Research of efficiency of influence of ultrasonic treatment on asphalt and paraffin oil deposits

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Abstract. In the oil and gas industry, asphalt and paraffin oil deposits generated in process equipment, tanks and pipelines are a major problem. Their accumulation in the flow section and tanks leads to a sharp decrease in the level of productivity of the entire system. Currently, many methods are used to delete asphalt-resin and paraffin oil deposits. These methods are mainly based on thermochemical methods, the use of which involves high costs and an increase in the level of danger of the works carried out. This paper discusses the ultrasonic effect on asphalt and paraffin oil deposits in order to melt them and, as a result, better removal. This method is sufficiently effective, safe, simple and environmentally friendly to be used in manufacturing processes.

1. Introduction

Ultrasound refers to elastic vibrations of medium with frequency from 16-20 kHz to 108 MHz.

If in a solid environment, such as gases, liquids or solid bodies, particles of medium will be removed from equilibrium position, then elastic forces acting on them from other particles will return them to equilibrium position. Herewith, the particles will oscillate. The propagation of elastic vibrations in a continuous medium is a wave-like process. Oscillations with a frequency of 0 to 20 Hz are called sulphonic, at a frequency of 20 Hz to 16-20 kHz, vibrations create audible sounds. Ultrasonic oscillations correspond to frequencies from 16-20 kHz to 108 MHz, while vibrations with frequency more than 108 MHz are called hypersonic.

During transportation and storage of oil and viscous dark oil products, asphalt-resin and paraffin deposits are formed and accumulated. Deposits can form a deposit layer at the bottom of the tank up to 10% of its volume for several months [1].

Asphalt-resin and paraffin deposits vary in composition and are complex systems that include oil, water, inorganic compounds and mechanical impurities that vary widely [2, 3].

The high molecular weight paraffinic hydrocarbons of deposits have a high solidification temperature, they form highly viscous deposits under normal conditions, sometimes going to a solid state. Polycyclic aromatic structures containing sulphur, oxygen, nitrogen and various trace elements are part of the composition of resins and asphaltenes [4, 5].

Sometimes refineries ignore asphalt-resin and paraffin deposits disposal methods and use the simplest methods of burning on the grounds. This results in adverse effects on the environment. Therefore, the current problem for the oil industry is to solve the problem of a large amount of deposits,
which will increase the depth of oil refining and reduce the negative impact of waste on the environment [6, 7].

Various chemical, thermal and mechanical methods are used to prevent and reduce the growth of asphalt and paraffinic deposits and inorganic salts and to remove them during storage of oil in tanks at oil pumping stations and refineries. Moreover, chemical methods have become the most common. Thus, about 10% of deposits-complicated wells are currently treated with various chemical compounds. However, the use of chemical protection methods against asphalt-resin and paraffin deposits and organic salts significantly increases the cost of oil and often exacerbates environmental problems.

In general, the composition of highly paraffinic crude oil consists of paraffins (from 5% to 70%), and the content of asphaltenes and resin can reach 20%. [8]

In this work we will consider a method of removing asphalt-resin and paraffinic deposits, which consists in ultrasonic exposure on them.

2. Equipment used during the experiment

In the course of the work, an experiment was carried out on ultrasonic exposure on asphalt-resin and paraffin deposits in order to detect their temperature at which solid asphalt-resin and paraffin deposits are transferred to a liquid state, as well as to set the time for reaching this temperature during ultrasonic treatment at installed acoustic capacities.

In operation, deposits were processed using an ultrasonic emitter. Emitter is equipped with magnetostrictive converter. The power consumption of the ultrasonic generator is 4000 W, the maximum acoustic power (output) is 2000 W. In the work, the studies were carried out at a power equal to 50% of the maximum (i.e. 1000 W) and 100% (2000 W).

The principle diagram of the ultrasonic generator is shown in figure 1.

![Figure 1. Principle diagram of ultrasonic generator.](image)

1 – ultrasonic transducer; 2 – concentrator; 3 – emitter; 4 – zero flange.

Action of ultrasonic generator consists in excitation of cavitation in treated liquid. Ultrasonic frequency voltage is supplied from ultrasonic generator to ultrasonic transducer 1 in which voltage is converted into mechanical vibrations of ultrasonic frequency. These vibrations go further into the emitter containing the concentrator 2. With its help vibrations are amplified at the output of emitter 3. The technical characteristics of the ultrasonic generator IL.10 are shown in table 1.

| Parameter                        | Value   |
|----------------------------------|---------|
| Maximum output power, W          | 2000    |
| Operating frequency, kHz         | 22 ± 10%|
| Power consumption, not more than, W | 4000    |
Supply voltage, W & 380± 10% 3 phases  
Power supply frequency, Hz & 50, 60  
Overall dimensions, mm & 480x500x175  
Weight, not more than, kg & 19  

The external view of the ultrasonic generator is shown in figure 2.

![Figure 2. External view of ultrasonic generator IL10.](image)

**3. Investigation of the effect of ultrasonic treatment on asphalt-resin and paraffin oil deposits**

During the experiment, the deposits were placed in a glass beaker, followed by a 20 mm deep and 70 mm diameter recess in the centre of the deposits (for the installation of a emitter), which was filled with water (10 ml volume) to make wet contact between the emitter and the surrounding deposits. The measurement of the deposition temperature during the experiment was carried out by a pyrometer.

The deposits used during the experiment, as well as the laboratory bench for the experiment, are shown in figures 3, 4.

![Figure 3. Capacity with asphalt-resin and paraffin oil deposits.](image)
Figure 4. Laboratory test bench for ultrasound experiment.

Ultrasonic exposure was performed at acoustic capacities of 1000 W and 2000 W. Graphical representation of the obtained data is shown in figures 5, 6.

Figure 5. Results of the deposits ultrasonic processing experiment at an acoustic power of 1000 W.

Figure 6. Results of the deposits ultrasound processing experiment at 2000 W acoustic power.
Deposits transferred as a result of ultrasonic treatment to liquid state are shown in figure 7.

Figure 7. Vessel with molten deposit mass.

4. A comparison of the heating time of deposits to their melting point using ultrasonic exposure and only thermal exposure

It is also necessary to compare the time to reach the melting temperature of deposits using ultrasonic treatment and only heat exposure. In the future, it will allow us to understand how many times the ultrasound is effective compared to only thermal heating.

To determine the heating time of asphalt-resin and paraffin oil deposits to the melting temperature using only thermal exposure, we use the physical formula:

\[ t = \frac{\rho V (c(T_2 - T_1) + \lambda_d)}{Q}, \]  

where \( \rho \) – deposits density, \( \rho = 970 \text{ kg/m}^3 \);

\( V \) – deposits volume, \( V = 350 \cdot 10^{-6} \text{ m}^3 \);

\( T_1, T_2 \) – temperature of deposits before processing and their melting, respectively, \( T_1 = 23,5 \, ^\circ\text{C} \), \( T_2 = 42,5 \, ^\circ\text{C} \);

\( \lambda_d \) – specific heat of fusion of deposits, \( \lambda_d = 160 \text{ kJ/kg} \);

\( Q \) – acoustic (output) power of the emitter, \( W \).

The calculation results by the above formula are summarized in table 2. Also in this table, we summarize the results of calculating the effectiveness of the use of ultrasonic exposure (how many times is the time to reach the melting temperature with ultrasonic exposure than with thermal exposure only).

| Acoustic (output) power of the emitter, W | The time to reach the melting temperature with only thermal exposure, s | The time to reach the melting temperature under ultrasonic exposure, s | Ultrasound effectiveness |
|------------------------------------------|---------------------------------------------------------------|---------------------------------------------------------------|------------------------|
| 1000                                     | 67                                                          | 52                                                          | 1.29                   |
| 2000                                     | 33                                                          | 27                                                          | 1.24                   |
5. Conclusion
In such a way, during the experiment, the transfer of sediments to the liquid state was observed at 42°C temperature, as can be seen from the obtained graphs, which, when the oil temperature approached the 42 °C, showed a slight deceleration of the temperature growth ("site" on the curve of the deposit temperature versus the time of ultrasonic treatment), related to the phase change of the studied sediments to the liquid state. At the same time during ultrasonic treatment at acoustic power of 1000 W the time to reach this temperature was 57 seconds, and at power of 2000 W this time was 27 seconds.

With only thermal exposure, the heating time to the melting temperature was 67 seconds at a power of 1000 W and 33 seconds at a power of 2000 W.

It is also important to note that when deposits are heated to the melting temperature, the ultrasonic effect is on average 1.27 times more effective than thermal exposure only, which also confirms the effectiveness of the use of ultrasonic technology to delete deposits.

The advantage of ultrasonic processing is lower energy costs compared with thermal heating, as well as a greater level of safety and environmental friendliness.

The use of ultrasonic processing is of great scientific and practical interest.

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