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STUDY OF EFFECT OF NEW COMPOSITION ON DEMULSIFICATION OF MURADKHANLI OIL AND MATHEMATICAL MODELING OF RESULTS

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Abstract

This article presents a comprehensive study on the demulsification of highly stable emulsified oil from the Muradkhanli field, a major heavy oil-producing site in Azerbaijan. Both physical (temperature effect) and physicochemical methods were evaluated. ND-12 (Azerbaijan) and Dissolvan-4411 (Germany) demulsifiers, along with two newly developed reagent compositions (A-1 and A-2), were tested. Experiments were conducted using the bottle test method, and separated, residual, and ballast water contents were quantified. While certain emulsified oils can release significant water at 50–60 °C without demulsifiers, Muradkhanli oil forms exceptionally stable emulsions that require advanced treatments. The A-series compositions significantly enhanced demulsification efficiency, accelerating phase separation even at moderate temperatures. In particular, the A-1 composition achieved superior performance, reducing residual water content to 0.06 % and ballast water to 0.09 % at 600 g/t and 60 °C. Furthermore, a mathematical model was developed for A-1 to assess its dependence on temperature, reagent dosage, and time, with polynomial curves and 3D response surfaces confirming strong agreement with experimental data. Overall, these results demonstrate the promising potential of advanced reagent compositions to overcome the challenges associated with stable water-oil emulsions in heavy resinous crude oils. This approach offers practical insights for optimizing field separation processes and improving operational efficiency in global heavy oil production.

Keywords: reagent; composition; demulsification; water-oil emulsion; optimal concentration; efficiency; modeling.

ДОСЛІДЖЕННЯ ВПЛИВУ НОВОГО КОМПОЗИЦІЙНОГО РЕАГЕНТУ НА ДЕЕМУЛЬГАЦІЮ МУРАДХАНЛІВСЬКОЇ НАФТИ ТА МАТЕМАТИЧНЕ МОДЕЛЮВАННЯ РЕЗУЛЬТАТІВ

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Анотація

У статті представлено комплексне дослідження процесу деемульгації високостабільної емульгованої нафти з родовища Мурадханлі – одного з провідних об'єктів видобутку важкої нафти в Азербайджані. Були задіяні як фізичні (вплив температури), так і фізико-хімічні методи. Для дослідження використовували деемульгатори ND-12 (Азербайджан) та Dissolvan-4411 (Німеччина), а також дві нові композиції реагентів (А-1 та А-2). Експерименти проводили за методом «бутильного тесту», визначали кількість відокремленої, залишкової та баластної води. Хоча деякі емульговані нафти можуть вивільняти значну кількість води за 50–60 °C без застосування реагентів, мурадханлівська нафта утворює надзвичайно стабільні емульсії, для руйнування яких необхідні більш ефективні методи. Композиції серії А значно підвищили ефективність деемульгації, прискоривши розділення фаз навіть за помірних температур. Зокрема, композиція А-1 продемонструвала найкращі результати, зменшивши вміст залишкової води до 0.06 % і баластної води до 0.09 % за 600 г/т і температурі 60 °C. Крім того, для А-1 була розроблена математична модель для оцінки залежності процесу від температури, дози реагенту та часу; отримані поліноміальні криві та 3D-поверхні відгуку, які підтвердили високу узгодженість із експериментальними даними. Загалом результати демонструють перспективність використання нових композицій реагентів для вирішення проблеми стабільних водонафтових емульсій у важкій смолистій нафті. Запропонований підхід пропонує практичні рішення для оптимізації процесів розділення на місцях і підвищення ефективності виробничих операцій під час глобального видобутку важкої нафти.

Ключові слова: реагент; композиція; деемульгація; водонафтова емульсія; оптимальна концентрація; ефективність; моделювання.

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Introduction

The demulsification process for water-oil emulsions is essential in preparing crude oil for processing. Water presence in oil increases both the volume and viscosity of the liquid, complicating its transportation. Often, the efficiency of the demulsifier used in oil dehydration depends on its compatibility with the oil and the application method. The choice of demulsifiers for each water-oil emulsion and for varying oil compositions is determined through experimental methods, beginning with an assessment of the formation water separation process [1–5]. One technique for enhancing oil recovery from oil-rich reservoirs involves treating the well's bottom zone with chemical reagents. During chemical enhanced oil recovery, aqueous solutions of surfactants, polymer solutions, alkaline solutions, acids, and compositions of chemical reagents are used. By utilizing chemical reagents, the oil recovery factor can increase by up to 20 %, due to the reduction in the viscosity ratio between oil and water, the formation of surfactants at the phase boundary that lower surface tension, and the improvement of oil flowability [6–8]. However, the chemical reagents used to enhance oil recovery also contribute to the formation of emulsions. Naphthenic acids in the oil easily lead to the formation of emulsions. However, due to the weakness of their adsorption layer, the resulting emulsion exhibits poor stability. The crude oil extracted from wells contains mechanical impurities, salts, dissolved gases, and a significant amount of formation water. In some cases, the water content in the oil produced from reservoirs can reach 95 %. The technology used in oil preparation processes at oil fields includes the use of reagents, or more specifically demulsifiers, which facilitate the separation of water-oil emulsions into oil and water. The intensive mixing of water and oil during extraction from wells leads to dispersion, which in turn contributes to the formation of stable water-oil emulsions. Factors such as the nature of the oil, the production technology used, and the mixing of oil with water during collection and the operation of pump units are among the primary reasons for the formation of water-oil emulsions at oil fields [9; 10]. The presence of water in oil increases the volume and viscosity of the liquid, raising the costs associated with the electricity needed for transportation. Water in the oil can settle at the bottom of pipelines, causing corrosion. In pipelines passing through cold climates, the freezing of water can lead to pipeline

damage. During the processing of oil containing emulsified water, the efficiency of fractionation units and condensers decreases significantly, requiring a larger amount of fuel to heat the raw material. Additionally, salt deposition occurs at heat exchange sites at the bottoms of tanks, and equipment corrosion and destruction also take place [11; 12]. To protect pipelines from corrosion, prevent the formation of stable emulsions that are difficult to break down at refineries, and significantly reduce transportation costs, the most economically efficient method is to ensure thorough dehydration of the oil at the production sites. Therefore, the preparation of oil for transportation under field conditions plays an important role among the main processes, such as the transportation, collection, and extraction of crude oil. The delivery of oil to refineries or its export, the quality of the products derived from it, as well as the efficiency and reliability of main pipelines, depend on the quality of the prepared oil. The distribution of demulsifiers used in the demulsification of stable water-oil and oil-water emulsions between the oil and water phases depends on the nature of the reagent (its solubility in oil or water), the composition of the oil, the mineralization of formation water, the degree of water content in the oil, the intensity and duration of mixing, and the demulsification temperature. Depending on the composition and properties of the natural surfactants in the oil, the distribution of the same demulsifier in the water-oil system of different fields can vary. From this perspective, the use of compositions rather than individual demulsifiers is more appropriate when preparing stable emulsions formed by heavy oils for transportation [13]. The application of effective compositions allows for the demulsification process to occur at lower temperatures, reducing the amount of reagent used. During demulsification at lower temperatures, the quality parameters of the oil remain unchanged, and a larger amount of water is separated. In contrast, increasing the amount of reagent during the application of individual demulsifiers becomes ineffective after a certain point. When a significant amount of water remains in the oil, it becomes necessary to increase the temperature. Although the demulsification process accelerates with rising temperatures, conducting it at temperatures above 60 °C is not advisable for oil quality [14].

Objective of the study: The objective of the study is to develop and investigate highly efficient compositions that save heat and energy during the

demulsification of heavy oils that form stable water-oil emulsions.

Research methodology

One of the widely used methods to evaluate the demulsification ability of reagents and their compositions is the bottle test (static settling) method. For this, reagents or compositions are first dissolved in a solvent and then added to the packaged oil samples to be investigated in various concentrations. After the reagents are added, they are mixed thoroughly for 1 minute and then left in a water bath. Depending on the demulsification ability of the tested demulsifier, the separation of water is recorded at various time intervals. The amount of separated water is calculated based on the following mathematical relation [15-24]:

$$X\% = \frac{w}{w_0} 100\% \quad (1)$$

where, w_0 – is the initial amount of water in the emulsion, %, w – is the amount of water separated during demulsification, %.

Additionally, the amount of ballast water in the oil sample after demulsification is calculated based on the following empirical formula, using the amount of water separated from the emulsion and the initial water content of a 100-gram oil sample at various temperatures over a two-hour period [17-20]:

$$S\% = \frac{m_1 - m_2}{m_3 - m_2} 100\% \quad (2)$$

where, S – is the percentage of ballast water after demulsification %, m_1 – is the amount of water in the oil before demulsification (%), m_2 is the amount of water separated from the oil during demulsification (%), m_3 is the amount of the oil sample (%).

The amount of residual water in the oil is determined using the Din-Stark apparatus in accordance with the GOST 2477-2014 standards (Fig. 1).

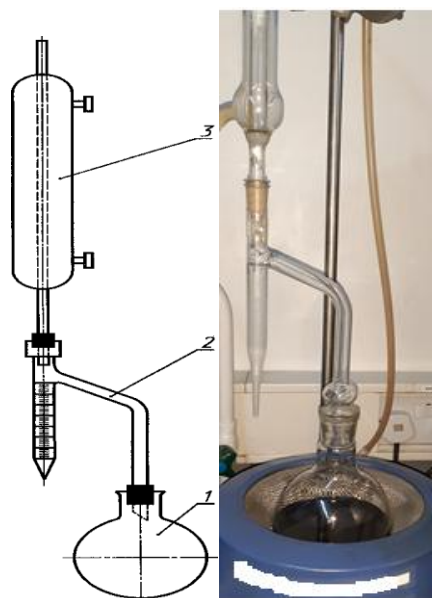


Fig. 1. General view of the Din-Stark apparatus: 1 – flask, 2 water trap, 3 – condenser

The oil sample used in the study is heavy emulsified oil from the Muradkhanli field, and its

physical-chemical properties are shown in the following table:

Table 1.

Physical-chemical properties of Muradkhanli oil

1	Density 20°C, kg/m ³	947.3
2	Viscosity 20°C, mP·s,	2157
3	Water content, % by mass	41
4	Chloride salts content, mg/L	534.3
5	Mechanical impurities content, % by mass	5.86
6	Resins content, % by mass	18.1
7	Asphaltenes content, % by mass	4.5
8	Paraffins content, % by mass	5.8
9	Freezing temperature, °C	+19.5

Results and their discussion

The oil sample used in the study exhibits the characteristics of a stable emulsified oil, enabling it to retain formation water for extended periods. The high content of asphaltenes, resins, paraffin components, and significant salt levels contribute to the increased stability of the emulsion. Consequently, the study initially focused on

examining the effect of temperature on emulsion stability. Since temperatures of 20 and 30°C did not significantly impact the stability of these emulsions, research was conducted at higher temperatures. Specifically, the demulsification process of 41% water-saturated Muradkhanli oil was investigated at temperatures of 40, 50, 60, and 70°C, and the results are shown in Table 2.

Table 2

Demulsification of Muradkhanli oil at various temperatures

Temperature, °C	Amount of separated water, g				Amount of ballast water, %
Demulsification time, hours	0.5	1.0	1.5	2.0	
40	2.9	6.4	8.2	10.2	34.3
50	3.2	7.4	10.5	12.1	32.9
60	5.2	10.4	16.7	18.8	27.3
70	8.5	14.9	22.8	31.4	14.1

Table 2 shows that the effect of temperature on the interfacial tension between the water and oil phases is quite significant. From the experiments conducted over a period of 2 hours, it can be observed that at a temperature of 70 °C, the residual water content was 9.6 %, and the ballast water content was 14.1 %. The presence of 14.1 % ballast water in the oil is an undesirable result

during the preparation of oil in field conditions, which necessitates the use of chemical reagents.

Therefore, studies were conducted on the demulsifiers ND-12 and Dissolvan-4411 at concentrations of 200, 400, and 600 g/t at a temperature of 40 °C, and the results are illustrated in Fig. 2.

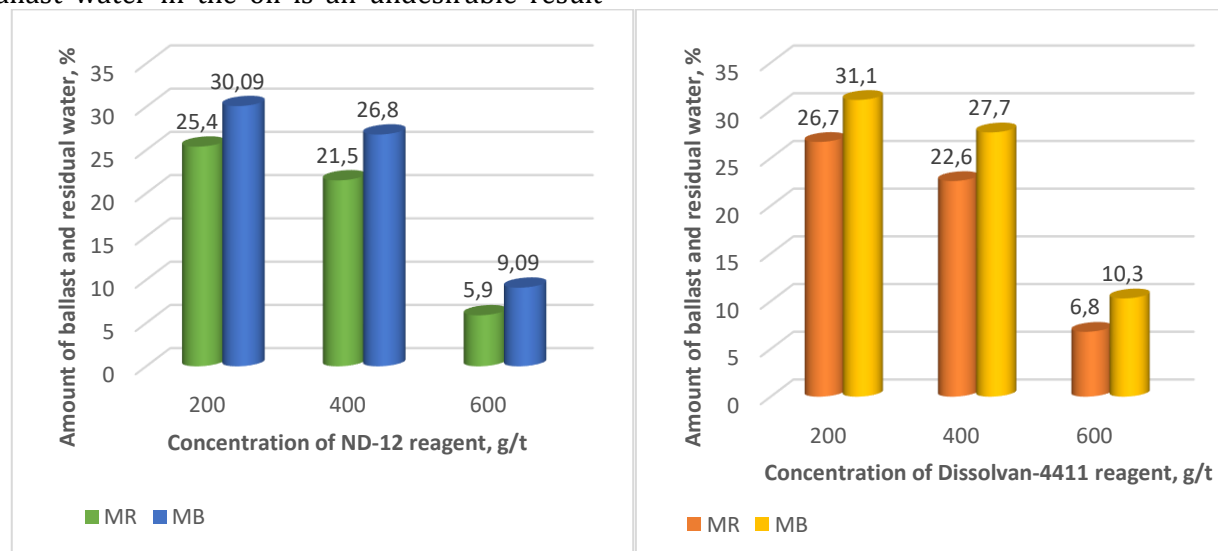


Fig. 2. Dependence of ballast and residual water content on the concentration of ND-12 and Dissolvan-4411 reagents during demulsification at 40 °C

From the Fig. 2., it can be observed that as the concentration of the demulsifiers increases, the demulsification process accelerates. At a concentration of 600 g/t, the ND-12 demulsifier resulted in a residual water content of 5.9 % and a ballast water content of 9.09 %. In contrast, the Dissolvan-4411 demulsifier resulted in a residual water content of 6.8 % and a ballast water content of 10.3 %. The data shows that at 40 °C, the results

obtained with the maximum concentration of the reagents are better than those obtained at 70 °C. However, the demulsification results at 40 °C with ND-12 and Dissolvan-4411 do not meet the requirements for preparing oil for transportation.

Therefore, experiments were continued with ND-12 and Dissolvan-4411 demulsifiers at concentrations of 600 g/t at temperatures of 50, 60, and 70 °C, and the results are shown in Fig. 3.

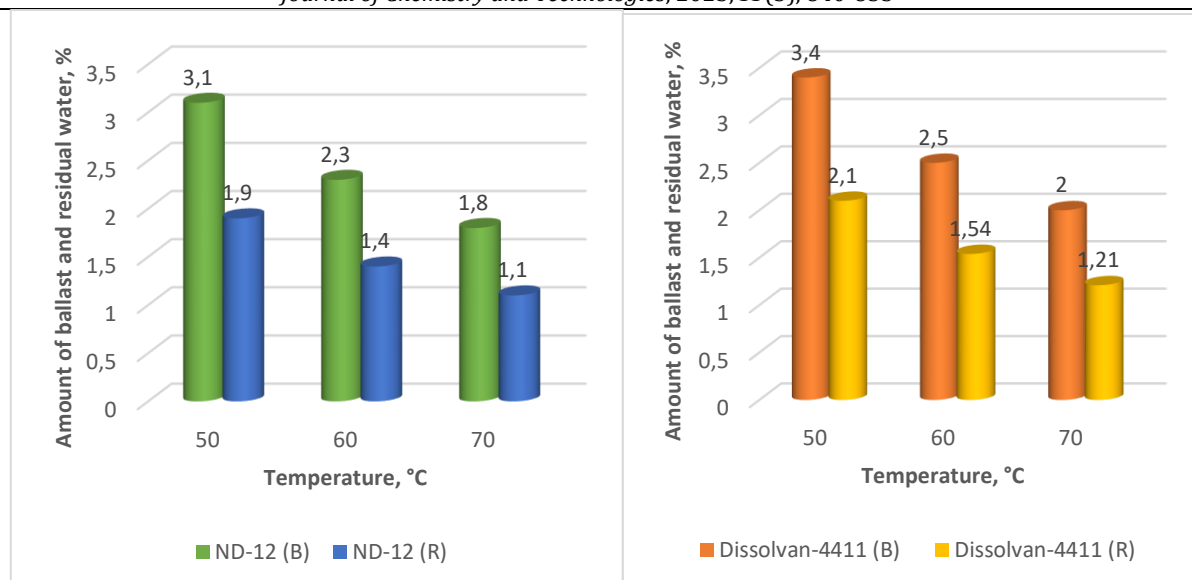


Fig. 3. Effect of temperature and reagent concentration on demulsification: residual and ballast water content

From Fig. 3, it is evident that increasing the temperature and the effect of reagents significantly accelerates the demulsification process, resulting in a considerable reduction in residual and ballast water content. With the ND-12 demulsifier at a concentration of 600 g/t and at a temperature of 70 °C, the residual water content was 1.1 % and the ballast water content was 1.8 %. For the same temperature and concentration, the Dissolvan-4411 demulsifier resulted in a residual water content of 1.21 % and a ballast water content of 2 %. Given that the required amount of formation water in oil for transportation is 0.5 %, the demulsification

results with ND-12 and Dissolvan-4411 at 70 °C and 600 g/t are not satisfactory.

Thus, for the effective breaking of such stable emulsions, the preparation and application of compositions with the correct ratio of components is a globally relevant method. Notably, compositions prepared by mixing demulsifiers with corrosion agents in suitable proportions can enhance the effectiveness of demulsifiers, yielding more successful results. During the research, two compositions with the conditional names A-1 and A-2 were prepared by adding Gossypol resin as a corrosion agent and isopropanol as a surfactant to ND-12 and Dissolvan-4411, respectively. The composition ratios are shown in Table 3.

Table 3

Conventional name and component content of the composition

1	A-1	ND-12+Gossypol resin +isopropanol	4:1.5:0.5
2	A-2	Dissolvan-4411+Gossypol resin+isopropanol	4:1.5:0.5

Studies were conducted on the effectiveness of compositions as well as individual reagents at concentrations of 200, 400, and 600 g/t. For comparison purposes, the initial temperature was set at 40 °C. The results of residual and ballast

water content from experimental trials of compositions A-1 and A-2 at the specified concentrations and temperature are shown in Table 4.

Table 4

Demulsification of oil samples with A-1 composition at 40°C

Nº	Compositio n	Consumption, g/t	Amount of separated water, g	Amount of residual water, g	Amount of ballast water, %
1	A-1	200	24.8	16.2	21.5
		400	27.1	13.9	19.1
		600	36.6	4.4	6.9
2	A-2	200	23.5	17.5	22.9
		400	25.7	15.3	20.6
		600	35.8	5.2	8.1

Based on Table 4, it can be noted that the results of compositions A-1 and A-2 were superior compared to the individual demulsifiers ND-12

and Dissolvan-4411 at the same temperature and concentration intervals. Specifically, with the A-1 composition, the residual water content in 41 %

emulsified Muradkhanli oil was reduced to 4.4 %, and the corresponding ballast water content was reduced to 6.9 %. For the A-2 composition, the residual water content was reduced to 5.2 % and the ballast water content to 8.1 %. Although the results with these compositions were higher than those with individual reagents, the amounts of

residual and ballast water in the oil remained significant. Therefore, further research was conducted with compositions at concentrations of 300, 400, 500, and 600 g/t at temperatures of 50 and 60°C. The results of these experimental trials are shown in Tables 5 and 6.

Table 5

Demulsification of Muradkhanli oil sample with A-1 composition

Initial dilution rate %	Deemulsification temperature, °C	Consumption, g/t	Percentage of water released (volume%)			
			30 min	60 min	90 min	120 min
41	50° C	300	59.7	78.9	91.2	95.4
		400	67.2	87.4	93.5	97.8
		500	78.1	90.7	95.2	99.1
		600	81.3	93.6	97.4	99.82
	60° C	300	63.4	82.6	93.1	96
		400	70.4	88.7	95.3	98
		500	81.6	92.4	97.1	99.4
		600	85.7	94.8	98.3	99.86

Table 6

Demulsification of Muradkhanli oil sample with A-2 composition

Initial dilution rate %	Deemulsification temperature, °C	Consumption, g/t	Percentage of water released (volume%)			
			30 min	60	90	120
41	50° C	300	57.9	76.2	88.0	92.9
		400	64.8	85.3	91.8	95.8
		500	75.7	88.8	94.1	98.1
		600	79.5	91.9	96.2	99.3
	60° C	300	62.1	80.5	89.3	93
		400	68.7	87.0	93.6	96.4
		500	80.0	90.5	95.8	99.0
		600	83.2	93.6	97.2	99.6

It can be observed from both tables that the results of A-1 and A-2 compositions at a temperature of 60 °C are quite effective. Specifically, with the effect of the A-1 composition, 99.86 % of the 41 % water was separated through

demulsification, while with the A-2 composition, 99.6 % of it was separated. The dependencies of the research results expressed in terms of residual and ballast water are shown in Table 7 and Figs. 4 and 5.

Table 7

Amount of residual water during demulsification with A-1 and A-2 compositions at 50 and 60°C temperatures

Composition	Time, minute	Temperature, °C	Consumption, g/t	Amount of residual water, %
A-1	120	50	300	1.9
			400	0.9
			500	0.4
			600	0.1
		60	300	1.6
			400	0.8
			500	0.3
			600	0.06
A-2	120	50	300	2.9
			400	1.7
			500	0.8
			600	0.3
		60	300	2.9
			400	1.5
			500	0.4
			600	0.2

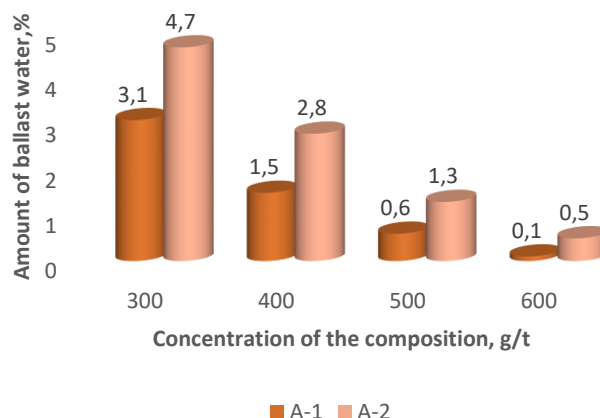


Fig. 4. Dependence of the concentration of compositions on the amount of ballast water at a temperature of 50°C

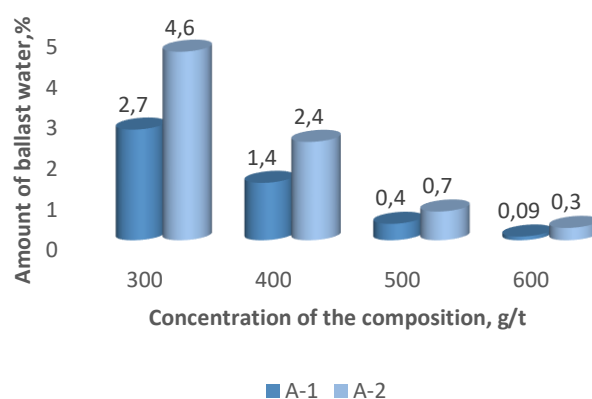


Fig. 5. Dependence of the concentration of compositions on the amount of ballast water at a temperature of 60°C

The tables and figures indicate that while both compositions perform better than individual reagents, the best result was achieved with the A-1 composition. Under the influence of A-1 at 60 °C during demulsification, the ballast water content was reduced to 0.09 %, whereas with A-2, it was 0.3 %. Consequently, for optimal results in field conditions, the A-1 composition will reduce both reagent consumption and energy costs. This

approach enables efficient demulsification of stable emulsions at 60 °C without needing to increase the temperature to 70 °C.

Since the A-1 composition showed the best efficiency, a 3D graph was created to show the dependency of residual and ballast water amounts on the demulsification time, temperature, and composition concentration, as illustrated in Fig. 6-11.

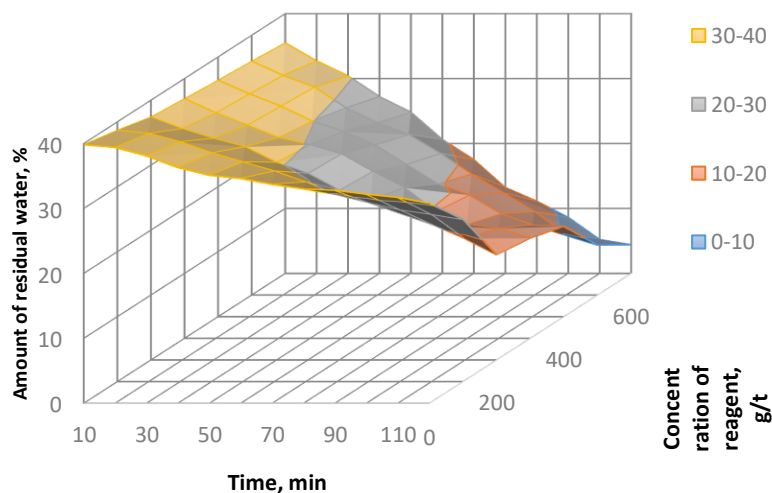


Fig. 6. Dependence of residual water content in Muradkhanli oil on time and A-1 concentration at a temperature of 40°C

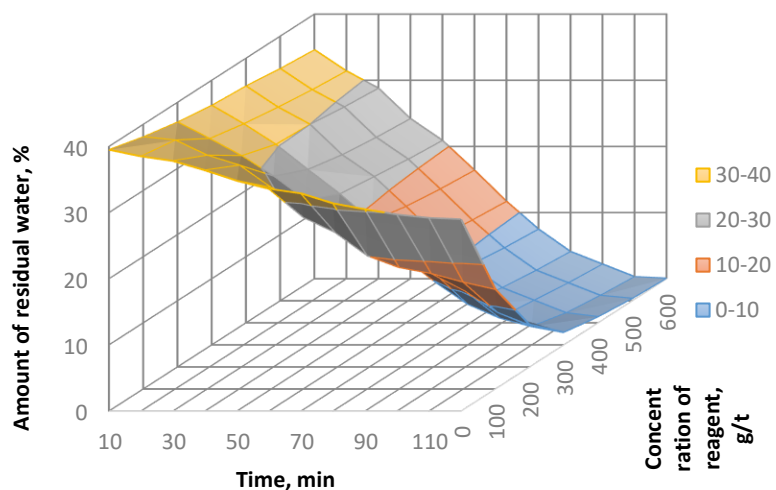


Fig. 7. Dependence of residual water content in Muradkhanli oil on time and A-1 concentration at a temperature of 50 °C

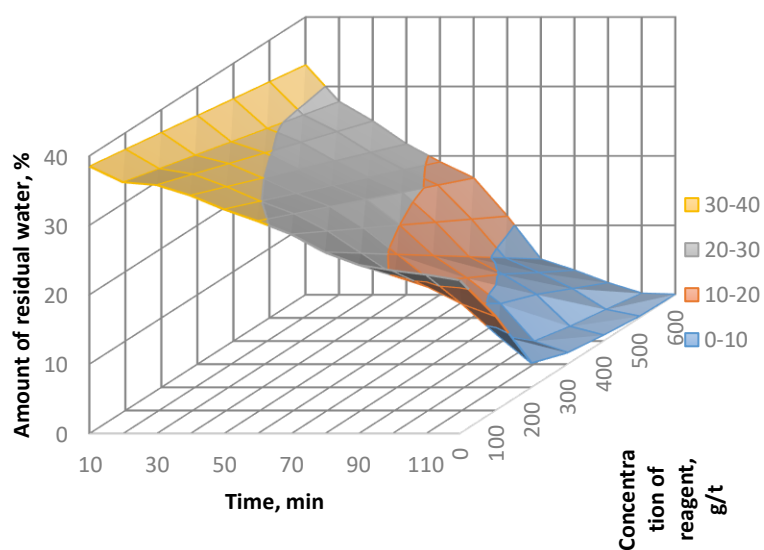


Fig. 8. Dependence of residual water content in Muradkhanli oil on time and A-1 concentration at a temperature of 60 °C

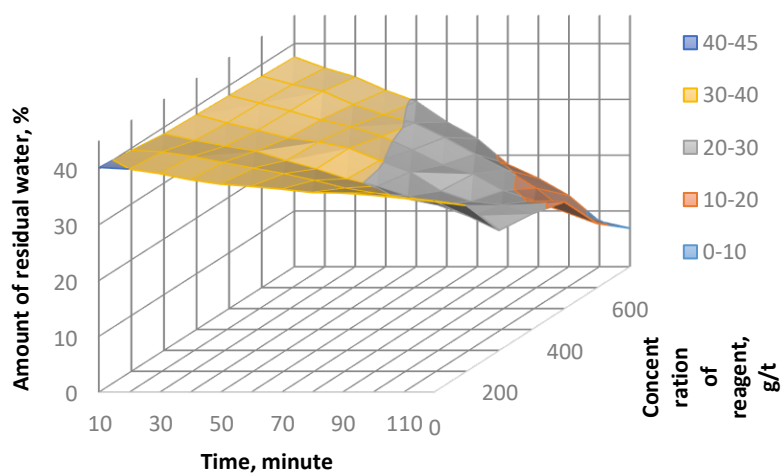


Fig. 9. Dependence of ballast water content in Muradkhanli oil on time and A-1 concentration at a temperature of 40 °C

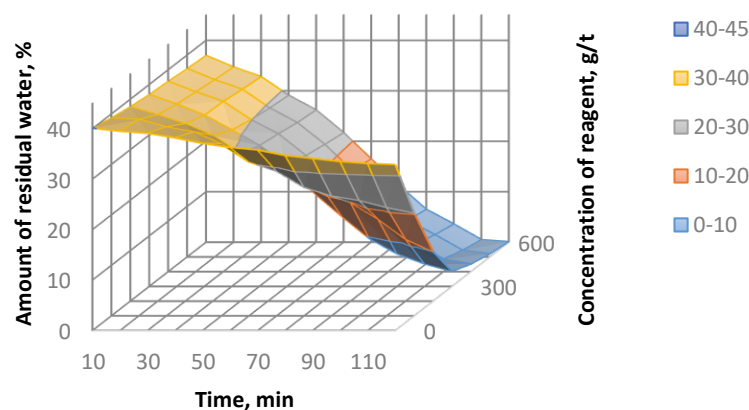


Fig. 10. Dependence of ballast water content in Muradkhanli oil on time and A-1 concentration at a temperature of 50 °C

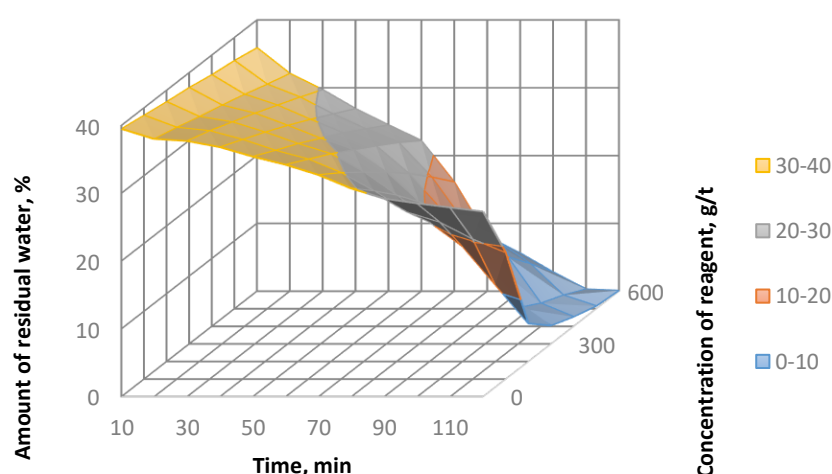


Fig. 11. Dependence of ballast water content in Muradkhanli oil on time and A-1 concentration at a temperature of 60 °C

From the 3D figs, we can observe that the surface areas dependent on the amount of water are represented in different colors. The 0–5 interval represents the minimum water amount; thus, the color area that covers a larger region indicates that the amount, time, and temperature are yielding the highest results. This is evident in the dependencies of ballast water and residual water at a temperature of 60 °C, as observed in Fig. 6 to 11.

In recent years, empirical modeling based on non-linear difference series (numerical series) and differential equations, including multi-dimensional equations, has been increasingly employed. The application of empirical modeling, as opposed to theoretical modeling, is related to the fact that many problems lack theoretical foundations or are limited by theoretical constraints (poorly solved) and that theoretically obtained models can be computationally more expensive. At the same time, empirically obtained models can provide quick solutions. The creation of empirical or semi-empirical models for complex

physical phenomena involves a detailed study of the experimental curve due to its complexity. This is because the creation of phenomenological models for complex processes characterized by continuous changes in flow nature is theoretically unknown or very complex. For most complex phenomena, there is a need to develop empirical models for large ranges of parameter variability with minimal cost, and in many cases, piecewise approximations in the form of empirical equations are used for different flow areas. The difficulty in developing empirical models for complex physical phenomena primarily involves the analysis and study of the experimental curve across the entire region, along with the identification of characteristic points and transitions associated with its modification.

It is known that the following conditions must be fulfilled in order to establish the empirical model that describes the experimental research:

- Ensuring the boundary conditions of the problem for the experimental curve.

$$Y(x)\Big|_{x=0} = Y_0(x) \cdot Y(x)\Big|_{x \rightarrow \infty} = Y_\infty(x) \quad (3)$$

– Specifying characteristic points on the experimental curve (such as inflection points, extremum points, regions of increase or decrease of the curve, etc.);

– Ensuring steady-state conditions in certain regions of the curve.

The construction of the final model and the selection of smoothing functions for different regions of the curve involve choosing smoothing functions that match the form of the experimental curve, adhering to all boundary conditions, and

successfully estimating the coefficients of the unknowns included in the equation.

The dependence of demulsification on the amount of demulsifier allows us to conclude that it reflects a non-linear relationship (Fig. 12). Nevertheless, we attempted to obtain a regression equation in polynomial form. Its form is as follows:

$$y = A_0 + A_1 \cdot x_1 + A_2 \cdot x_2 + A_3 \cdot x_3 \quad (4)$$

✓ A_0 is the intercept (constant term of the model)

✓ A_1 is the coefficient for demulsification time

✓ A_2 is the coefficient for temperature

✓ A_3 is the coefficient for the amount of A-1 composition

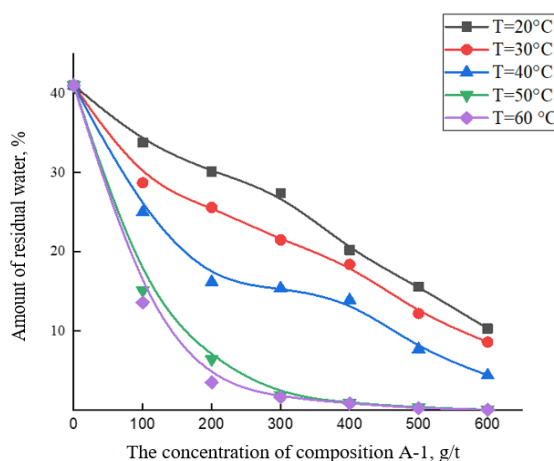


Fig. 12. Curve of demulsification dependency on the amount of demulsifier. Demulsification time – 120 min.
($y = 38.76 \cdot \exp(-0.01 \cdot x)$)

The coefficient A_2 (temperature) being higher than the coefficients of other factors confirms that temperature is the most significant parameter affecting the process.

The statistical indicators of the model for the demulsification process of Muradkhanli oil using the A-1 composition are as follows: Number of

points: 360; Degrees of freedom: 356; Residual sum of squares: 4419.19399; R-Square (COD): 0.89835; Adj. R-Square: 0.89749.

The curve of the experimental indicators and the curve of the calculated points based on the polynomial model are presented in Fig.13.

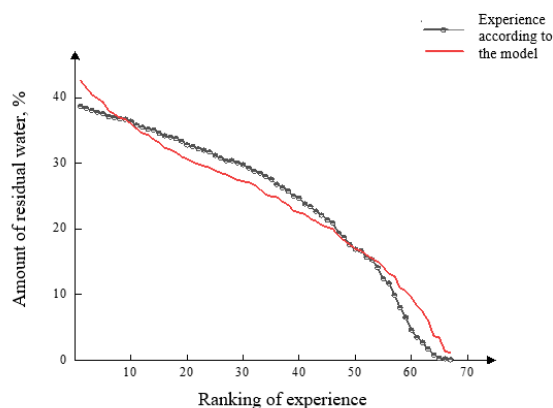


Fig. 13. Output curves for the 3-parameter polynomial model and experiments

This model is sufficiently adequate and accurately represents the profile of the variables. Although the reliability is quite high ($R^2 = 0.90$),

the model lacks physical meaning. Therefore, we sought to find a more suitable model.

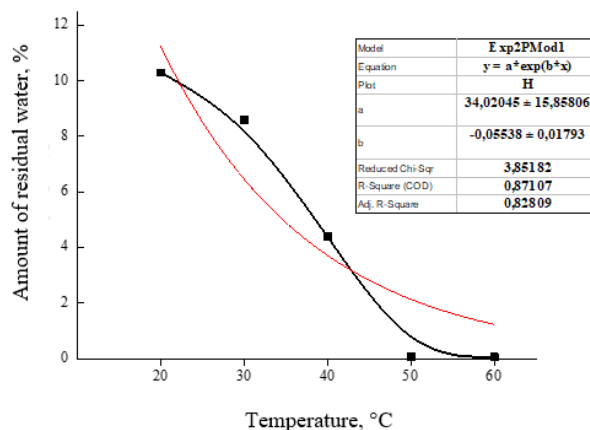


Fig. 14. Dependency curve of demulsification on temperature. Demulsification duration – 120 min.
 $(y = 34.02 \cdot \exp(-0.055 \cdot x))$

The effect of temperature on the demulsification process is, on average, 5.5 times greater than the effect of the demulsifier. The ratio of the coefficients in the regression dependencies (0.055 and 0.01) demonstrates this. This means that if an additional 25 g of demulsifier results in an extra 1 g of water being separated over a period of 2 hours, the same result can be achieved by increasing the temperature by 5 °C under the same conditions. However, exceeding the temperature limit can negatively impact the quality of the oils.

Considering that the initial amount of water in the emulsion is 41 % and that the residual water content in the emulsion, after a period of 2 hours with a certain amount of demulsifier, is 0.03 %, it is necessary for the function representing this dependence to include the y_0 parameter, which determines the initial and final amounts of water in the emulsion. The obtained experimental results are expressed by the following equation:

$$Y = y_0 \cdot \exp(-G \cdot k) \quad (5)$$

It is evident that when the amount of G demulsifier is zero, that is, in the absence of the composition's effect, demulsification does not occur; $Y = y_0 = 41$ (assuming the effects of gravity

on demulsification are negligible). As the amount of demulsifier increases, $Y = y_\infty$ approaches zero. This means that the selected function satisfies the boundary conditions.

Considering that the dependency of the k -coefficient on temperature for Muradkhanli field oil is simple, it can be expressed by the following simple formula:

$$k = \text{Intercept} + B1 \cdot T^1 + B2 \cdot T^2 \quad (6)$$

As a result, the amount of water separated from the emulsion at any temperature and any amount of demulsifier (demulsification time of 120 min) can be found using the following equation:

$$y = 41 \cdot \exp((1.79E-05 \cdot T + 3.59E-06 \cdot T^2) \cdot G) \quad (7)$$

A comparative analysis of the effect of demulsification at 60 °C and various amounts of demulsifier based on the model calculations is provided in Table 8. The small values of absolute and relative errors (max = 9.11 %) and the high values of determination coefficients (R-Square (COD) = 0.99 and adjusted R-Square = 0.95372) indicate that the proposed model accurately reflects the experimental data. The calculated F-test value being greater than the table value confirms the adequacy of the model.

Table 8

Comparative analysis of model calculations					
Separation of water from the emulsion		Relative error, %	Calculated value of the Fisher criterion	Tabulated value of the Fisher criterion F.INV.RT(0.05;2;2)	Statistical indicators of the model
According to the experiment. $Y_{\text{exp.}}\%$	According to the model. $Y_{\text{mod.}}\%$				
41	41.9	2.2	70	19	Reduced Chi-Sqr =0.18089
25	27	8.0			R-Square (COD)=0.95372
18	19	5.5			Adj. R-Square=0.99372
3	2.9	3.3			
0.3	0.28	6.6			

The factors affecting the separation of water from the oil dispersion system are the duration of the demulsification process, the amount of composition, and temperature.

After confirming that the report and experimental values match based on

mathematical modeling, the effect of the A-1 composition on the quality parameters of Muradkhanli oil was investigated and is shown in Table 9 [25].

Table 9

Physical-chemical indicators of Muradkhanli oil obtained in accordance with GOST 51858-2020 at the optimal concentration of A-1 composition

Nº	Indicators	Crude oil	Refined oil.	Refined oil with reagent	Conducted test methods
1	Density: at 20°C, kg/m ³	947.3	883.5	876.5	GOST 3900. ASTM D1298
2	Specific API, °API	-	27.94	29.98	ASTM D1250
3	Sulfur, % by mass	0.26	0.26	0.26	GOST 1437. GOST P 51947. ASTM D4294
4	Water content, % by mass	41.0	0.48	0.14	GOST 2477. ASTM D4006
5	Determination of kinematic viscosity. cSt	-	-	-	ASTM D445
	At 0 °C	487.89	118.78	112.63	
	At 10 °C	318.72	96.51	83.48	
	At 20 °C	239.97	78.53	71.46	
	At 30 °C	127.32	54.78	48.34	
	At 40 °C	93.51	29.56	21.14	
6	Saturated vapor pressure, kPa	11.7	22.3	23.6	GOST 1756. GOST 52340. ASTM D323
7	Freezing temperature, °C	+19.5	+12.5	+7.0	ASTM D5853
8	Amount of mechanical impurities, % by mass	5.86	0.0096	0.0087	GOST 6370. ASTM D473
9	Residue of coke in the fraction boiling above 260 °C, % by mass	-	4.78	4.27	ASTM D189
10	Mercaptan. Sulfur content, ppm	-	14.1	13.2	GOST P 50802. GOST 17323. UOP 163
11	Hydrogen sulfide, ppm	Not detectable	Not detectable	Not detectable	GOST P 50802. GOST 17323. UOP 163
12	Chlorides in oil, ppm	-	2.7	2.1	ASTM D4929
13	Amount of chlorides in the fraction boiling up to 204 °C, ppm	-	0.8	0.5	GOST 52247. ASTM D4929
14	Nitrogen content, ppm	-	1112	1109	ASTM D4629
15	Amount of salts, mg/L	534.3	79.6	23.8	GOST 21534. ASTM D3230
16	Acid number, mg KOH/g	-	2.97	0.14	GOST 5985
17	Ash content, % by mass	-	0.034	0.012	ASTM D482
18	Amount of asphaltenes, % by mass	4.5	4.3	3.9	IP 143
19	Amount of paraffins, % by mass	5.12	4.54	3.12	GOST 11851. BP 237/76
20	For the fraction boiling up to 360 °C: Iodine number (Bromine number), g/100g	-	3.6	3.2	GOST 2070-82. ASTM D1159/1160
21	Vanadium, ppm	-	7.1	6.9	ASTM D 5708
22	Nickel, ppm	-	3.8	3.5	ASTM D 5708
23	Iron, ppm	-	5.2	4.9	ASTM D 5708
24	Arsenic, ppm	-	11.9	11.4	ASTM D 5708
25	Copper, ppm	-	1.7	1.3	ASTM D 5708
26	Lead, ppm	-	1.5	1.3	ASTM D 5708
27	Sodium, ppm	-	12.1	11.7	ASTM D 5708
28	Silicon, ppm	-	18.7	18.5	ASTM D 5708
29	Aluminum, ppm	-	2.3	2.1	ASTM D 5708
30	Cadmium, ppm	-	43.6	43.4	ASTM D 5708

31	Mercury, ppm	-	52.8	52.6	ASTM D 5708
32	Molecular weight, g/mol	-	354.78	354.62	ASTM D2502
33	Characterizing factor	-	11.98	11.93	UOP 375
34	Distillation (at 101.5 kPa), °C	-	-	-	GOST 2177. ASTM D 86
	Initial boiling point	-	81	78	
	10% distillate	-	159	157	
	15 % distillate	-	185	183	
	20 % distillate	-	213	211	
	25 % distillate	-	241	238	
	30 % distillate	-	262	260	
	35 % distillate	-	283	281	
	40 % distillate	-	299	297	
	45 % distillate	-	323	321	
	50 % distillate	-	341	338	
	55 % distillate	-	345	343	
	60 % distillate	-	351	349	
	65 % distillate	-	361	357	
	70 % distillate	-	371	368	
	75 % distillate	-	374	372	
	80 % distillate	-	377	375	
	85 % distillate	-	381	379	
	Final boiling point.	-	383	382	
35	Amount of resins, % by mass	18.15	17.31	16.27	Chromatography method

It has been found from Table 9 that, according to the standard methodologies for genetic analysis of oils, there is no negative impact of the A-1 composition on the composition of Muradkhanli oil after demulsification. On the contrary, it was revealed that the amount of various foreign impurities in the oil composition was minimized.

Conclusion

1. For the first time, the demulsification process of heavy oil from SOCAR's Muradkhanli field, characterized by aggregate-kinetic stable water-oil emulsion, was studied using individual reagents ND-12 and Dissolvan-4411 at temperatures of 40 °C, 50 °C, 60 °C, and 70 °C. Additionally, the effects of newly prepared compositions with nominal names A-1 and A-2 at these temperatures were also examined, and their optimal concentrations were determined. It was established that the optimal concentrations of ND-12, Dissolvan-4411, A-1, and A-2 reagents are 600 g/t at the highest temperature.

2. Results from numerous experiments showed that at 70 °C, after two hours of treatment, the residual and ballast water content in Muradkhanli oil with a 41 % water cut, using the

optimal concentrations of ND-12 and Dissolvan-4411, was 1.1 % and 1.8 %, and 1.21 % and 2.0 %, respectively. However, at 60 °C, the residual and ballast water content in the tested oil samples with the optimal concentrations of the A-1 and A-2 new compositions was 0.06 % and 0.09 %, and 0.2 % and 0.3 %, respectively.

3. For the first time, a 3D graph was constructed showing the dependence of residual and ballast water content on demulsification duration, temperature, and concentration of the A-1 composition, which demonstrated the highest effectiveness in breaking stable water-oil emulsions. Mathematical modeling of the obtained results revealed that the most favorable demulsification conditions are achieved at 70 °C and a concentration of 600 g/t, under which the lowest values of both residual and ballast water were observed. These modeling results are in close agreement with the experimental data, thereby confirming the adequacy of the proposed model. Consequently, the use of the A-1 composition can be recommended as an economically and environmentally efficient reagent for application under field conditions.

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