MECHANISM MICROWAVE RADIATION IN THERMOCHEMICAL DESTRUCTION OF SUSTAINABLE WATER-OIL EMULSIONS

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Abstract. This paper presents the results of a study of the mechanism of microwave radiation (microwave radiation penetration depth, chaotic movements of microwave fluxes, the amount of energy emitted by microwave radiation of OWE, changes in atomic, electronic and structural polarization of associated substances of OWE) during thermochemical destruction of stable oil-water emulsions (OWE).

It has been established that the combined use of thermochemical and microwave effects on stable OWE increases the intensity of collisions between water globules and the difference in densities of oil and produced water.

Keywords: mechanism, microwave radiation, water-oil emulsion, thermochemical destruction, stability.

I. INTRODUCTION

In recent years, oil production is growing due to the extraction from the depths of a significant amount of produced water in the form of oil-water emulsions (OWE). This is facilitated by the presence in the extracted oil of resins, asphaltenes, paraffins, naphthenic acids, dispersed mechanical impurities, mineral salts, etc. [1].

The turbulent movement of such mixtures in the trunk of tubing pipes, pumps and other forms a stable OWE not stratified even after 2-3 days.

In practice, for the destruction of such highly stable OWE, a thermochemical method is widely used, based on raising the temperature and using a demulsifier (surfactant) with a higher activity than the surfactant contained in the emulsion itself [2].

However, often the addition of a demulsifier with a significant excess (200% or more) does not give the desired results. This is due to the high stability of the reservation shell of water droplets, which consists of resins, asphaltenes, paraffins, mechanical dispersed impurities and mineral salts of various nature [3].

II. EXPERIMENTAL

The localization of the above components in the oil of substances can be represented by the following scheme presented in fig. 1.

![Fig. 1. Localization of a water droplet in oil and related hydrocarbon substances.](image-url)
Here, the high strength of the shell of water droplets is ensured by the formation of associates and complex compounds between petroleum-related substances with different chemical activities and nature. Analysis of many non-ionic and ionic surfactants studied as a stable OWE demulsifier showed that today there is no universal demulsifier for the effective destruction of highly stable OWE of different composition [4,5].

Therefore, today, the search continues for effective demulsifying agents and their compositions, as well as methods for dehydrating and desalting oils, taking into account their chemical composition and colloid-chemical properties [6,7].

In this direction, electromagnetic (EM) processing of stable OWE, which changes its dipole polarization, surface tension, and viscosity, is of definite scientific and practical interest [8].

At the same time, the complex multicomponent composition of water-oil emulsions gives preference to its high-frequency (HF) and superhigh-frequency (SHF) EM emissions.

With HF, EM radiation, the polarities and surface tensions of resins, asphaltenes, and paraffins mainly change and with microwave radiation, there is a change in these indicators in the reservoir water, which contains mineral salts of different nature.

Therefore, when choosing the frequency of EM treatment of stable OWE, it is necessary to study its composition and content of the above-mentioned substances. It is more difficult to destroy stable OWE with a high content of dispersed mechanical impurities adsorbed on the surface of the reservation shell of the formation water droplets, even when using highly active surfactants i.e. demulsifiers.

III. RESULTS AND DISCUSSIONS

In this case, it is considered effective to use electrophysical effects, for example, HF or SHF EM processing of stable OWE. Such effects not only change the polarity and surface tension of the associated OWE substances, but also reduce its viscosity by increasing the temperature. The chaotic motion of EM HF or microwave fluxes and their stress among themselves contributes to the generation of heat or an increase in the temperature of the OWE.

Such motion of EM fluxes in stable OWE can be represented in the form of the diagram illustrated in Fig. 2.
It should be replaced that the thermal conductivity of oil is low and therefore, HF and SHF allows for a more intensive reduction of the viscosity of a stable OWE due to a volume increase in its temperature. This is also accompanied by a change in the atomic, electronic, and structural polarization of the associated OWE substances [9].

The penetration depth of microwave radiation (SHF) at a compact temperature for water is 3.5 cm, and for oil 1-1.5 cm, which should be taken into account when processing stable OWE [10].

The dielectric constant ($\varepsilon$) of water at room temperature is 78.5, and for oil 30-35 what shows microwave contribution to the amount of energy emitted by microwave radiation of OWE at a frequency ($\upsilon$) of 2450 MHz [11]:

$$q = 0.555 \cdot 10^{-14} \cdot \varepsilon \cdot \upsilon \cdot E^2;$$  \hspace{1cm} (1)

It can be seen from equation (1) that microwave radiation, as compared with traditional (convective) heating of a OWE, proceeds at high speed.

It is known that with microwave radiation OWE created from 3 to 6 (multimode and monomode) modes, providing its uniform volume heating. Moreover, the intensity of the EM field in the OWE is not the same. there are “hot and cold” zones that stabilize in a short time.

In fig. 3 shows the movement of microwave radiation (MWR) elements of the microwave installation.)

From fig. 3, it can be seen that in case of multimode radiation (a), EM streams hitting the apparatus walls are reflected in a certain opposite direction, what happens randomly by the many movements of the EM flows (before attenuation), and in the case of single-mode (b) EM, the flows move mainly in one direction, practically without changing the radiation velocity.

As noted earlier, the mechanism for the demulsification of stable OWE consists of several stages:
- collisions of globules of water droplets;
- formation of large water droplets;
- settling of the formed large drops of water.

The combined use of thermochemical and microwave effects on sustainable OWE, increases the intensity of the collision of water globules between themselves and the density difference between oil and produced water. The role of the demulsifier is to weaken the strength of the armoring sheath of water globules, due to which stable surfactants are destroyed.

When disclosing the mechanism of the process in question, one should take into account the peculiarity of the role of paraffin in stable OWE, which gives the emulsion the properties of a non-Newtonian fluid due to its phase transition with increasing temperature from a solid to a liquid. In the
temperature range (35-50°C) for melting solid paraffins, a sharp change in the viscosity of the OWE is observed.

We studied the change in the content of solid paraffins in OWE with an increase in its temperature.

The results of the observations are presented in Fig. 4.

From fig. 4, it can be seen that at room temperature (20-25°C) the content of paraffin wax in OWE is more than 70%, and the remaining paraffins are in the molten state. When the temperature of the OWE rises above 50°C, the content of solid paraffins is less than 30%, while the others are high-melting paraffins and ceresins.

Consequently, depending on the content and melting point of paraffins in OWE, the need for its microwave radiation (SHF) at a frequency of 2450 MHz increases.

The collision of water droplets with the microwave radiation of stable OWE squeezes out the reservation layer of the globule shell and thereby destroys it due to compression. This is accompanied by an increase in pressure inside the globules of water and the destruction of the associates in the reservation shell of the drops.

Modern advances in the field of research of microscopic structures, such as the dispersed phase of a OWE, develop knowledge of the mechanism of formation and destruction of stable OWE by the following definitions:

- “cluster dispersion” - a structure in which the basic elements of the dispersed phase are independent close-packed associates or clusters of water droplets;
- “gel clusters” - a structure in which clusters flocculate in long chains and branched aggregates;
- “gel drops” - close-packed structures, in which the individual elements of water are the basic elements of the dispersed phase [12].

Such an explanation of the mechanism of formation of stable OWE requires additional experimental evidence because its basis contains some plausible assumptions.

If we consider that fine water droplets ranging in size from 5 to 20 microns are considered difficult-separable components of stable OWE, then their connection with each other without external influence is difficult to destroy.
IV. CONCLUSION

Thus, it can be concluded that the universal mechanism revealing the formation and destruction of stable OWE has not yet been formulated because of the specific characteristics of the dispersed composition and colloidal-chemical properties of oils and their emulsions of various nature. It is considered correct to explain the mechanism of formation and destruction of stable OWE individually, taking into account the above-mentioned features of oil. The same applies to the evaluation of the role of high frequency and microwave radiation, with the destruction of sustainable OWE. All this ultimately ensures the intensification of individual stages of the process under consideration.

REFERENCES