About a method of acoustic impact on high viscosity oil fields

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Abstract. The report describes the method of the acoustic impact on the oil reservoir. Chemical decomposition of formation water molecules occurs with the help of energy-accumulating substances. Water becomes a supplier of hydrogen and oxygen. This allows the processes of hydrogenation and synthesis of new compounds. The decomposition of water is carried out using activated aluminum. As a result of the reaction, hydrogen is released, which provides the reaction of hydrogenation of all fractions of heavy oils. Industrial tests of the new method of acoustic impact were carried out at one of the fields with high viscosity of the Embamunaigas company in 2016. Pilot tests revealed an increase in the flowability of heavy oil during the hydrogenation of its components. The increase in well productivity was recorded during the first days of testing a new method. The negative side of the tests was the colmatation of the well with the released aluminum oxide. Physical and chemical processes on the surface of the reacting components were studied. In the course of the research, the state of the phase interface was studied. The spectral composition of the responses at the phase interface was measured. The report presents the results of measurements of the spectral response of water to external influences. The test results of the new acoustic method showed the need for additional research.

1. Introduction

The oil and gas field development system is formed at the initial stage of the field life cycle. One of the key elements of creating an oil field development system is the selection of primary, secondary, and tertiary methods. Primary methods of development of an oil and gas reservoir are the set of natural forces (types of energy) that ensure the movement of oil or gas in the porous system of the reservoir to the bottom of producing wells. Secondary development methods to maintain reservoir pressure include methods of injecting working agents in the form of water (waterflooding) and natural gas. Tertiary development methods in terrigenous and carbonate reservoirs are conventionally divided into two types - the method of enhanced oil recovery (EOR) and the method of improved oil recovery (IOR), depending on the prevailing influence on the component multipliers in the equation for the oil recovery coefficient: coverage ratio and displacement factor, respectively [1-5].

A new direction in the methods of the acoustic impact on the reservoir is the chemical decomposition of the molecules of produced water using energy-accumulating substances [6-10]. In this case, water is a supplier of hydrogen and oxygen, which allows the processes of hydrogenation and synthesis of new compounds. The acoustic impact was carried out using a pulse generator that operated at the frequency of decomposition of water, i.e. 42.8 kHz. These studies should be aimed at
preventing the negative effects of the processes of oil hydrogenation under natural conditions with the help of energy-accumulating substances.

The pilot tests of a new acoustic method of enhanced oil recovery in fields with high viscous oil showed its efficiency. The set of experimental results shows that the layered structure of the “water-solid” interface is the basis for controlling the chemical composition of heavy oil under acoustic impact.

The change in the chemical composition of heavy oil by the hydrogenation of oil under conditions of natural occurrence is an acoustic effect, carried out using a chemical reaction of water decomposition with activated aluminum [11-13]. The released hydrogen provides the reaction of hydrogenation of all fractions of heavy oils [4, 7, 14 and 15].

2. Pilot tests of the method of the acoustic impact on the field with high oil viscosity

Pilot tests of the acoustic method to change the viscosity of oil by hydrogenating its components were carried out in Embamunaigas (Kazakhstan) in 2016 year [7]. As a result of industrial tests, a positive result was obtained for reducing the viscosity of oil and increasing the productivity of wells during several days of testing. At the same time, the colmatation of wellbore zones with the released aluminum oxide was noted. It took from two to four weeks to clean the wellbore zones from the dropped alumina compounds. The study of the state of the phase boundary was performed using measurements of the spectral composition of the responses at the phase interface. The work used the frequency of decomposition of water, which was experimentally detected by A. Pucharich [16]. The report presents the results of measurements of the spectral responses of water to an external acoustic effect, which was carried out from a pulse generator operating at the frequency of water decomposition, i.e. 42.8 kHz. To study the processes of oil decomposition at the interface, an experimental test bench was made, the functional diagram of which is shown in Figure 1.

![Functional diagram of the experimental setup](image)

Figure 1. Functional diagram of the experimental setup for the evaluation of the acoustic response at the interface, where 1 - oil-water phase boundary; 2 - quartz cuvettes; 3 - pulse generator; 4 - USB spectrograph; 5 - 1 channel of the spectrograph; 6 - 2 channel spectrograph; 7 - a device for measuring the electrical resistance of the fluid at the interface.

Oil samples were investigated by infrared spectroscopy at the Institute of chemistry of the Academy of Sciences of the Republic of Kazakhstan on the spectrograph. The characteristic features of the oil spectrum from Zhetybay field are shown in Figure 2.

Figure 3 shows the spectrogram of the source water, from which it is clear that the response spectrum includes the fundamental frequency (42.8 kHz), which has a maximum amplitude and the first two harmonics, the amplitude values of which are much less (2-3 times) basic.

Analysis of the spectrogram indicates that the oil sample contains a small amount of amines, many thiophosphochloride halides. Along with saturated hydrocarbons, there are complex compounds of the CH and CH₂ groups. Carbometaethers and aliphatic hydrocarbons with linear chains were identified with the CH₃ group. In addition, ring structures in the form of benzene derivatives with various forms
of substitution are present in sufficient quantity. Heavy oils contain a large amount of sulfur and its compounds, therefore for the model experiment there were pressed sulfur tablets (Figure 4).

**Figure 2.** An infrared spectrum of oil from the Zhetybai field.

**Figure 3.** The spectral composition of the response of water at a frequency of 42.8 kHz.

**Figure 4.** The spectral composition of the response of pressed sulfur, covered with water at a frequency of 42.8 kHz.
Sulfur pressed, covered with a film of water gives the maximum response to the frequency of exposure, and the harmonic components of this response have a 3-braided structure. Resonance conditions correspond to a different dimension of the structural elements of the response. For a triplet response, the model of the layered structure of the phase boundary can be represented as a diagram shown in Figure 5.

![Figure 5. The hypothetical structure of the phase boundary, where 1 is the low-frequency response; 2 is the main signal and 3 is the high-frequency response.](image)

With a similar structure of the phase boundary, the conductivity of the main signal depends on the state of the upper and lower boundaries and, accordingly, in the case of hydrogenation, at least three reaction products may be present at the output, which is confirmed by the results of [7, 8]. The report shows that this effect can be used to obtain desired properties in petroleum compositions by an external impact on the interface by an electromagnetic pulse effect on the frequency of water decomposition. Thus, additional opportunities have been revealed for controlling the structure of the interface by using powders of different dispersion. This is a new effect based on the achievements of such branches of science as optics, metallurgy and tribotechnology.

The set of experimental results show that the layered structure of the “water-solid” interface is the basis for controlling the chemical composition of heavy oil under acoustic impact, and indicate that the state of the oil-water phase interface determines the conditions for the splitting of heavy oil into new compounds, providing for the processes of hydrogenation and structuring of the resulting hydrocarbons.

3. Conclusions
Experimental evidence of the existence of the processes of synthesis and decomposition of hydrocarbons during an acoustic impact on the oil-water phase boundary has been obtained. To identify the mechanism of controlling the phase boundary in the oil-water compositions, an experimental setup was created to measure the spectral composition of the responses when acting on the phase boundary at the frequency of water decomposition.

The results of physical modeling to study the structure of the interface between the phases "water-solid" showed that any inhomogeneity that prevents the passage of the acoustic signal causes a response at the fundamental frequency of decomposition of water and at the frequencies of the harmonic series. The components of more viscous oil at the phase boundary play an important role. The effect of the appearance of a layered structure of the “water – solid” interface appears, allowing one to control the mechanism of interaction between the separated phases during an external acoustic effect at the frequency of water decomposition, hydrogenation processes occur and, accordingly, the synthesis of hydrocarbons with benzene group derivatives.
Acknowledgements
The authors would like to thank management of the Kazakh National Research Technical University named after K.I. Satpaev and the Oil and Gas Research Institute of Russian Academy of Sciences for the permission to present and publish this paper based on the results of the project "The Fundamental Basis of Innovative Technologies in the Oil and Gas Industry", No. AAAA A16-116031750016-3.

References
[1] Basnieva I, Zolotukhin A, Eremin N and U dovina E 1994 Comparative Analysis of Successful Application of EOR in Russia and CIS Proc. of University of Tulsa Centennial Petroleum Engineering Symposium. https://search.crossref.org/?q=10.2523%2F28002-ms
[2] Zolotukhin A, Eremin N, Nazarova L and Ponomarenko Ev 1991 The theory of fuzzy sets for the problem of the selecting recovery methods on the oil field Neftyanoe Khoyzaystvo - Oil Industry, 3 21-23.
[3] Eremin N, Zheltov Yu and Makarova E 1993 The well-spacing ratio and the application of the oil recovery methods EOR/IOR. Neftyanoe Khoyzaystvo - Oil Industry 11 28-31.
[4] Zolotukhin A and Eremin N 1986 Design of development of oil fields with the use of in-situ combustion (Gubkin Russian State University of Oil and Gas, Moscow, Russia) 73. https://www.researchgate.net/publication/330669021_Design_of_development_of_oil_fields_with_the_use_of_in-situ_combustion
[5] Sinitnikov A, Eremin N and Ibatullin R 1994 A Mathematical Model of Microbial Enhanced Oil Recovery MEOR Method for Mixed Type Rock Society of Petroleum Engineers. https://search.crossref.org/?q=10.2118%2F28903-MS
[6] Ahmed Y et al 2019 Acoustic Characterisation of Phase Inversion in a Water-Oil System. Society of Petroleum Engineers. https://search.crossref.org/?q=10.2118%2F194885-MS&page=
[7] Alishova Z and Eremin N 2018 Obtaining the preset properties during hydrogenation process by controlling the state of the phases division boundary Geology, Geophysics and Development of Oil and Gas Fields 8 66–70.
[8] Alishova Z and Metaka G 2017 Experimental evidence of the existence of natural processes of resource reproduction Commonwealth, 16(2) 4-9.
[9] Wang Z et al 1988 Acoustic Velocities in Petroleum Oils SPE Annual Technical Conference and Exhibition. https://search.crossref.org/?q=10.2118%2F18163-MS
[10] Yeo L, Matar O K, Perez de Ortiz E S and Hewitt G F 2002 Phase inversion and associated phenomena Multiphase. Sci Technol, 1(1) 12–51.
[11] Johnson J, Olsson B et al 2019 High Temperature Hydrogen Attack Life Assessment Modeling and Inspection. NACE Int. Corrosion 2019, 24-28 March, Nashville, Tennessee, USA
[12] Metaxa G et al 1977 The method of processing metals and alloys. Certificate of authorship. The USSR. 12.09.1977.
[13] Sokalsky D 1979 Hydrogenation in solutions (Nauka, Alma-Ata) 364.
[14] Mancilla-Polanco A et al 2019 Phase Behavior of Heavy-Oil/Propane Mixtures Society of Petroleum Engineers. https://doi.org/10.2118/184988-pa
[15] Marco G, Basnieva I, Eremin N, Sardanashvili O and Kraus Z 2019 About thermal oil recovery during the extraction of heavy oil and bitumen for the fields of Venezuela Actual Problems of Oil and Gas 24(1).
[16] Pucharich A 1983 Patent USD №9.394.230 issued 19.07.1983.