



Destabilization and Destroying of Resistant Water-Oil Emulsions Formed with Mechanical Admissions

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ABSTRACT: The article examines the mechanisms of destabilization and destruction of stable water-oil emulsions formed in the presence of mechanical impurities in the extracted products of oil fields. It has been shown that solid particles of mineral and organic origin contribute to the stabilization of emulsions according to the Pickering type, forming strong adsorption layers at the "oil-water" phase boundary. Physicochemical factors of emulsion stability, including the dispersity of the solid phase, interfacial tension, rheological properties of the system, and the influence of natural surfactants of oil, were analyzed. Modern methods of emulsion destabilization are considered: chemical (using demulsifiers), thermal, electrical, and combined approaches. Particular attention is paid to the influence of mechanical impurities on the effectiveness of reagent treatment and water droplet coalescence processes. Based on the analysis of experimental data, recommendations have been proposed for increasing the efficiency of destroying stable water-oil emulsions under production conditions.

KEY WORDS: water-oil emulsion; emulsion stability; mechanical impurities; Pickering effect; demulsifiers; interfacial tension; coalescence; adsorption layer; oil field preparation; emulsion destabilization.

I. INTRODUCTION

The presence in water-oil emulsions of natural emulsifying components of oil (resins, asphaltenes, naphthenic acids), as well as solid mechanical impurities capable of adsorption at the interface between phases, significantly increases the aggregative stability of dispersed systems. An additional complicating factor is the entry of corrosive particles and iron compounds into well production, which are formed due to the high mineralization and aggressiveness of formation waters. These components form strong interfacial adsorption layers and spatial structures that prevent water droplet coalescence and hinder oil dehydration processes. In modern conditions of oil field preparation, this necessitates the use of more efficient reagent systems. New generation deemulsifiers should have pronounced wetting, dispersing, peptizing, and flocculating properties, ensuring the destruction of protective membranes around water droplets and intensifying the processes of their enlargement and separation from oil [1].

In the late stages of field development, various reagents and chemicals are intensively used to treat the bottomhole zone of the reservoir near the wells, increase the oil recovery of the reservoirs, combat salt and paraffin deposits in wells, pipelines, and technological apparatuses, as well as during the overhaul of wells. During the implementation of these measures, mud deposits accumulated in the well production and collection system are washed away, and highly viscous masses are formed along the entire flow of well production from the reservoir to the oil preparation facilities. Under these conditions, the density and viscosity of oil increase, the gas factor decreases, and the content of formation water, natural emulsifiers, and mechanical impurities increases. The result of such changes in the physicochemical properties of the well product is an increase in the stability of water-oil emulsions. This leads to complications in the processes of dehydration and desalination of oil at OPP [2].

II. MATERIALS AND METHODS

Water-oil emulsions are complex dispersed systems, widespread in the processes of oil extraction, collection, and preparation. Their formation occurs mainly as a result of mechanical mixing, turbulent flow, changes in pressure



and temperature. The stability of the emulsion is determined by the protective layer formed on the interphase surface.

In many studies, it was noted that the high stability of the emulsion is associated with natural surfactants - asphaltenes and resins. It has been shown that asphaltene molecules form a strong elastic film around water droplets, significantly slowing down the coalescence of droplets. It is also experimentally substantiated that the stability of the emulsion is directly related to the rheological properties of the adsorption layer.

As the strength of the adsorption film increases, the aggregation of droplets becomes more difficult, and the phase separation time increases.

Therefore, the mechanical and physicochemical properties of the adsorption layer are of decisive importance in the process of emulsion decomposition.

Mechanical impurities (mineral particles, clay fractions, corrosion products, paraffin crystals, etc.) found in oil significantly affect the stability of water-oil emulsions. In the scientific literature, two different roles of these particles are noted:

Solid particles adsorb onto the surface of water droplets, strengthening the adsorption layer. This phenomenon is known in colloidal chemistry as Pickering emulsions. Particles are located at the phase boundary, mechanically "protecting" the droplets and limiting coalescence.

In studies published in the American Chemical Society, it was found that particle size and surface energy directly affect the degree of emulsion stability.

Fine dispersed particles form a dense layer during adsorption, ensuring the long-term stability of the emulsion. Under certain conditions, mechanical additives can also accelerate the decomposition of the emulsion. This is explained by the following mechanisms:

- Local damage to the adsorption film as a result of particle collisions;
- Deformation of droplets under the influence of the weight of the solid phase;
- Compression and rupture of the liquid layer between films.

Under conditions of turbulent flow, mechanical particles thin the film between the droplets, intensifying the coalescence process. This is especially evident in oils with high water cross-sections.

Mechanical factors (compression, centrifugal forces, vibration, hydrodynamic stress) play an important role in the decomposition of the emulsion. Studies have shown that when an external mechanical force is applied to the emulsion, the adsorption film undergoes elastic deformation, and after a certain critical force, it ruptures.

The rupture of the adsorption film occurs in the following stages:

1. Droplet convergence;
2. Thinning of the adsorption layer;
3. Film cracking upon reaching the critical thickness;
4. Coalescence and phase separation.

In the presence of mechanical impurities, this process is complicated, since particles can increase the strength of the film or, conversely, create local defects. Therefore, it is recommended to combine mechanical and chemical methods for effective emulsion decomposition.

The literature indicates that the effectiveness of chemical demulsifiers in emulsion decomposition depends on the presence of mechanical impurities. Demulsifiers weaken the adsorption film, and mechanical factors physically destroy it.

Therefore, the following comprehensive approach is used in modern oil refining plants:

- Treatment with a chemical reagent;



- Heating (reducing viscosity);
- Application of an electrostatic field;
- Mechanical separation (separators, hydrocyclones).

It has been experimentally confirmed that with an increase in the amount of mechanical additives, the consumption of the demulsifier can also increase.

Since the Mullahol field is in the late stage of development, considering important scientific and practical aspects of the change in the physicochemical indicators and rheological properties of the Devonian oil of this field from the beginning of its design development (2002) to the present day of development (2026) is a relevant research.

The work used the laser diffraction method, the Din-Stark method, the gravitational settling method, the areometric method, the microscopic method, and others. Comparative studies of the physicochemical properties of the operating wells of the Mullahol field, in particular, for wells No. 12 and No. 47, located adjacent to each other, were conducted. The physicochemical properties and composition of the well oil are presented in Table. 1. and 2.

It was established that, despite the proximity of the wells, the properties of the No. 12 well product differ significantly from the properties of the No. 47 well product. The product of well No. 47 has higher viscosity and density, and also contains more resins, asphaltenes, paraffins, and mechanical impurities.

III. RESULTS

Apparently, this is explained by the uneven distribution of applied chemical reagents in the formation.

Table 1

Physicochemical properties and composition of Devonian oil from well No. 12 of the Mullahol field (2026)

Density at 20°C, kg/m ³	Viscosity at 20°C, m ² /s·10 ⁻⁶	Water content, % vol.	Paraffins, % by mass.	Asphaltenes, % by mass.	Resins, % by mass.	Total sulfur, % by mass.	Mechanical impurities, % by mass.	FeS, mg/l
819.0	109.4.	86.2.	3.6.	11.2.	13.9.	3.2.	0.26	218.

Table 2

Physicochemical properties and composition of Devonian oil from well No. 47 of the Mullahol field (2026)

Density at 20°C, kg/m ³	Viscosity at 20°C, m ² /s·10 ⁻⁶	Water content, % vol.	Paraffins, % by mass.	Asphaltenes, % by mass.	Resins, % by mass.	Total sulfur, % by mass.	Mechanical impurities, % by mass.	FeS, mg/l
818.0	110.6.	84.0	3.8.	11.3.	14.2.	3.2.	0.24	116.

Changes in the physicochemical properties and composition of the mixture of all Devonian oil wells of the Mullahol field (2002-2026) are presented in Table. 3.

Table 3

Change in the physicochemical properties and composition of the mixture of all Devonian oil wells of the Mullahol field during operation

Deposit development stage	Density at 20°C, kg/m ³	Viscosity at 20°C, m ² /s·10 ⁻⁶	Water content, % vol.	Paraffins, % by mass.	Asphaltenes, % by mass.	Resins, % by mass.	Total sulfur, % by mass.	Mechanical impurities, % by mass.	Fe S, mg /l
Initial stage of operation, 2002	816.9.	48.5	6.23.	1.3.	3.6.	8.3.	1.73	0.04	-
Late-stage operation, 2026	818.0	64.2.	87.0	2.34.	8.2.	13.9.	2.7.	0.13	27.0

During the field's operation, significant changes occurred in the main parameters of the Devonian oil's physicochemical properties. According to "SANEG" LLC, the gas factor of Mullahol oil decreased from 27 m³/t to 18 m³/t. 3 shows that the reservoir water content, oil density, and viscosity have significantly increased. The production of wells increased the content of mechanical impurities, paraffin, resins, asphaltenes, and total sulfur. The presence of FeS - a product of intensive corrosion - is also noted as a result of the interaction of hydrogen sulfide contained in the well product with the metal surface of pipelines and equipment. This is an additional factor in the formation of stable water-oil emulsions [3,4]. Consequently, increasing the effectiveness of demulsification at the dehydration stage of the Devonian oil of the Mullahol field is a top priority in the problem of oil well product preparation. The solution to the set goal consists of theoretical substantiation and experimental selection of a deemulsifier that ensures effective destruction of a stable water-oil emulsion, with an optimal required specific flow rate, moderate cost, and an average annual oil fluid flow temperature of 20°C, under conditions of preliminary discharge of reservoir water at the production and collection points of oil wells and intra-oil demulsification [1,6].

The deemulsifier-free oil product of the Mullahol field (sample selected in January 2026) has the following physicochemical properties: total oil water content (free+emulsified formation water) - 87% by volume; mechanical impurity content - 0.13% by mass; $\rho_{20} = 818.0 \text{ kg/m}^3$; $\nu_{20} = 64.2 \cdot 10^{-6} \text{ m}^2/\text{s}$.

It is clear that the operation of wells such as well No. 47 affects the properties of the total mixture of emulsions of all wells in the field and leads to further complications in the preparation of the total product of wells at oil treatment plants.

The technological regime for preparing the total product of oil wells in the field cannot be selected based on the properties of individual wells. To solve the oil preparation problem, it is necessary to investigate the properties of the total mixture of oil emulsions from all wells in the field. Comparative studies of the deemulsifying effect were conducted using the most common industrial reagents-deemulsifiers of domestic and foreign production. The studies were conducted using a bottle test using a laboratory settling tank (Fig. 1) [5].

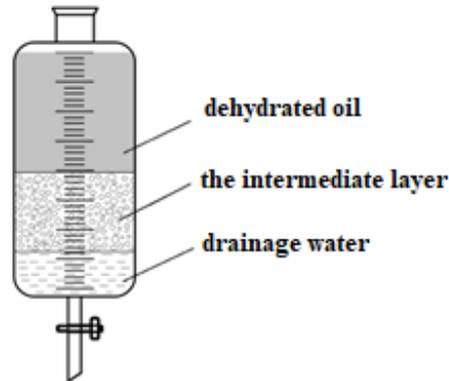


Figure 1. Laboratory oil settling tank

The test results of the surfactant reagents are presented in the table. 4. Among the tested imported reagents (Table. 4) FLEC-D and MOS1411 demulsifiers exhibited the greatest effect [7].

Table 4
Results of tests of reagents and demulsifiers

Deemulsifier	Specific consumption, g/t	Amount of water released during 2 hours of oil settling, % vol.	Residual water content in pre-dehydrated oil, % by volume.
Diproxamine 157-65M	80	63.4.	19.1.
	100	65.7.	16.3.
	120	69.9.	11.8.
Proxanol-305	80	59.6.	22.3.
	100	63.2.	17.5.
	120	67.6.	12.6.
Sulfanol	80	65.3.	15.5.
	100	67.5.	13.8.
	120	71.4.	9.7.
FLEC-D	80	68.6.	13.5.
	100	76.7.	10.2.
	120	79.0.	8.1.
Dissolvan 4411	80	67.3.	13.9.
	100	74.8.	11.0.
	120	77.1.	8.6.
MOS1411	80	71.2.	12.5.
	100	79.3.	9.3.
	120	81.4.	7.7.

IV. DISCUSSION

Diproxamine 157-65M and Proxanol-305 reagents showed less effectiveness in tests, as they are not deemulsifiers in terms of their main functional purpose, but at the same time, possessing a high detergent effect, they are used to remove hydrocarbon deposits in technological equipment, as well as in barges and tankers transporting oil and heavy (dark) petroleum products. Based on this table, one can indirectly judge the formation of the intermediate layer, which is formed during the settling process. If we subtract the sum of the amount of water released and the residual water content in the dehydrated oil from the oil water content value, we can find out how much water remained in the intermediate layer. The higher the effectiveness of the applied demulsifier, the less water remains in the intermediate layer [8].



VI. CONCLUSION AND FUTURE WORK

From a wide range of tested demulsifiers, reagents that exhibited the greatest effect - FLEC-D and MOS1411 - can be isolated. However, the desired effect on the preliminary dehydration of oil is not ensured, as the residual water content in oil exceeds 10%. The FLEC-D demulsifier is an imported reagent and has a significantly higher cost than any domestic analogue, therefore the profitability of its use is low. It is much easier to carry out the sale and purchase of domestic reagents by oil refineries, while excluding excessive material and financial costs, customs duties and taxes, overhead and energy costs, the time factor of delivery, force majeure circumstances, etc. The MOS1411 demulsifier, in addition to its high demulsifying properties, is affordable and does not require long and expensive transportation costs.

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