with a kinematic viscosity of 17 cSt, a Viscosity Index of 200, and a pour point of -64°C was established.

Further research is required to reduce the pour point of Talakan base oil to -40°C and establish the optimal concentration of additives by using the Design of Experiments approach.

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