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STRUCTURAL ANALYSIS OF THE HEAVY OIL DEMULSIFICATION PROCESS

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During oil production and its movement with produced water, stable oil emulsions containing water are formed. The reason for the formation of oil emulsions is the effective mixing of oil with produced water during its rise through the wellbore and subsequent movement along industrial pipelines. The process of deemulsification (dewatering of emulsions) is considered one of the key technological difficulties encountered in the oil industry. The high stability of emulsions formed on the basis of heavy oil is associated with the high concentrations of resins and asphaltenes in their composition. The article provides a systematic analysis of the demulsification of heavy oil emulsions, highlighting the detailed study of their physicochemical properties in developing effective deemulsification methods. Particular emphasis is placed on the potential of using environmentally safe and biodegradable demulsifiers. The analysis of the conducted studies is of practical and theoretical importance for specialists and researchers in the field.

Keywords: *Deemulsification, emulsions, biodemulsifiers, mineral salts, asphaltenes, resins, high-viscosity oil fields*

INTRODUCTION

The presence of mechanical impurities in the oil composition - especially sand and clay particles – leads to numerous technological and operational challenges. These impurities accelerate the intensive wear of pipelines and transport equipment, complicate processing operations, and also increase the amount of fuel oil and tar. Simultaneously, the formation of deposits in refrigeration units, furnaces and heat exchangers leads to a decrease in heat transfer capacity and, as a result, to more rapid equipment failure. Furthermore, mechanical impurities often create conditions for the formation of stable emulsions that are difficult to separate. The presence of mineral salts either in crystalline form or dissolved poses further challenges. These salts intensify corrosion in pipelines and transport systems and increase the stability of emulsions that complicate their technological processing [1-2].

As a result of the abovementioned factors, there is a need for complex oil treatment prior to transportation. This treatment process involves the removal of mechanical impurities, water, mineral salts and gas from the oil composition. Preparation of oil for transportation is carried out in accordance with the requirements of existing regulatory documents and technical standards, which impose strict requirements on the product's quality [4, 9].

STRUCTURAL ANALYSIS

To determine the optimal method for oil purification, namely, the demulsification process, it is essential to conduct a comprehensive study of emulsion formation mechanism and their properties. Emulsions begin to form at the early stage of oil production, starting from the movement of oil from the reservoir to the wellhead, and continue to develop during the transportation process in the mining infrastructure. In other words, emulsions form in areas where oil and water are in continuous contact and subjected to mixing. The intensity of emulsion formation in the well mainly depends on the production technology, which, in turn, defined by the geological characteristics of the reservoir, the exploitation period and the physicochemical properties of the oil [5].

The development of the fuel and energy complex of Azerbaijan involves not only the exploration of new, promising oil and gas fields, but also the intensified production from existing ones. Currently, a large number of high-viscosity oil fields are being developed. These oils, in most cases, exhibit abnormal characteristics and are non-Newtonian fluids, which creates additional challenges during extraction and complicates the transportation of the extracted product [7, 8, 10].

The presence of water in oil increases transportation costs, while mineral salts in the crystalline form and aqueous solutions in oil accelerate corrosion of metal surfaces in equipment and pipelines. Mechanical impurities in oil lead to the wear of pumps and pipeline systems, deterioration of the quality of the refined oil products, and disruption of the oil processing operations. All these factors necessitate the importance of oil preparation. Oil preparation is a treatment process aimed at removing impurities from oil (water, mineral salts, mechanical impurities, light hydrocarbon gases). These components hinder both the transportation and further processing of oil [3, 6]. One of the significant challenges during oil production and oil sludge processing is the separation of water-oil emulsions, which vary in composition and stability. Today, in many major oil fields in our country and abroad, water saturation exceeds 80%. The water and mechanical impurities extracted alongside the oil are not completely separated and often form stable emulsions. Further processing of these emulsions requires special equipment and highly efficient demulsifiers to ensure the production of high-quality crude oil.

Currently, the following methods are primarily used to break conventional crude oil emulsions: thermal (heating and microwave irradiation), mechanical (gravity sedimentation, centrifugation, filtration, membrane and ultrasonic treatment), chemical, biological, electrical and magnetic methods. Among these, the most widely applied method is the combined use of heating and chemical demulsifiers.

In thermochemical and electro-desalination plants, the amount of salt and water in the oil is reduced to acceptable levels, enabling the production of first-grade oil. Demulsifiers are used to resolve these challenges. These chemical reagents, in addition to their primary functions, must have the ability to break down oil emulsions on an industrial scale, and certain requirements are imposed on them [11]. The demulsifier must have high activity so that it can break down the emulsion even with low doses. Along with activity, the addition of this substance should not adversely affect the quality of the oil and final refined products. The demulsifier must be able to mix effectively with the system in which it is introduced and establish close contact with the emulsifier.

During the processing of an oil emulsion, the demulsifier enters the oil phase and interacts with the protective layers on the surface of the emulsified water droplets. As a result, there may be a connection between the composition and structure of the stabilizer on the surface of the water droplets and the composition and structure of the demulsifiers capable of effectively breaking the emulsion.

RESULTS AND DISCUSSION

To examine the connection between the demulsifiers properties and the hydrocarbon composition of the oil, the emulsions were classified into three groups based on the ratio of total asphaltene and resin content to paraffin: Mixed type (ratio 0.75 – 1.39); Resin type (2.16 – 3.28); High resin type (above 4).

This is a conditional classification to some extent, which allows to identify trends in the processing of oil emulsions with different hydrocarbon compositions using demulsifiers. The obtained regularities make it possible to identify the most effective subgroup of compounds within this class, select raw materials based on structural characteristics, and develop a production technology for these substances. This approach enables the production of substances with high demulsification ability, suitable for the preparation technologies of oil with diverse physicochemical properties [12].

Chemical demulsification is one of the most widely used and versatile methods for breaking various types of emulsions. The essence of this method is the addition of chemicals (demulsifiers) to disrupt the stability of emulsions. Since the demulsifier is a surface-active compound, when added to the emulsion, it enters the oil-water interface, disrupts the solid layer there, and causes the coalescence of water droplets [13, 15].

Emulsions formed as a result of the hydration of oils with complex rheological properties are highly stable and cannot be effectively separated by mechanical sedimentation methods under normal temperature conditions. Therefore, it is essential to apply combined methods for the demulsification of such emulsions. The main technology widely used in the oil fields of Azerbaijan is the thermo-chemical demulsification method. This method offers a significant economic advantage over other methods. Currently, approximately 80% of water-oil emulsions are processed by using the thermo-chemical method.

The widespread adoption of the method is influenced by several key factors. These include the ability to perform the treatment process regardless of the water content in the oil, without requiring modifications to existing equipment and technology. Additionally, the structural simplicity of the devices and the circumstances created for the application of various demulsifiers are suitable for the specific physicochemical properties of the emulsion without modifying the equipment [14].

During oil production and its movement with produced water, stable oil emulsions containing water are formed. These emulsions form primarily due to the intense mixing of oil with produced water as it rises to the surface of the earth in the wellbore and then moves along industrial pipelines. The most common type of emulsions encountered in the oil and gas industry are "water-in-oil" type emulsions. The dispersion of water droplets in oil is facilitated by the surface -active materials (SAMs) contained in crude oil, such as asphaltenes, paraffins, resins and naphthenic acids. These SAMs exist in suspension form [16 - 17]. The density of these natural SAMs contribute significantly to the stability of the emulsions and is generally higher in heavy oils than in light oils. Among other parameters, the quality of the crude (produced) oil is influenced by its moisture content, which can vary can range from 90% to 0.1%. Another quality of crude oil is salt content, which can vary from a few mg/l to g/l. Water and salts in oil create a number of difficulties in the transportation and processing. The effectiveness of the used demulsifier reagents plays a crucial role in addressing these during the collection and initial (treatment) preparation of crude oil. Although, there are many types of demulsifiers, it is often not possible to remove water to the required extent in oil wells collection and processing systems. The increase in the share of high-viscosity oils and water content make this challenge even more pressing. The use of compositional substances is several times more effective than the use of any substance in its pure form. Based on the above, the development of new compositional demulsifiers based on existing and available surfactants becomes relevant [18]. The selection of effective demulsifiers is carried out in two stages: in the first stage, promising demulsifiers are selected from among existing reagents as a result of numerous experiments; in the second stage, the most effective demulsifiers with higher activity than those used in the field are identified from among promising reagents. Moreover, ongoing work is being done to modify existing demulsifiers and study their synergistic effect with other reagents [19-20]. It is often found the demulsifiers selected for testing are not sufficiently effective under specific circumstances. In this case, a blending approach is applied, which essentially means developing a new demulsifier formula. For this, there are dozens, even hundreds of such components available to manufacturers, typically categorized into functional groups. Each group is assumed to have similar effect on the emulsion, such as rapid water separation, the formation of a clear-water interphase boundary, or the low hydrocarbon content in the separated water. However, in practice, it is difficult to assess how a specific functional base group will function under particular circumstances until laboratory tests are conducted. This is due to the fact that the properties they display are mostly determined by the features of the emulsions being processed and the state of technology.

The primary disadvantages of chemical demulsification are the contamination of the separated products, as well as the toxicity and non-biodegradability of the chemicals used in the separated water during demulsification. Furthermore, this method may not always be economically viable for the demulsification of all kinds of oil emulsions.

Another method developed in recent years for the breakdown of oil emulsions is biological demulsification. A biodemulsifier is a type of biologically active substance that helps to destabilize oil emulsions. Biodemulsifiers are eco-friendly and their use does not cause secondary pollution. One of the key advantages of biodemulsifiers is that they can be obtained from agricultural and industrial wastes [21].

However, although this approach is environmentally safer and economically more profitable, it is time-consuming and very sensitive to operating conditions. It should be noted that heavy oil emulsions have rarely been applied in research in this field.

In the preparation of oil in the mining conditions, not only the type of demulsifier, but also the processing technology plays a critical role. Chemical demulsification of oil emulsions consists of two stages: delivery of the demulsifier to the surface of emulsified water droplets and penetration of the demulsifier into the protective layer and its dispersion. The first stage is particularly crucial, since it limits the process of disintegration of the protective layers. It depends on the method of introducing the demulsifier, its physicochemical properties, the composition of the oil phase and the turbulence of the flow. The solubility of the demulsifier in the oil phase has a significant impact on the effectiveness of this stage. To influence this stage, the hydrodynamic parameters of the emulsified flow are changed and the method of introducing the demulsifier is selected.

In the second stage of chemical demulsification, the key process is the interaction between the demulsifier and the surface of water droplets. This process can be intensified by creating defects or stress concentrators in the protective layers by mechanical or physical means, facilitated by the demulsifier. In Azerbaijan, a reagent known as "Petrov contact" was used as a demulsifier and was referred to in the industry as "illuminated contact". Subsequently, neutralized black contact (NBK) and its various modifications were introduced into production. Since 1967, "Disolvan-4411", a foreign- made demulsifiers, has been widely used in the country. Significant research on the development of effective demulsifiers has also been carried out in Russia (Bashkiria, Tatarstan). In the late 1980s, Azerbaijan began importing the "Reapon-4" reagent from Tatarstan. However, to this day, "Disolvan" remains the most well-known foreign demulsifier used in the region. Among domestically produced products, "ALKAN DE-202" and "ALKAN DE-318" reagents are quite competitive, according to the results of recent years [22].

The demulsification performance of various demulsifiers of both domestic and foreign production (Proksanol 186, 305, Proksamin 385, Oksiphos, Diprosamin 157, Sulfanol, as well as products from German companies “HEKST” and “BASF”, and the Japanese company “HYBBELKS”, etc.) was evaluated on emulsified oils of the Oil and Gas Production Departments (OGPDs) of the “Azneft” Production Union. According to the results of the conducted studies, many reagents did not demonstrate sufficient economic efficiency. Their application caused additional costs, which was economically inefficient. Studies conducted in recent years have indicated that the effectiveness of the reagent depends on the water content of the emulsion, and the stability of the emulsion depends on the qualitative composition of the oil. Therefore, the dosage of the reagent is often not precisely maintained in the technological instructions, the amount of the reagent varies depending on the qualitative and quantitative composition of the oil. For this reason, there is a need to develop new technologies based on the combined application of reagents and physical fields.

The studies used oil samples with varying emulsion stability, water content, and physicochemical properties. Results showed that mechanical impurities and paraffin-resin components in the oil reduced the effectiveness of demulsifiers, complicating the selection of an appropriate reagent.

The experiments were carried out under circumstances where reagent consumption ranged from 50–300 g/ton and the temperature varied between 313 and 348 K. Oil samples with different degrees of water content were analyzed after a four-hour settling phase. The residual water content in the obtained product was measured using a Dinah–Stark apparatus. The results from the “Muradkhanli” oil field are presented in Table [7].

Table.

Results of dehydration of "Muradkhanli" oils with demulsifiers

OGPD	Initial amount of water in oil, %	Chemical reagents	Reagent consumption, q/t	Heating temperature, K	Amount of water remaining in oil, %
Muradkhanli oil	40,0	Disolvan 4490	100		38,7
			200		36,5
			300		30,2
	68,0	Separol-3341	100		1,5
			150		1,0
			200		0,9
			100		39,2
			200		38,9
			300		38,6
			100		39,1
			200		37,8
		Separol 25	100		39,2
			200		30,8
			300		68,0
		Progalit 444	100		39,1
			200		37,8
			300		36,9
		Dislovan 4411	100		39,2
			200		30,8
			300		30,2

CONCLUSION

This article provides a general scientific overview of the current state of research on heavy oil demulsification, highlighting the main challenges and existing technologies. The specific advantages and limitations of each method, their different efficiency indicators, energy and time consumption, and the level of compliance with environmental requirements are examined. The benefits of "positive" demulsification methods, which are considered harmless and eco-friendly, are particularly analyzed in this context.

The study particularly emphasizes how crucial it is to accurately determine the physicochemical properties and parameters of heavy oil emulsions in order to develop effective demulsification methods. Simultaneously, attention is drawn to key research gaps that remain insufficiently explored and are relevant for future research. Therefore, the impact of high oil viscosity on the stability of emulsions, as well as the absence of demulsification processes in real field settings or on production sites are identified as current research gaps.

It is expected that this article will open up new scientific directions for experts and researchers in the field, fostering the formation of innovative ideas and contributing future technological advancements.

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AĞIR NEFTLƏRİN DEMULSASİYA PROSESİNİN STRUKTUR TƏHLİLİ

H.T. Əliyeva, M.R. Manafov

Neftin hasilatı zamanı və onun lay suyu ilə birgə hərəkəti nəticəsində su tərkibli dayanıqlı neft emulsiyaları əmələ gəlir. Neft emulsiyalarının yaranmasının səbəbi, neftin lay suyu ilə birlikdə quyunun gövdəsində yer səthinə qalxması və daha sonra sənaye kommunikasiyaları boyunca hərəkəti zamanı effektiv qarışmasıdır. Deemulqasiya (emulsiyaların susuzlaşdırılması) prosesi neft sənayesində qarşıya çıxan əsas texnoloji çətinliklərdən biri kimi qiymətləndirilir. Ağır neft əsasında formalaşan emulsiyaların yüksək stabilliyi onların tərkibindəki qatran və asfaltentlərin yüksək qatılıqları ilə əlaqədardır. Məqalədə ağır neft emulsiyalarının deemulqasiyası məsələsi sistemli şəkildə təhlil olunur və bu emulsiyaların fiziki-kimyəvi xüsusiyyətlərinin dərindən öyrənilməsinin effektiv deemulqasiya metodlarının işlənib hazırlanması baxımından mühüm rol oynadığı göstərilir. Xüsusi olaraq, ekoloji baxımdan təhlükəsiz və bioloji parçalanabilən deemulqatorların tətbiq perspektivlərinə diqqət yönəldilmişdir. Aparılmış tədqiqatların analizi sahə üzrə mütəxəssislər və tədqiqatçılar üçün praktik və nəzəri əhəmiyyət kəsb edir.

Açar sözlər: *Deemulqasiya, emulsiyalar, biodeemulqator, mineral duzlar, asfaltenlər, qatranlar, yüksək özlülüklü neft yataqları*

СТРУКТУРНЫЙ АНАЛИЗ ПРОЦЕССА ДЕЭМУЛЬГАЦИИ ТЯЖЕЛОЙ НЕФТИ

Х.Т. Алиева, М.Р. Манафов

В процессе добычи нефти и её перемещения с пластовой водой образуются устойчивые нефтяные эмульсии, содержащие воду. Причиной образования нефтяных эмульсий является эффективное смешивание нефти с пластовой водой при её подъёме по стволу скважины и последующем движении по промысловым трубопроводам. Процесс деэмульгации (обезвоживания эмульсий) считается одной из ключевых технологических трудностей, возникающих в нефтяной промышленности. Высокая устойчивость эмульсий, образующихся на основе тяжёлой нефти, связана с высоким содержанием смол и асфальтенов в их составе. В статье представлен системный анализ процесса деэмульгации тяжёлых нефтяных эмульсий, в котором особое внимание уделяется детальному изучению их физико-химических свойств для разработки эффективных методов деэмульгации. Особое внимание уделено перспективам использования экологически безопасных и биоразлагаемых деэмульгаторов. Анализ проведённых исследований имеет практическое и теоретическое значение для специалистов и исследователей в данной области.

Ключевые слова: *Деэмульгация, эмульсии, биодеэмульгаторы, минеральные соли, асфальтены, смолы, месторождения высоковязкой нефти*