Technology of Ultrasonic Treatment of High-Viscosity Oil from Yarega Oilfield to Improve the Rheological Properties of Oil

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Abstract. The article investigates the possibility of applying ultrasonic treatment oil from Yarega oilfield to improve of rheological properties, reduce oil viscosity in Russian pipeline transportation system, and increase its efficiency and performance. Created laboratory test bed of ultrasonic waves.

1. Introduction
World petroleum industry is characterized by the decrease of low viscosity oil recovery and by the increase of hard-to-recover viscous oil and bitumen. The world reserves analysis of viscous oil with a viscosity more than 25 mPa·s has shown, that the main reserves are located in the countries such as Canada, Venezuela and Russia. According to the various sources, global reserves of viscous oil are estimated at least 1 trillion tons [1].

The necessity to reduce production and transportation costs for viscous oil is a topical problem for the oil companies. Currently, such methods as oil heating, addition, magnetic and ultrasonic field effects are applied to improve the rheological properties Ultrasonic processing of viscous oil is a promising and economically profitable method of oil processing. However, the issue connected with the complex influence of ultrasonic treatment and depressor additives has not been covered properly. The integrated impact can have high treatment efficiency and a prolonged recovery time of oil properties.

The aim of this work is to conduct experimental research and to point out the correlations between ultrasonic treatment and viscous oil depressor additives integrated application.

2. Materials and methods
In the process of the research, Yarega field viscous oil treatment of 3000 ml and viscosity of 500 mPa·s with depressor additives DPN and DPN-1R, also ultrasonic transducer Ultrasonic with a frequency up to 25 kHz and 20 µm amplitude has been carried out. The processed oil was placed in the special thermostats, and was processed by ultrasound and depressor additives both separately and independently [2].

Ultrasonic treatment has been carried out using a rod waveguide that is placed in oil at depth of 50 mm. Depressor additives have been heated up to 60 °C before processing. The sample thermostation by special thermostats has been carried out before and after oil processing. The viscosity has been measured by viscometer VUB-1R by measuring 50 ml outflow time [3].

Figure 1 illustrates the model of the test bed.
Figure 1. Model of the test bed.
1 – thermostat; 2 – oil tanks; 3 – pump; 4 – ultrasonic rods; 5 – additives input unit.

To determine the effective area and the values of ultrasonic treatment intensity, both experimental analysis and Minnaert's linear theory of ultrasonic treatment effectiveness evaluation in inviscid cavitating liquids have been used.

For the latter we describe the dynamics of the cavitation bubble occurrence and the cavitation bubble radius dependence on time $R(t)$ using Nolting-Naires equation. We write the wave resistance of the processed liquid[4]:

$$
\rho_1 c_1 = \rho_0 c_0 \left( \frac{1 - K + \frac{\rho_2}{\rho_0 K}}{1 - K + \frac{\rho_2}{\rho_0 K}} \right)^{0.5},
$$

(1)

where $\rho_0$, $\rho_1$, $\rho_2$ - density of a perfect fluid, density of a cavity and density of raw liquid; $K$ - average index of cavitation; $\beta_0$, $\beta_1$, $\beta_2$ - compressibility factor of a perfect fluid, a cavity and raw liquid;

The average index of cavitation is determined according to the following formula:

$$
R = \frac{1}{t} \int_0^t R(t) dt R_{MAX},
$$

(2)

where $t$ - period of ultrasonic wave oscillation; $R(t)$ - cavity radius time-dependent; $R_{MAX}$ - maximum cavity radius;

And to determine the $R_{MAX}$ linear theory generalization is used:

$$
f = \frac{1}{2\pi R_{MAX}^4} \left\{ \frac{4}{3\gamma} \left( \frac{2\sigma}{R_{MAX}^2} + \rho_0 \right) - \frac{2\sigma}{\rho R_{MAX}^2} - \frac{2\mu}{\rho R_{MAX}^2} \right\},
$$

(3)

where $\gamma$ - adiabatic index of air; $\sigma$ - surface tension;
\( \mu \) - dynamic viscosity;

Numerical solution of the resulting equation for \( R_{\text{MAX}} \) defines the maximum average radius of the cavity.

3. Results and Discussion

The effective area and ultrasonic processing intensity value of viscous oil which is equal to 12 W/cm\(^2\) have been determined in the research process. The processed oil viscosity measurements and rheological properties relaxation time were carried out every 12 hours at the following time periods: 12 hours, 24 hours, 36 hours, 48 hours, 60 and 72 hours (figure 2-4).

Figure 2 illustrates the result of experiments with the ultrasonic treatment application.

![Figure 2](image)

**Figure 2.** The dependence of oil dynamic viscosity on the sample storage time after ultrasonic treatment.

Figure 3 shows the result of experiments with the use of depressor additives.
**Figure 3.** Oil dynamic viscosity dependence on the sample storage time after applying depressor additives.

Figure 4 shows the result of viscous oil complex processing experiments

| t, hour | 0 | 12 | 24 | 36 | 48 | 60 | 72 |
|---------|---|----|----|----|----|----|----|
| µ, mPa·s | 300 | 340 | 360 | 380 | 400 | 420 | 460 |

**Figure 4.** Depicting oil dynamic viscosity dependence on the sample storage time after combined processing method.

4. Conclusion
Oil dynamic viscosity has increased in comparison with the baseline values after treatment in the study process. This phenomenon is explained by the fact that primary and secondary molecular bonds have been destroyed by ultrasonic treatment, resulting in increased number of free molecules that has made their coagulation possible. This phenomenon is more noticeable after 72 hours of sedimentation. Research data show that exponential growth of viscosity is a characteristic of original oil.

The processing (treatment) results have showed that application of combined method of viscous oil processing is effective and can be used for short-term viscous oil processing at the tank farms or railway tanks at low temperatures.

References
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