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Research Article

In Situ Application of Demulsifiers for Water in Oil Crude Oil Emulsion Type

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Abstract

This study investigates the process of demulsification in liquid-phase dispersed systems, focusing on the separation of water-oil emulsions that commonly occur in oil fields. Such kind of emulsions formed during oil production reduce recovery efficiency and increase operational challenges. To address this problem, a new technological approach involving the in-situ application of demulsifiers directly within the reservoir was developed. Laboratory experiments were performed using crude oil and emulsion samples collected from the Kursangi oil field. The experimental program included determining emulsion stability and separation efficiency under varying demulsifier concentrations in ambiant temperature conditions. The results demonstrated that the introduction of demulsifiers into the reservoir environment effectively decreased emulsion stability and accelerated phase separation. This improvement led to higher oil recovery efficiency and reduced processing time. In addition, the method contributed to prolonging equipment service life and minimizing the potential for corrosion and scaling. The findings provide a basis for optimizing oil production processes through the proper selection and application of demulsifiers in reservoir conditions, offering both technological and economic benefits for petroleum field operations.

Keywords

Demulsification, In Situ Demulsification, Petroleum Emulsions

1. Introduction

Water-oil emulsions formed during oil production reduce the efficiency of production processes, shorten the service life of equipment, and lead to additional technological costs [1]. It is well known that the materials like asphaltene and resin stabilizes the emulsion of crude oils and Effective breaking of such emulsions, i.e., the demulsification process by using chemical demulsifiers is considered a priority direction in the oil-chemical industry [5, 6]. This problem is particularly significant in Azerbaijan's oil production sector, as the formation of emulsions is common, and the demulsification process is carried out continuously from the platform to the oil terminals.

During drilling and production, the mixing of oil and water results in various types of emulsions: water-in-oil emulsions (W/O), where water droplets are dispersed in oil, and oil-in-water emulsions (O/W), where oil droplets are dispersed in water [2]. These emulsions create serious difficulties in the purification and processing of crude oil [3, 4, 9].

Breaking emulsions within the reservoir (well or field conditions) has significant potential to improve the efficiency

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of technological processes. Traditionally, the demulsification process which includes heating and adding chemical is carried out either at the surface or at the well bottom, which leads to additional equipment and energy costs. Therefore, carrying out the demulsification process within the reservoir by injecting formation water back into the reservoir and mixing it with a demulsifier to break the existing emulsion without altering its physicochemical properties has been proposed. This approach aims to reduce additional costs in production, extend the life of wells and equipment, and improve the quality of the produced oil. [8]

Research in this area is mainly associated with the works of scientists such as A. Firoozabadi, M. Sun, K. Mogensen, and M. Bennetzen. Their study, "Demulsifier in Injected Water for Improved Recovery of Crudes That Form Water/Oil Emulsion," investigates the role of demulsifiers used in the reservoir in enhancing oil recovery. However, other studies on this topic are very limited, and further research is needed [1].

In Azerbaijan, research in this field has not yet been fully systematized. Laboratory studies conducted on samples from the Kursangi oil field indicate that oil emulsions have a complex physicochemical structure and require specially formulated demulsifiers and conditions for effective breaking. Creating a reservoir model and studying demulsification processes based on this model is crucial for developing technologies suitable for local conditions.

Effective management of demulsification in liquid dispersions is also environmentally important. Timely and efficient resolution of emulsion problems prevents environmental pollution during oil production and reduces processing costs. Therefore, improving demulsification technologies, developing new chemical agents, and creating novel methods are primary goals of research.

This study aims to investigate reservoir-based demulsification technologies for hard-to-break emulsions under laboratory conditions, taking into account the specific characteristics of Azerbaijan's significant Kursangi oil field. The results of the study will contribute to reducing additional costs in oil production, optimizing technological processes, and minimizing environmental risks. During the experimental phase, different demulsifier concentrations (aqueous solutions prepared at corresponding percentages) were applied, and the effects of these processes on the emulsion structure and water-phase separation were monitored dynamically.

Laboratory studies quantitatively measured changes in the water content of the emulsion, conducted relevant analyses, and determined the efficiency of the demulsifier. At the same time, based on the experimental results obtained, oil recovery indicators were calculated, and the effect of different concentration levels on production was evaluated.

2. Materials and Methods

The experiments were conducted under laboratory conditions at room temperature. The model reservoir was prepared in a cylindrical glass tube, which served as the experimental medium. The glass tube had a length of 70 cm and an internal diameter of 5 cm.

First, the glass tube model was completely filled with compacted sand (quartz). Then, the model was fully saturated with distilled water to simulate the presence of formation water, thereby wetting the model with water. This approach is widely used in international studies, as most natural oil reservoirs consist of water-wet formations, making the laboratory model closer to field conditions.

In the next stage, crude oil samples taken from the Kursangi field were injected into the tube by displacing the water, saturating the model reservoir with oil (Figure 1).

This method allowed the interaction between oil and water, which occurs under natural reservoir conditions, to be simulated in the laboratory.

Figure 1. *Displacement of water by oil in a water wet layer.*

Displacement Experiment

In the initial experiment, the displacing solution was divided into two stages based on its type. In the first stage, ordinary water was applied to the model reservoir to carry out oil displacement. In the second stage, three different experiments were conducted based on the concentration of the displacing solution: chemical demulsifiers were used at 20 ppm, 35 ppm, and 50 ppm, respectively. ND-12 was selected as the chemical demulsifier for the experiment; ND-12 is a widely used chemical demulsifier in oil fields by Azneft Production Union where in research [7] it was experimentally proved by a comparison.

After preparing the model reservoir, its total weight was 525 grams. Following the saturation of the model reservoir with oil, an increase in weight was observed, and the total weight became 612 grams. Based on this result, the total volume of oil retained in the model was determined. The weight difference:

$$612-525=87 \text{ g}$$

Considering that the density of oil is close to that of water (approximately 1 g/cm^3), this difference corresponds to roughly 87 ml of oil.

In each stage, the displacement process was carried out using the apparatus shown in the figure. The solutions were introduced from the top of the model reservoir and moved downward through the reservoir under natural gravity (Figure 2). This approach allowed a comparative study of the effect of demulsifiers on the oil separation process under reservoir-like conditions.

Figure 2. *Demulsifier in injected water.*

Figure 3. *Mixing of both demulsifier solutions, and emulsion.*

Before the displacement process, both the demulsifier solutions and the crude oil samples taken from the Kursangi field were heated and thoroughly mixed using a magnetic stirrer to ensure the uniformity of their physical properties. This procedure facilitated a more even distribution of the liquids within the reservoir model and contributed to increasing the accuracy of the experimental results (Figure 3).

3. Results and Discussions

Within the framework of the laboratory experiments, the liquids displaced from the reservoir model were collected in four flasks of different capacities. The capacities of the flasks used were 100 ml, 50 ml, 250 ml, and 250 ml, respectively. For each flask, the filling time (in minutes) was recorded, and the volumes of water and oil were separately noted based on visual observation.

Table 1. *50 ppm demulsifier solution.*

50 ppm demulsifier solution				
S.İ	**T (min)**	**V (total)**	**V (water)**	**V (oil)**
1	41 min	100 ml	80 ml	20 ml
2	6 min	50 ml	45 ml	5 ml
3	21 min	250 ml	240 ml	10 ml
4	17 min	250 ml	245 ml	5 ml

Table 2. *Injection of 35 ppm demulsifier solution.*

35 ppm demulsifier concentration solution				
S.İ	**T (min)**	**V (total)**	**V (water)**	**V (oil)**
1	45 min	100 ml	85 ml	15 ml
2	7 min	50 ml	47 ml	3 ml
3	23 min	250 ml	243 ml	7 ml
4	19 min	250 ml	246 ml	4 ml

Table 3. *20 ppm demulsifier concentration solution.*

S.İ	**T (min)**	**V (total)**	**V (water)**	**V (oil)**
1	50 min	100 ml	88 ml	12 ml
2	8 min	50 ml	48 ml	2 ml
3	25 min	250 ml	245 ml	5 ml
4	21 min	250 ml	247 ml	3 ml

Table 4. Amount of water in crude oil sample and the product samples of each demulsifier concentration solutions.

Laboratory Experiment Method	Products	Water content (%)
ASTM D95	Crude oil from field	54
	Crude oil after displacement with 20 ppm demulsifer solution	52
	Crude oil after displacement with 35 ppm demulsifer solution	45
	Crude oil after displacement with 50 ppm demulsifer solution	40

The water content of the initial crude oil and the products obtained after displacement was determined using the ASTM D95 laboratory method (Table 4).

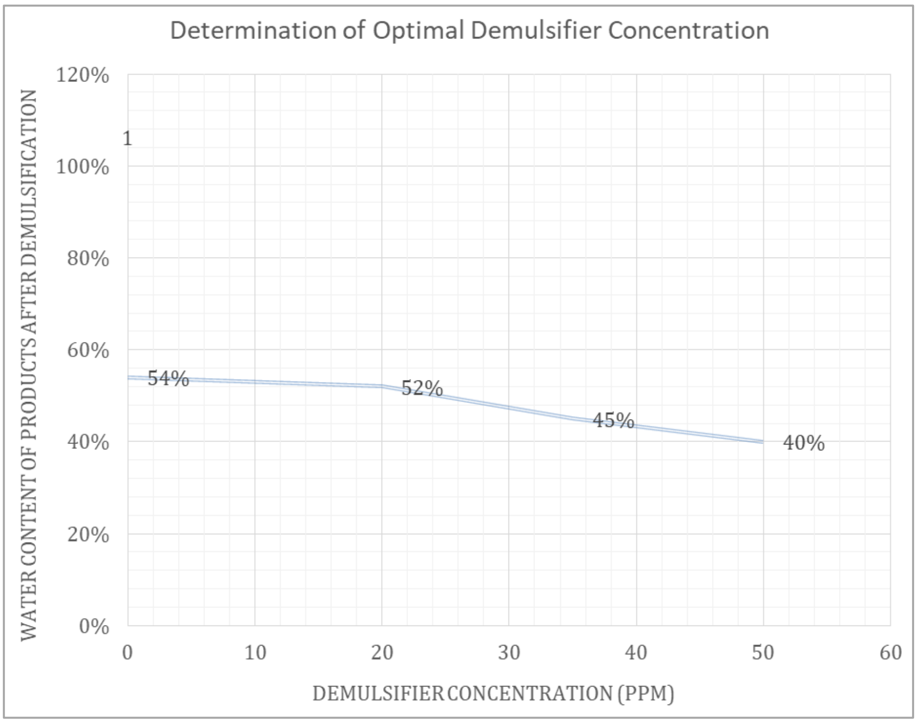

Figure 4. Comparison of demulsifier solutions.

Based on the experimental results, the displacement process using a 50 ppm concentration of demulsifier solution produced the most effective outcome. At this concentration, the percentage of water in the emulsion was lower than that observed with other concentrations. According to analyses conducted using the ASTM D95 laboratory method, the initial water content of the crude oil was 54%, while treatment with the 50 ppm demulsifier reduced the water content to 40% (Table 4).

In addition, oil recovery during displacement with the 50 ppm demulsifier solution was also high. In the experiments, the volume of recovered oil was 40 ml, while the total oil reserve in the reservoir model was 87 ml. This indicates an oil recovery factor of 40:87, or approximately 46%, for the 50 ppm concentration. For comparison, displacement using a 20 ppm concentration yielded 29 ml of oil, corresponding to a recovery factor of 29:87, or roughly 33%.

These results indicate that the 50 ppm demulsifier solution outperformed other concentrations in both reducing the water content in the emulsion and increasing the volume of recovered oil (Figure 4).

The difficulty of breaking the emulsion at room temperature was attributed to the emulsion's composition, the particle size distribution of clay, and the viscosity-temperature relationship of the samples. At lower temperatures, the effect of various surfactants on crude oil emulsions was tested using the bottle test method, and the demulsification mechanism was analyzed through microscopic experiments. The results showed that the emulsion samples did not contain colloidal asphaltenes, so no abnormal conditions were observed; however, the presence of numerous clay particles ranging from 1 to 100 micrometers hindered emulsion breaking at low temperatures.

PR-type demulsifiers reduce the interfacial tension between oil and water and simultaneously adsorb SiO_2 particles, creating favorable conditions for rapid demulsification and flocculation at low temperatures. When the PR3 demulsifier was applied under field conditions, the oil content in the separated water reached 3000 mg/L within one day, and after five days of continuous demulsification, this value decreased to 1000 mg/L [10].

4. Conclusion

The experimental results and ASTM D95 laboratory analyses clearly demonstrate that the application of demulsifiers has a significant positive effect on crude oil emulsion separation. As the concentration of the demulsifier increased, the water content in the produced oil decreased, indicating more efficient demulsification. Among the concentrations tested, 50 ppm was found to be optimal, achieving the highest reduction in water content and the greatest oil recovery factor. These findings confirm the effectiveness of in-situ demulsifier application under reservoir-like conditions and highlight its potential to improve oil production efficiency and reduce operational challenges.

Future research will focus on developing a novel quantitative measure, the Demulsification Factor (D-factor), to systematically evaluate demulsifier performance and optimize application strategies in field conditions.

Abbreviations

O/W	Oil in Water Emulsion
W/O	Water in Oil Emulsion
PR	Polyoxyethylene Polyoxypropylene Quaternized Polyoxyolefins
ND-12	Specific Demulsifier for Oily Rocks of Azrbaijan Republic

Author Contributions

Orkhan Nabizada: Investigation, Methodology, Supervision, Visualization, Writing - original draft

Anvar Movsumzada: Methodology, Project administration, Supervision, Writing - original draft, Writing - review & editing

Conflicts of Interest

The authors declare no conflict of interest.

References

[1] A. Firoozabadi, M. Sun, K. Mogensen, M. Bennetzen "Demulsifier in Injected Water for Improved Recovery of Cudes That Form Water/Oil Emulsion".

[2] McLean, J. D. and Kilpatrick, P. K. 1997b. Effects of Asphaltene Solvency on Stability of Water-in-Crude-Oil Emulsions. J. Colloid and Interface Science 189 (2): 242-253. http://dx.doi.org/10.1006/jcis.1997.4807

[3] Guskova, I. A.; Khayarova, D. R.; Abzyapparova, E. R.; Zakirov, R. R.; Khramushina, I. M. Scientific and Technical Journal *Neftepromyslovoe Delo*, No. 6 (654), June 2023. ISSN 0207-2351.

[4] Mervin F Fingas, Ben Fieldhouse, James Lane, Josep V. Mullin What Causes the Formation of Water-in-Oil Emulsions Conference Paper *in* International Oil Spill Conference Proceedings ·January 2005 https://doi.org/10.7901/2169-3358-2001-1-109

[5] Kehinde Temitope Alao, Oluwaseun Ruth Alara, Nour Hamid Abdurahman Trending approaches on demulsification of crude oil in the petroleum industry Applied Petrochemical Research. https://doi.org/10.1007/s13203-021-00280-0

[6] J. Wu, Y. Xu, T. Dabros, and H. Hamza Effect of Demulsifier Properties on Destabilization of Water-in-Oil Emulsion.

[7] Khamidullina, F. F.; Khamidullin, R. F.; Mingazov, R. Kh.; Kiyamov, I. K. Search for an Effective Demulsifier for Oil Well Production Treatment Technology at the Late Stage of Reservoir Exploitation.

[8] Abdurahman H. N., and M. Nuraini Chemical Destabilization on Water in Crude Oil Emulsions World Academy of Science, Engineering and Technology International Journal of Chemical and Molecular Engineering Vol: 4, No: 2, 2010.

[9] Souleyman A Issaka, Abdurahman H Nour and Rosli Mohd Yunus "Review on the Fundamental Aspects of Petroleum Oil Emulsions and Techniques of Demulsification" J Pet Environ Biotechnol 2015, 6: 2. https://doi.org/10.4172/2157-7463.1000214

[10] Shaohui Jiang, Qingsong Li, Qiang Ma, Botao Xu and Tao Zou "Efficient Demulsification Performance of Emulsified Condensate Oil by Hyperbranched Low-Temperature Demulsifiers".