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Investigation of the Effect of Ultrasonic Treatment on The High-Viscosity Oil from Yarega Field In Komi Republic (Russian Federation)

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Abstract

The present work is devoted to experimental research of physical fields influence on rheological characteristics of heavy oil from Timan-Pechora region was study different types of exposure (ultrasound, magnetic field, pulsed magnetic transducer) on high-viscosity oil. Was described all used unit in work and shown figures about viscosity change after each one of fields and mix. In the end was made conclusions about better way to decrease the parameters of heavy oil viscosity.

Keywords: Heavy oil; High-viscosity oil; Physical exposure; Rheological properties

Introduction

In this work, the possibility of changing the rheological characteristics of high aromatic naphtha oil from Yarega field was investigated through the influence of external force fields.

Yarega field was discovered in the central part of Komi Republic in 1932. The deposit is located in a depth of 140-200 meters with the quartz sandstones capacity of 26 meters. The temperature in the reservoir is 6-8 °C. This is the first and the only field in Russia, which is exploited by mining method.

Density of oil varies in range from 0.91 to 0.94 g/sm^3, oil has a very high viscosity - up to 16,000 mPa-s. The amount of oil in 1 m^3 is 200 kg. Yarega oil belongs to nafteno-aromatic type with extremely low sulfur content for heavy oil - from 0.84 to 1.17%. This oil contains kerosene fractions from 8 to 12%. Vacuum distillation of oil gives 5.7% gasoil, 14.92% light oil, 5.37% watchmaker's oil and 21.79% spindle oil. Paraffin wax content is below 1% and asphaltene reaches to 20% or more.

Oil from Yarega filed (GOST 51858) refers to bituminous (the density is more than 895 kg/m^3 at 20 °C), that can give a serious problem with dehydration, transportation and processing, which are connected with structural properties of the oil. Solvation shell of oil makes a water reservation, thereby forming an emulsion. Dewatering of the oil is used for electricity demineralization installation involving sequential three-stage desalting and dehydration of heavy crude oil when it passes through the electrical dehydrators. Oil should not have water content more than 0.5% after processing but this condition is not always possible because of solid structure of solvation shell that leads to a complication of refinery processing of such oil.

Explanation

The oil from Yarega field is over 31 million tons and one million tons of oil is produced in a year and it is planned to increase the production to 6 million tons per year by 2016. By this date, the capacity of "LUKOIL-Ukhta refinery" will be increased, where heavy oil enters to the primary treatment.

In recent time, Yarega oil is transported by rail in tanks in to Ukhta Oil Refinery (Figure 1), where, it is handled and pumped through the pipeline with diameter of 325 mm at point of delivery and acceptance of oil in Ukhta Ltd. "LUKOIL-Ukhta oil and gaz" through measurement system coli-operation of oil №626.

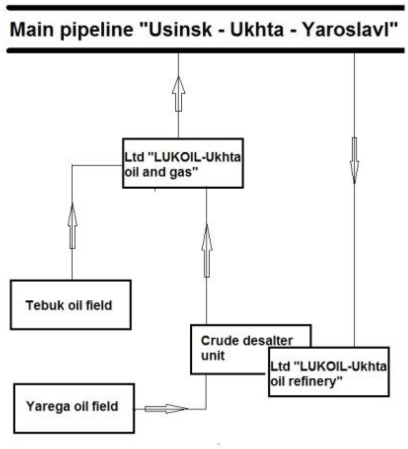

Figure 1: Technological scheme of Yarega oil transportation.

In turn, the light oil (density is 836.4 kg/m^3 at 20 °C), which is produced on Tebuk field, enters to the pipeline commissioning station "Ukhta" on oil pipeline (diameter is 530 mm) through measurement system coli-operation of oil №625, where, it is filled in one of the five tanks with capacity of 3000 m^3.

Then, oil from Yarega and Tebuk fields passes through the knot of mixing on the pipeline commissioning station "Ukhta" and enters into the pipeline of "North main pipeline" through the pipeline "LUKOIL-Komi" (diameter is 377 mm and length is 11.7 km). The density of the mixture shouldn't be more than 884, 7 kg/m^3 and kinematic viscosity shouldn't be more than 40 cSt at 20°C.

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Part of the resulted mixture from Usinsk, Yarega and Tebuk oil fields enters into "LUKOIL-Ukhta refinery".

By the ending 2015, commissioning of the pipeline from Yarega field to the point of oils mixing (12 km long) is planned. But, there are problems, which are associated with numbers of "Transoil" requirements for paged oil: heavy oil should be the first group of quality, construction site connection to the main pipeline and a separate item of the collection and treatment system. Dewatering oil unit, which are on the field, will not be able to provide dehydration of planned volume, so, the oil will be further processed on crude desalter unit in refineries.

Heavy oil refinery for producing fuel is uneconomical by classic technological scheme and in some cases, it is impossible because it contains a low amount of light (Fuel) fractions (not more than 15-20%). In this case, the high content of sulfur and resinous substances reduces the lifetime of the equipment at the refinery. Approved capacity of plant is 3,980 million tons of oil per year. The plant is classified as simple with the index of Nelson 3.7.

Today, the unit of primary oil processing includes Atmosphere pipe still-1 in the flow chart of the company, Atmosphere vacuum pipe still, installation for development of component of high-octane gasoline 35-11/300-95 with isomerization unit, unit of high-quality hydrofined production and hydrotreated diesel fuel, visbreaking and unit for production of various grades of bitumen.

It is necessary to develop and implement methods, which help to increase the yield of light fractions using inexpensive and effective external influences on oil, such as additional heating oil, the impact of ultrasound, magnetic field and microwave radiation, as well as possible combination of these methods.

In literature, evidence of processes intensification is often found only by influence of temperature. Evdokimov IN [1] shows that there are heat treatment temperature ranges, at which the viscosity properties of the oil is deteriorated considerably (Figure 2).

Figure 3 illustrates that the heat treatment can lead to a significant change of the oil freezing point.

It is necessary to research and select the effective temperature range of influence on the high-viscosity oil. Ultrasound is environmentally secure means of the efficiency improvement of technological processes in various branch of national economy. This method allows destroying the long paraffin molecules. Cavitation effects occur in ultrasound processing as following: fine bubbles, which are filled by the gas and

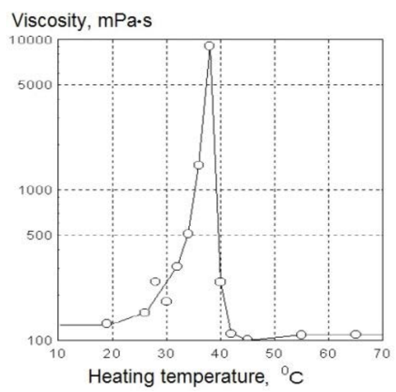

Figure 2: The dependence of viscosity on the temperature heat treatment.

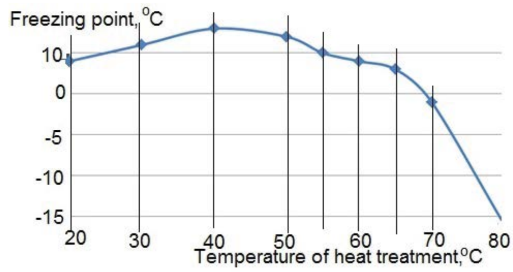

Figure 3: The dependence of Yarega oil freezing point of heat treatment temperature.

vapor, are formed, after which vacuum are collapsed immediately due to the transition in the compression phase. The cavitation treatment accelerates the diffusion of oil in the cavity wax and intensifies the process of its destruction.

Oil forms dispersion system by crystallization or coagulation of the components, which are in its components. Long, wax and resin molecules form some flexible grid, in which the nodes are dispersed phase, in which the solution exists, are randomly arranged. This lattice restricts the motion of the particles and provides it aggregative stable.

Continuous chain ruptures destroy the connection among the individual parts of the molecules after high-intensity ultrasonic waves.

Molecules are broken in C-C linkages, resulting in changing of physicochemical properties of liquids. Typically, recovery time of physicochemical properties after acoustic influence is 5-6 hours or more, so, it is advisable to choose the time and the intensity of such treatments, in which the recovery time is maximized.

In this paper, in addition to ultrasonic treatment the influence of magnetic and microwave radiation on the structure Yarega oil, and their combinations, have been investigated. Destruction efficiency of C-C bond is determined by the frequency magnetic field and dielectric properties of oil, which characterize its behavior in an external field. Therefore, a detailed investigation of the dependence of the dielectric properties of oil on the field frequency provides the possibility to establish the frequency range of the most effective action of the field. Therefore, by placing such sample in an external field at a frequency, which is corresponded to the maximum absorption, intense thermal and hydrodynamic effects can be occured, and the strength relation between the molecular dipoles of shell will be decreased. This will weaken the strength of the whole casing, which ultimately lead to the destruction of C-C bonds in the oil system.

A special circuit, which includes various power affects on the structure of Yarega oil, which consist ultrasonic transducers (Figure 4), the magnetic pulse emitter (Figure 5), sources of constant magnetic field (Figure 6) was developed for the study.

Company "Ultrasonic technique INLAB" made two units for the experimental research of effects on the abnormal oil by ultrasound:

- Ultrasonic generator IL10-4.0. with rod magnetostrictive transducer 4 kW (Figure 7);
- Ultrasonic bath with heating system IL100-4.

The main purpose of the generator is the feed of ultrasonic magnetostrictive transducer. Generator has been installed to the

Figure 4: General view of experimental ultrasonic device IL10 - 4.0.
1. Unit of the autonomous cooling, 2.Ultrasound converter, 3. Generator, 4. Ultrasound bath.

Figure 5: General view of the unit IL100-30.

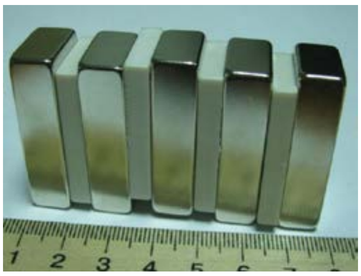

Figure 6: General view of the permanent neodymium magnets (NdFeB).

working frequency of 22 kHz ± 10%. The output power is established within 100%, 50% and 30% of nominal.

By this unit, abnormal oil was treated by ultrasound of 4 kW, staying in a bath, which was filled with water at room temperature; the sample is not virtually heated, making it possible to investigate the influence of ultrasonic vibrations without taking into account the thermal effect. Ability of the output power control allowed processing the oil sample with ultrasound intensity of 16 W/sm^2 8 W/sm^2 and 5 W/sm^2.

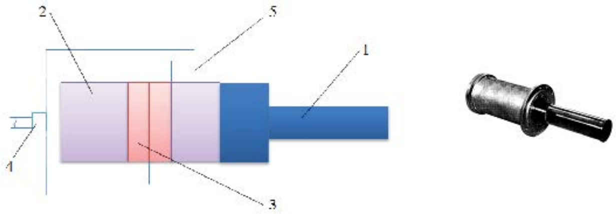

Figure 7: Ultrasonic magnetostrictive converter 4 kW: 1 – Hub, 2 - reflecting lining, 3 - piezoceramics, 4 - electric cable, 5 - the case.

Company "Ultrasonic technique INLAB" made installation IL100-30 "pulsed magnetic transducer" for experimental research on the irradiation of them-pulse magnetic field of petroleum.

The unit is designed for pulsed magnetic field on various materials, which are placed in the inductor. The unit can be used for magnetization of oil and gas equipment (reinforcement steel pipelines, etc.) to modify the rheological properties of oil.

The principle of operation is based on the pulse emitter of electro hydraulic effect, which is applied to generate shock waves in the liquid at its sample. The flow of electric discharge in the liquid is a complex set of phenomena: ionization and decomposition of molecules in the plasma channel and next to it, the light emission of the discharge channel, shock waves, intensity of ultrasonic radiation, formation, and the gas bubble pulsation, cavitations, pulsed magnetic fields. (Table 1)

Non-permanent neodymium magnets (NdFeB) were used for experimental research as sources of DC magnetic fields (Table 1) because they have magnetic force greater than the ferrite magnets (8-10 times more efficient). It has the ability to create strong magnetic fields at small dimensions.

The static magnetic field has been created by using neodymium magnet (NdFeB), wherein the magnetic field can be divided into 4 types (Figure 8):

• NS –magnity, which are arranged perpendicular to the flow (Figure 8.1);

• NN - magnets, which are arranged perpendicular to the flow (Figure 8.2);

• N / S -magnity, which are located parallel to the flow (Figure 8.3);

• N / N – magnets, which are disposed parallel to the flow (Figure 8.4).

For understanding changes in the structure and behavior of heavy oil for different types of exposure, it is necessary to study its rheological properties. Evdokimov IN [1] Flint L [2] Zhuikov PV [3] Kozachko MV [4] studied determining and changing the rheological properties of abnormal oil from Timan-Pechora province. Property researches are essential to determine the structure of Yarega oil, which is directly related to the content of light fractions.

The rotational viscometer Rheotest RN4.1 has been used for experimental research in the study of rheological characteristics of the oil (Figure 9 and 10).

The measuring device allows making measurements at suspension control shear stress (CS-Controlled Stress) and shearing rate (CR-

Mark magnet	Remanence		Coercive force				Energy output		Maximal working temperature
	Br, Тл		bHc		iHc		(BxH) max		
	kG	T	kOe	kA/m	kOe	kA/m	MGOe	kJ/m3	°C
N 30	10.8-11.2	1.08-1.12	9.8-10.5	780-836	≥ 12	≥ 955	28-30	223-239	≤ 80 °C

Table 1: Characteristics of NdFeB permanent magnets.

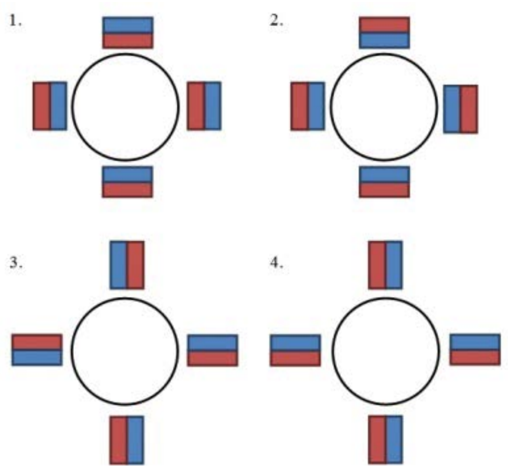

Figure 8: Options for the location of the magnets around the oil sample.

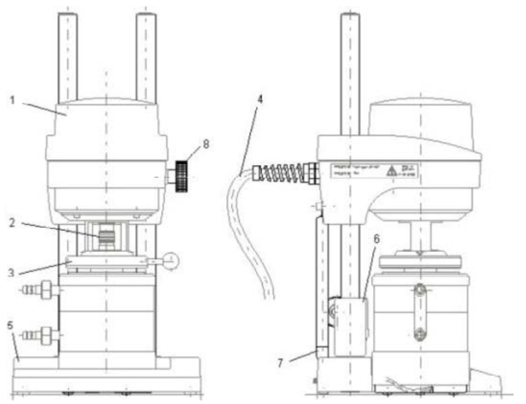

Figure 9: Rotational viscometer Rheotest RN4.1:1 - The drive measuring; 2 - plug connector; 3 – connector measuring tube; 4 - Connection cable; 5 - states; 6 - guide; 7 - shock; 8 – thumbscrew.

Controlled Rate).

Principle of equipment: rotational speed is provided the measurement and resistance of the sample shift is changed. Shear rate, shear stress and viscosity are calculated based on the measured torque and rotational speed set of geometry parameters of the measuring system.

The following approach was proposed in simulation of magnetic systems on permanent magnets: the selection of most effective location of magnesium, at which the maximum impact on the magnetic field streams occurs with the maximum change in the rheological properties of high-viscosity oil, which is transported by pipeline, was made with using experimental stand (Figure 11, Table 2).

It may be noted that using of magnetic treatment for improving rheological characteristics of abnormal oil significantly reduces oil viscosity. The maximum effectiveness is achieved by processing the magnetic alternating of field (type 1 and 2 NS NN).

At this moment, impulse magnetic field is mainly used in mining with abnormal oil.

The number of pulses and maximum induction of magnetic field plays an important role in research of effects of pulsed magnetic treatment of abnormal oil. The unit of "Pulsed magnetic transducer" enables using of magnetic pulses to the induction of up to 2.0 Tesla.

In total, during the experiment were processed and examined more than 25 samples of high-viscosity oil from Yarega field (Figure 12). The reason for choosing the end point of the pulses number (16 times) was a slight deterioration of the start of processing results. It is established

Figure 10: General view of the rotational viscometer Rheotest RN4.1.

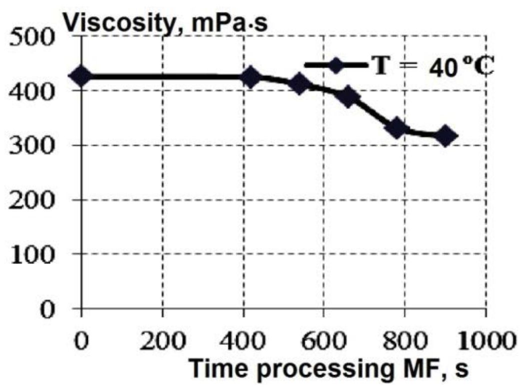

Figure 11: The dependence of change of dynamic viscosity of heavy oil under the influence of the magnetic field at temperature 40 ° C.

Type of oil	Type of magnetic field	Dynamic viscosity μ, mPa·s	Relaxation time, t, h.
High-viscosity oil from Yarega field	Initial co-distance	3660	-
	N-S	1895	3,75
	N-N	1877	3,5
	N/S	1980	3,1
	N/N	2011	2,8

Table 2: The results of changes in the dynamic viscosity and relaxation time of heavy oil at a temperature 40 °C.

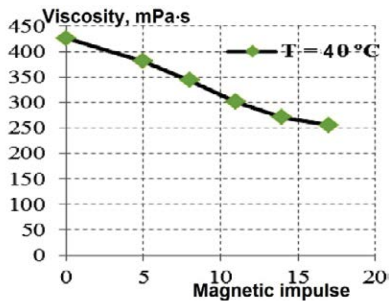

Figure 12: Impact of the number of magnetic pulses to change in the dynamic viscosity of abnormal oil at temperatures of 40 ° C.

that dynamic viscosity decreases during the treatment pulse magnetic fields at different temperatures.

Efficacy of pulsed magnetic field depends on the numbers of pulses-owls and the temperature, at which the treatment occurs. Uses of pulsed magnetic field together with other physical fields (ultrasonic vibrations and a constant magnetic field) are appropriate for improving the rheological properties of anomalous oils, in particular, reducing the dynamic viscosity.

Treatment of abnormal ultrasound Yaregskaya oil with power 4 kW, staying in a bath, which was filled with water at room temperature, was done with the help of experimental ultrasonic apparatus. The sample was virtually not heated, making it possible to investigate the influence of ultrasonic vibrations without taking into account the thermal effect (Figure 13).

Presumably, this effect occurs due to the emergence of a strong cavitations effect, which in turn accelerates the diffusion of oil in the cavity wax, intensifies the process of its destruction.

C-C bond in molecules is violated after high intensity cavitations for a long time, whereby there is a change of physical and chemical composition (decrease in molecular weight, the crystallization temperature, etc.) and the oil properties (viscosity, density, flash point, and others). During the pulse cavitations' processing of oil and oil products, which have been released by the collapse of cavitation bubbles; energy is used to break the chemical bonds between atoms of large molecules of hydrocarbon compounds.

Also, the efficiency of the impact of each physical field on high viscosity oil was researched. The experiment included all three effects, which were described previously (magnetic field, pulsed magnetic field and ultrasound). The dependence was obtained according to the study.

The results of studies of changes in the time-relaxation of high viscosity oil under the influence of physical fields (Figure 14) showed that the combined using of ultrasonic vibrations and magnetic fields increases the recovery time of the initial anomalous properties of oil. Oil samples were heated to the temperature of 50 °C and untreated by physical fields. Within 5 days data of changing the dynamic viscosity was taken.

In the future, study the effect of microwaves on the viscosity of heavy oil, the combined action of physical fields is planned.

In the company "Ultrasonic technique - INLAB» has been developed ultrasonic processing facility (Figure 15) for obtaining a finished product by ultrasonic dispersion (homogenizing, emulsifying) in continuously or cyclically mode of superimposed on the treated environment of the magnetic field. The magnetic field can be constant (0 - 50000 Hz), the variable (up to 1 T) and the combined - simultaneous imposition of the constant and variable components. Storage tank of 260 liters allows multiple processing portion of the hydrocarbon volume of 200 liters. Installation of automated monitoring and control

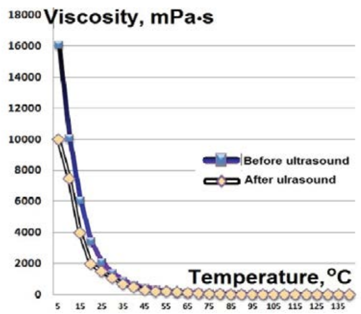

Figure 13: The dependence of heavy oil viscosity on the temperature.

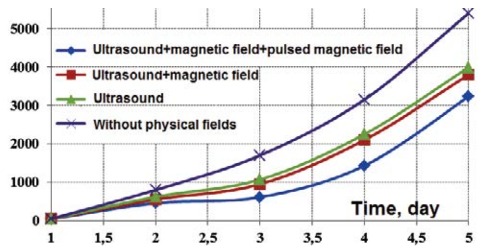

Figure 14: Changes relaxation time of heavy oil after exposure to physical fields.

Figure 15: Ultrasonic Processing Facility I100-35 / 2 with magnetic reactor.

is implemented under the control of a personal computer.

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