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Кафедра Геологии и разработки нефтяных месторождений

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Тема работы
Анализ эффективности проведенных мероприятий по интенсификации добычи нефти и увеличению нефтеотдачи пластов на А. нефтяном месторождении (ХМАО)

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Введение

В настоящее время, подавляющее число нефтяных месторождений России находится на последней стадии разработки, характеризующейся высокообводнённым (более 95%) фондом скважин, увеличением доли трудноизвлекаемых запасов в общей структуре запасов. Поэтому проблема повышения нефтеотдачи пластов на заключительных этапах разработки месторождений очень актуальна, так как вследствие естественного снижения извлекаемых запасов для большинства залежей и месторождений коэффициент нефтяной отдачи довольно низок.

Значимость методов по интенсификации добычи нефтикратно возрастает с вводом в разработку нефтяных месторождений с малопродуктивными пластами. Опыт показывает, что проблема интенсификации возникает практически с момента вскрытия продуктивных пластов в процессе бурения скважин. Она может быть решена с применением качественных буровых растворов, соответствующей техники и технологических приемов крепления скважин, обеспечивающих надежное разобщение продуктивных пластов и исключая возможность их кольматации.

Другая, не менее важная проблема – это восстановление продуктивности скважин, которая, как известно, снижается в процессе их эксплуатации по самым разнообразным причинам, например, отложение неорганических солей, высокомолекулярных компонентов нефти, образование стойких эмульсий и т.д.

Нередко продуктивность скважины снижается из-за нарушения технологии подземного ремонта скважин, а также при проведении ремонтно-изоляционных работ по ограничению притока воды из продуктивных пластов и т.д.

И, наконец, третья проблема – это увеличение коэффициента продуктивности скважины. Особую актуальность эта проблема приобретает в связи с необходимостью разработки месторождений с трудноизвлекаемыми

запасами нефти. Она решается, как известно, применением гидравлического разрыва пласта, гидropескоструйной перфорации, применением различных вариантов кислотных обработок. Развиваются и другие направления в разработке методов воздействия на призабойную зону пласта с целью увеличения коэффициента продуктивности скважин.

Целью данного проекта является анализ эффективности проведенных мероприятий по повышению нефтяной отдачи пласта.

Актуальность данной темы заключается в том, что значимость методов по интенсификации добычи нефти кратно возрастает с вводом в разработку нефтяных месторождений с малопродуктивными пластами. Увеличение коэффициента продуктивности скважины поможет в процессе разработки месторождений с трудноизвлекаемыми запасами нефти.

Задачи:

- изучить Геолого-технические характеристики месторождения;
- рассмотреть проведенные геолого-технические мероприятия по интенсификации добычи нефти;
- проанализировать влияние геолого-технических мероприятий на добычу нефти;
- рассчитать экономический эффект.

Аннотация

В первой части дипломного проекта рассматриваются общие сведения о месторождении, его расположение и характерные особенности территории, геолого-физическая характеристика А. месторождения, представлена оценка запасов нефти данного месторождения, текущее состояние разработки А. месторождения, представлен анализ структуры добывающего и нагнетательного фонда скважин.

Данное месторождение имеет некоторые особенности:

- по запасам нефти многопластовое, крупное;
- территория месторождения сильно заболочена, с многочисленными мелкими озерами;
- площадь месторождения представляет собой платообразную возвышенность с сильно денудированными склонами, изрезанными оврагами.

Геологический разрез А. месторождения сложен толщей мезозойско-кайнозойских пород, залегающих на поверхности палеозойского фундамента.

Керновым материалом разрез месторождения охарактеризован неравномерно. Наиболее полно изучены в этом отношении отложения, к которым приурочены промышленно нефтеносные горизонты, то есть нижняя часть алымской, верхняя часть ванденской свит, содержащие продуктивные пласты АВ₁³–АВ₅, подошва ванденской (БВ₆) и кровля мегионской (БВ₈) свит. Достаточно полно изучена васюганская свита, в кровле которой выделяется продуктивный пласт Ю₁¹.

А. месторождение находится на осложняющей третьей стадии разработки, которая в основном характеризуется снижением добычи нефти, низким темпом отбора нефти от НИЗ, уменьшением фонда скважин вследствие их обводнения. На А. месторождении за последние 8 лет отмечается более высокая тенденция падения уровней добычи нефти. Вновь вводимые и исторические скважины характеризуются более низкими показателями разработки, нежели ожидалось.

Во второй части дипломного проекта рассматриваются все геолого-технические мероприятия, направленные на повышение нефтеотдачи пласта проводимые на данном месторождении.

На А. месторождении в процессе всего периода разработки применяли различные виды мероприятий по интенсификации добычи нефти и увеличению нефтеотдачи пластов. В целом их можно разделить на несколько групп, а именно:

- зарезка боковых стволов;
- гидравлический пласта (ГРП);
- переводы скважин на другой объект разработки;
- перфорационные работы по дострелам и перестрелам объектов разработки (ПВР);
- физико-химические ОПЗ скважин;
- ремонтно-изоляционные работы (РИР);
- выравнивание профиля приемистости;

В целом на месторождении проведено 3589 мероприятий по интенсификации добычи нефти и увеличению нефтеотдачи пластов. Всего за весь период разработки месторождения за счет указанных мероприятий было добыто 11,9% накопленной добычи нефти месторождения.

В третьей части дипломного проекта рассматривается технологическая эффективность всех проведенных мероприятий по повышению нефтеотдачи пласта. Так же в данной части дипломного проекта будет сравнена расчетная технологическая эффективность мероприятий с данными промысла.

В четвертой части проведен расчет экономической эффективности производства гидромеханической щелевой перфорации перед проведением работ гидравлического разрыва.

Обоснование эффективности проведения мероприятий производится на основе сравнения его с базовым вариантом, в качестве которого принимается ситуация без проведения мероприятия. Прирост накопленного потока денежной наличности составляет около 50%.

В пятой части дипломного работы рассмотрена социальная ответственность оператора добычи нефти и газа. Описаны виды вредного воздействия на окружающую среду. Проведен анализ всех опасных и вредных факторов рабочей зоны, таких как: шум, метеорологические условия, электромагнитное излучение, вредные вещества, электрический ток и пожар.

Enhanced Oil Recovery

By nature crude oil is a limited resource. Nevertheless, the amount of crude oil available has to meet the worldwide demands. From time to time, oil production has been intentionally reduced, and this has resulted in serious oil crises accompanied by a general increase in the oil price. This in turn has forced the oil industry to recover oil from more complicated areas, where the oil is less accessible meaning that recovery techniques are constantly advanced. This has contributed to the development of techniques for enhanced oil recovery, (EOR), which while used today, also constantly undergo further advancement and development. Up to two thirds of the crude oil remains trapped in the reservoirs after primary and secondary recovery in an average oil reservoir, [Rosen et al., 2005]. EOR is then required to optimize the depletion, as the remaining oil is trapped in the pore structure inside the reservoir. EOR covers several different advanced recovery techniques, which will be introduced in this chapter.

The focus in this thesis has been on the phase behavior properties inside the reservoir in connection with surfactant flooding and oil/ brine systems. The phase behavior in the surfactant system is overall the most important factor determining the success of a chemical flood [Skauge and Fotland, 1990]. Currently, there are no adequate models (such as equations of state) to describe phase behavior in such systems. Consequently phase behavior must be measured experimentally, which is both challenging and time-consuming.

1.1 Enhanced Oil Recovery

Several mechanisms contribute to the primary production of oil. Primary production is in general understood as rather inefficient, as it produces less than 20 % of the original oil in place, [Morrow, 1991, p.5]. With the goal of improving oil recovery, EOR is introduced, employing more efficient recovery methods. Oil recovery methods usually fall into one of the following three categories:

- Primary recovery: Recovery by depletion
- Secondary recovery: Recovery by water or gas flooding

- Tertiary recovery: Recovery of the residual oil (also known as Enhanced Oil Recovery, (EOR))

It is not unusual that the so-called tertiary oil recovery takes place either as the primary or the secondary step chronologically, because this entails a more feasible process for certain reservoirs, [Green & Willhite, 1998, pp.1-10]. Another commonly used designation is improved oil recovery (IOR), which covers a broader range of activities. IOR can also include EOR, where IOR and EOR in general are defined as follows:

- Improved Oil Recovery (IOR): Injection of fluids, which are already present in the reservoir, e.g. water.
- Enhanced Oil Recovery (EOR): Injection of fluids, which are not normally present in the reservoir, e.g. surfactants.

The concepts of IOR and EOR in practice are often mixed. Nowadays, oil recovery processes are typically classified as primary, secondary and EOR processes. From a fundamental point of view EOR should be understood as methods or techniques whereby extrinsic energy and materials are added to a reservoir to control:

- Wettability
- Interfacial tensions (IFT)
- Fluid properties
- Establish pressure gradients necessary to overcome retaining forces
- Move the remaining crude oil in a controlled manner towards a production well.

One aspect of EOR operations, which in all processes has a considerable influence on the result, is the ability to control the flow of the displacement fluid, so-called mobility control. Since flow pattern prediction is very uncertain, predicting oil recovery becomes difficult. These uncertainties challenge EOR processes. While it is desirable to design the most efficient process in order to increase oil recovery,

economic feasibility of the EOR process is more crucial than any other aspect, in order to commercialize the process [Sharp, 1975].

1.1.1 EOR Processes

Much work has been performed in the area of fluid injection with the objective of improving oil recovery by the natural drive mechanism. The most widely used technique is waterflooding, which has been applied for more than 60 years. The oil left in the swept zone after waterflooding then becomes the main target for tertiary oil recovery, [Morrow, 1991, p.6-10].

The primary goals in EOR operations are to displace or alter the mobility of the remaining oil in the reservoir. Using conventional waterflooding techniques is preferable as long as it is economically feasible. Remaining oil left after primary and secondary recovery operations over long time periods is usually distributed in pores in the reservoir, where the oil is trapped, mainly due to capillary forces and viscous forces. EOR techniques will contribute to a longer lifetime of already existing reservoirs. Unfortunately the application of EOR does not only bring advantages. Using EOR is correlated with higher risks and increases the requirement for additional facilities and investments. The common classifications of different EOR processes are [Green and Willhite, 1998, p.1-10]:

- Mobility-control
- Chemical processes
- Miscible processes
- Thermal Processes
- Other (e.g. microbial EOR)

In general the EOR processes involve injection of gas or fluids into the oil reservoir, displacing crude oil from the reservoir towards a production well. The injection processes supplement the natural energy present in the reservoir. The injected fluid also interacts with rock and oil trapped in the reservoir creating advantageous conditions for oil recovery.

Mobility-control is a process based on maintaining favorable mobility ratios between crude oil and water, by increasing water viscosity and decreasing water relative permeability. Can improve sweep efficiency over waterflooding during surfactant processes.

Chemical processes are injection of a specific liquid chemical that effectively creates desirable phase behavior properties, to improve oil displacement. The principles are illustrated in figure 1.1.

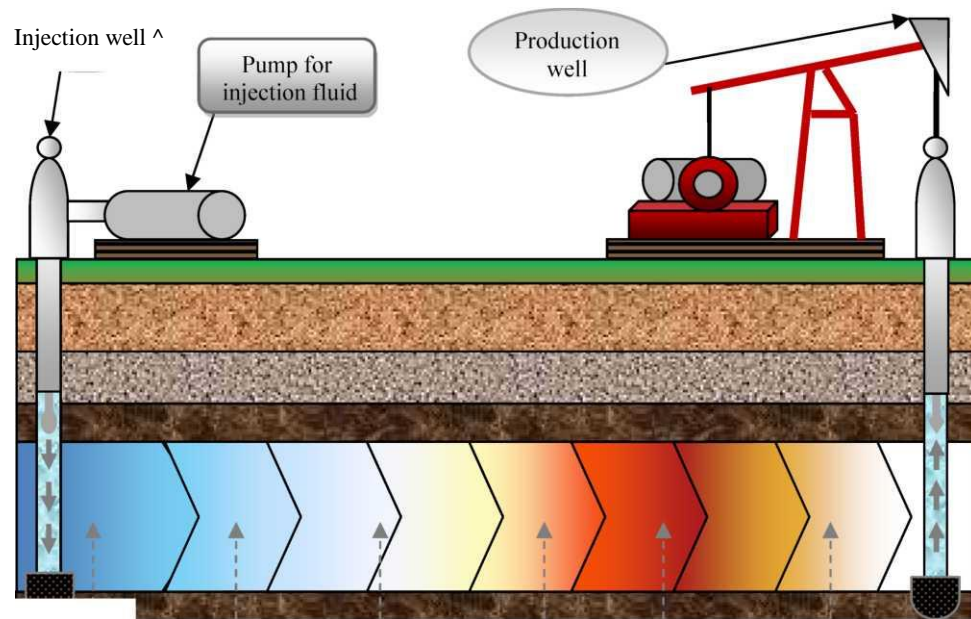


Figure 1.1. Chemical flooding, which is the injection of water and chemicals. Besides the economic point of view, the complexity rises as several additional tasks such as preflush of the reservoir and injection of additional fluids must be applied to accomplish an efficient process.

Surfactant flooding is an example of chemical flooding. This is a complex process, where the displacement is immiscible, as water or brine does not mix with oil. However, this condition is changed by the addition of surfactants. The technique creates low interfacial tension (IFT), where especially an ultra low IFT (0.001mN/m) between the displacing fluid and the oil is a requirement in order to mobilize the residual oil. The liquid surfactant injected into the reservoir is often a complex chemical system, which creates a so-called micelle solution. During surfactant flooding it is essential that the complex system forms microemulsions with the residual oil as this supports the decrease of the IFT and increases the mobility. However, the formation of microemulsions may also be a significant disadvantage, as microemulsions may plug the pores. It is also important to be aware of the high loss of surfactant, occurring as a result of adsorption and phase partitioning inside the reservoir. It is known that surfactant systems are sensitive to high temperatures and high salinity, leading to requirements for developing surfactant systems that can withstand such conditions. Other chemical processes have also been developed, such as alkaline flooding and various processes where

alcohols are introduced. In alkaline flooding, alkaline chemicals are injected into the reservoir, where they react with certain components in the oil to generate surfactants in situ. Alcohol processes have so far only been tested in laboratories and have not yet been applied in the field.

Miscible processes are based on the injection of a gas or fluid, which is miscible with the crude oil at reservoir conditions, in order to mobilize the crude oil in the reservoir. The process is illustrated in figure 1.2. This process relies on the modification of the components either in the injected phase or in the reservoir oil phase. Modification of either injected fluid or gas or the reservoir oil is achieved through multiple contacts between the injected phase and the oil phase with mass transfer of components between the phases, [Green & Willhite, 1998, p.7]. E.g. injection of CO₂ as a liquid will entail extraction of the heavier hydrocarbons from the reservoir oil, which will allow the displacement front to become miscible, [Holm, 1986].

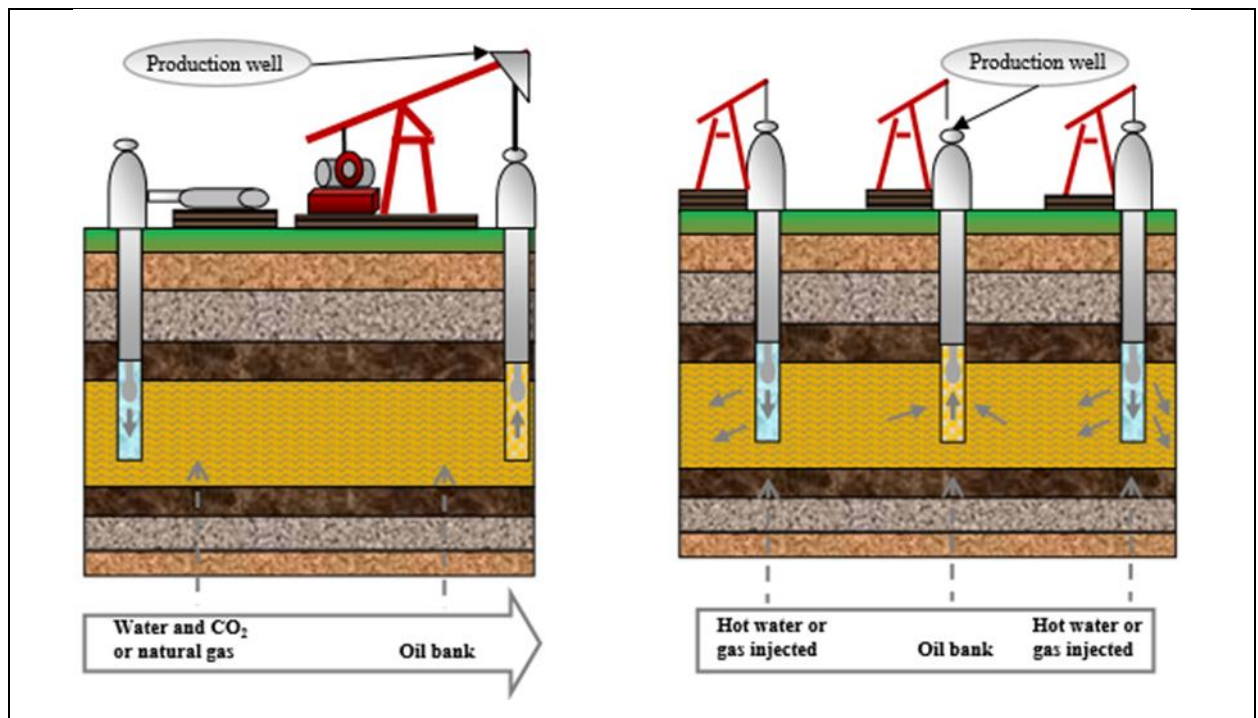


Figure 1.2. Miscible process control, where the injected fluid does mix with oil. In this process the oil is supposed to be mobilized

Figure 1.3. Thermal process control. Thermal energy is injected into the reservoir. The injected energy mobilizes the trapped oil and

Thermal processes are typically applied to heavy oils. Thermal recovery processes rely on the use of thermal energy. A hot phase of e.g. steam, hot water or a combustible gas is injected into the reservoir in order to increase the temperature

of the trapped oil and gas and thereby reduce oil viscosity, [Green and Willhite, 1998, p.301]. The process is depicted in figure 1.3. The injected hot stream facilitates the flow to the production wells by increasing the pressure and reducing the resistance to flow.

1.2 Surfactant Flooding

Surfactant flooding is injection of one or more liquid chemicals and surfactants. The injection effectively controls the phase behavior properties in the oil reservoir, thus mobilizing the trapped crude oil by lowering IFT between the injected liquid and the oil. The principle of surfactant flooding is illustrated in figure 1.4.

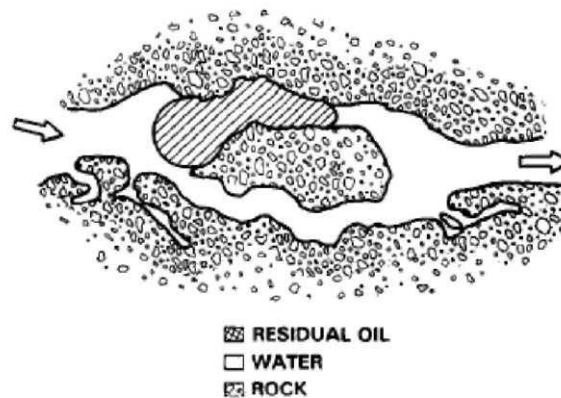


Figure 1.4. Principle of flooding, where residual oil is trapped in the reservoir, [O'Brien, 1982]. For the movement of oil through the narrow capillary pores, very low oil/water interfacial tension (IFT) is required; preferably ultra low IFT at 0.001 mN/m is desirable.

There is a great potential for chemical processes with surfactant flooding, since there is the possibility of designing a process where the overall displacement efficiency can be increased. Nowadays many mature reservoirs under waterflood have decreasing production rates despite having 50-75 % of the original oil left inside the reservoir [Flaaten et al., 2008]. In such cases it is likely that surfactant flooding can increase the economic productivity.

Surfactants are added to decrease the IFT between oil and water. Co-surfactants are blended into the liquid surfactant solution in order to improve the

properties of the surfactant solution. The co-surfactant either serves as a promoter or as an active agent in the blended surfactant solution to provide optimal conditions with respect to temperature, pressure and salinity. Due to certain physical characteristics of the reservoir, such as adsorption to the rock and trapping of the fluid in the pore structure, considerable losses of the surfactant may occur. The stability of the surfactant system at reservoir conditions is also of great relevance. It is well known that surfactant systems are sensitive to high temperature and high salinity and therefore surfactants that can resist these conditions should be used [Green and Willhite, 1998, p.7]. Surfactant flooding creates microemulsion solutions, which may contain different combinations of surfactants, co-surfactants, hydrocarbons, water and electrolytes [Green and Willhite, 1998, p.239-300]. Polymers are also often added to the injected surfactant solution, to increase viscosity, thus maintaining mobility control. In general there are three types of surfactant flooding for EOR [Rosen et al., 2005].

Surfactant systems usually consist of both surfactants and co-surfactants. However the combination of multiple components in the surfactant solution system does not work well in practice as chromatographic separation occurs in the reservoir. The solution concentration quickly changes from its optimal value as the separation takes place. The optimization criterion in surfactant flooding is to maximize the amount of oil recovered, while minimizing the chemical cost. While it is necessary to reach low IFT for the surfactant system, minimizing only the IFT may not always coincide with optimal oil recovery, as low IFT is not the only essential condition to meet in order to get a successful and efficient oil recovery, [Fathi and Ramirez, 1984]. E.g. attention to the optimal salinity is crucial to include as well.

1.2.1 Surfactants

In surfactant flooding, the chemical system contains surface active agents, surfactants, which are polymeric molecules that lower the IFT between the liquid surfactant solution and the residual oil. Surfactants adsorb on a surface or fluid/fluid interface when present at low concentrations. The most common structural form for

surfactants is where they contain a nonpolar part, a hydrocarbon 'tail', and a polar or ionic part. The structure is shown in figure 1.5.

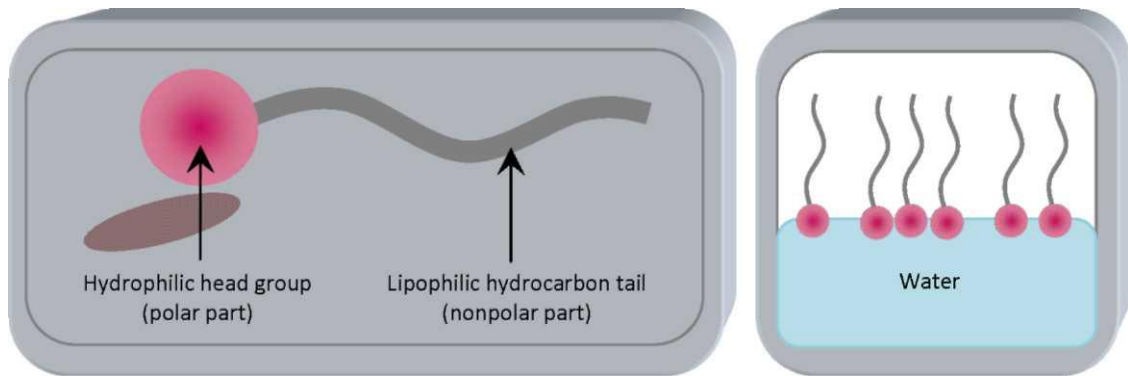


Figure 1.5. Surfactant molecule and surfactant orientation in water. Surfactants are also referred to as amphiphile molecules because they contain a nonpolar 'tail' and a polar 'head'-group within the same molecule, [Green and Willhite, 1998, p.241].

It is the balance between the hydrophilic and hydrophobic parts of the surfactant that generates the characteristics of the surface active agent. In EOR with surfactant flooding the hydrophilic head interacts with water molecules and the hydrophobic tail interacts with the residual oil. Thus, surfactants can form water-in-oil or oil-in-water emulsions. Surfactant molecules are amphiphilic, as they have both hydrophilic and hydrophobic moieties. Amphiphiles adsorb effectively to interfaces and typically contribute to significant reductions of the interfacial energy, [Pashley and Karaman, 2004, p. 62].

The primary surfactant is directly involved in the microemulsion formation with regards to the EOR surfactant flooding process. The co-surfactant, if any, promotes or improves the activities of the primary surfactant, by e.g. changing the surface energy or the viscosity of the liquids. Due to chromatographic separation of surfactant, co-surfactant and any other components, throughout the reservoir, it can be problematic to create a multicomponent surfactant system capable of maintaining optimal properties throughout the flooding process. The predominant disadvantage of separation is that the control of the system deteriorates in the reservoir and therefore it should be avoided if possible. As the co-surfactants prevent gel

formation and reduce the equilibration time, they are hard to eliminate from the surfactant systems used for flooding. Oil reservoirs have different characteristics and therefore the structure of added surfactant must be tailored to meet the reservoir conditions to achieve a low IFT. For example the temperature, pressure and rock vary significantly from one reservoir to another.

1.2.2 Classification of Surfactants

Surfactants are frequently classified on the basis of the ionic nature of the head group, as anionic, cationic, nonionic or zwitterionic. Each type possesses certain characteristics depending on how the surfactant molecules ionize in aqueous solutions. In table 1.1 a few commonly used surfactants are shown.

Table 1.1. List of common surfactant molecules with different types of charge: anionic, cationic and non-ionic. [Pashley & Karaman, 2004, p.63]

Anionic	
Sodium dodecyl sulfate (SDS)	$CH_3 (CH_2)_n SO_3^- Na^+$
Sodium dodecyl benzene sulfonate	$CH_3 (CH_2)_{11} C_6 H_4 SO_3^- Na^+$
Cationic	
Cetyltrimethylammonium bromide (CTAB)	$CH_3 (CH_2)_{15} N (CH_3)_3 Br^-$
Dodecylamine hydrochloride	$CH_3 (CH_2)_{11} NH_3^+ Cl^-$
Non-ionic	
Polyethylene oxides	$CH_3 (CH_2)_7 (OCH_2CH_2)_8 OH$

Commonly used surfactants for EOR, are sulfonated hydrocarbons such as alcohol propoxylate sulfate or alcohol propoxylate sulfonate. To achieve an optimal surfactant flood for any given oil reservoir surfactants and polymers are often both included in the flooding. Surfactants are responsible for the reduction of the IFT and the polymer is added to improve the sweep efficiency, [Flaaten et al., 2008]. The demands on surfactants are numerous and it is a great challenge to distinguish which mechanisms are most dominant. Process conditions, such as high temperature and high pressure are often the reality in reservoir environments.

1.2.2.1 Use of Anionic Surfactants

Anionic surfactants are negatively charged. They are commonly used for various industrial applications, such as detergents (alkyl benzene sulfonates), soaps (fatty

acids), foaming agents (lauryl sulfate), and wetting agents (di-alkyl sulfosuccinate). Anionic surfactants are also the most commonly used in EOR. They display good surfactant properties, such as lowering the IFT, their ability to create self-assembled structures, are relatively stable, exhibit relatively low adsorption on reservoir rock and can be manufactured economically [Green & Willhite, 1998, p. 241]. Anionic surfactants dissociate in water to form an amphiphilic anion (negatively charged) and a cation (positively charged), which would typically be an alkaline metal such as sodium (Na^+) or potassium (K^+).

Wu et al. (2005) have investigated a series of branched alcohol propoxylate sulfate surfactants for the application in EOR. Their investigations show that the number of propoxylate groups has a significant influence on the IFT, the optimal salinity and the adsorption. Optimal salinity and adsorption are shown to decrease as the number of propoxy groups is increased. In their work the experiments are conducted at diluted surfactant concentrations, both with and without co-surfactants.

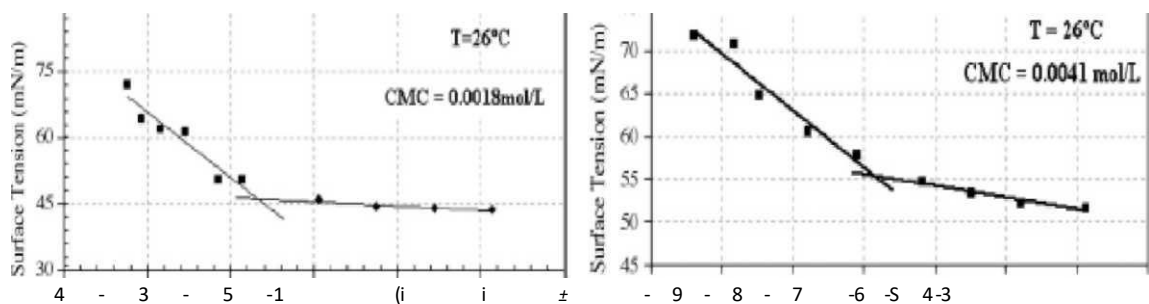
Barnes et al. (2008) investigate families of anionic surfactants, internal olefin sulfonates, (IOS), for use in surfactant flooding at high temperatures, (up to $150\text{ }^{\circ}\text{C}$), and with varying optimal salinities from 1 % to 13 % depending on the carbon number range. The IOS surfactants show little sensitivity to temperature, which could be an advantage for reservoirs with temperature gradients. Overall the IOS surfactants exhibit promising over a range of reservoir conditions covering moderate to high temperatures and from low to high salinity conditions. Both alcohol propoxylate sulfates and IOS have been studied [Levitt et al., 2006 and Flaaten et al., 2008], where they are identified as promising surfactant candidates for EOR processes. These surfactant candidates are available at low cost and have been tested in different reservoir cores resulting in enhanced oil recovery and low surfactant retention, [Levitt et al., 2006]. It was found in Levitt et al. (2006)'s work that mixing the IOS and the alcohol propoxylate sulfate give the best result. Furthermore Bryan and Kantzas (2007) have conducted an investigation of alkali surfactants for surfactant flooding of heavy oils. Their work showed that alkali surfactant flooding has a great potential for non-thermal heavy oil recovery, as the addition of alkali

surfactants reduced the IFT between oil and water by such a magnitude that formation of emulsions was possible.

1.2.2.2 Use of Nonionic surfactants

Nonionic surfactants have no charged head group. They are also identified for use in EOR, [Gupta and Mohanty, 2007], mainly as co-surfactants to promote the surfactant process. Their hydrophilic group is of a non-dissociating type, not ionizing in aqueous solutions. Examples of nonionic surfactants include alcohols, phenols, ethers, esters or amides.

Curbelo et al. (2007) studied nonionic surfactants with different degree of ethoxylation to investigate the correlation with the adsorption of surfactant in porous media (sandstone). From the experiments the variations in the surface tension with surfactant concentration are shown in figure 1.6.



(A) (B)

Figure 1.6. Determination of Critical Micelle Concentration (CMC) for two surfactants investigated. (A) is a surfactant with an ethoxylation degree of 9.5 and (B) is a surfactant with an ethoxylation degree of 15.0. The x-axis is the natural logarithm of the surfactant concentration. The break in both of the curves is where CMC is reached. [Curbelo et al., 2007]

Critical Micelle Concentration (CMC) is reached at a higher surfactant concentration for (B), with ethoxylation degree of 15.0, compared to (A), with ethoxylation degree at 9.5, seen in figure 1.7. With higher ethoxylation degree follows that the surfactant has a larger polar chain and consequently higher solubility towards the aqueous phase. Thus higher concentration of surfactant is required to assure formation of micelles. Curbelo et al. (2007) concluded that the adsorption to the sandstone core is higher in the case of the lower degree of ethoxylation, situation (A), which should be avoided in EOR surfactant flooding.

1.2.2.3 Use of Cationic Surfactants

Cationic surfactants have a positively charged head group. Cationic surfactants dissociate in water, forming an amphiphilic cation and anion, typically a halide (Br⁻, Cl⁻ etc.). During the synthesis to produce cationic surfactants, they undergo a high pressure hydrogenation reaction, which is in general more expensive compared to anionic surfactants. As a direct consequence cationic surfactants are not as widely used as anionic and nonionic surfactants.

It is, however, reported that cationic surfactants can be used to improve the spontaneous imbibition rate of water into preferentially oil-wet carbonate. Water containing surfactants of the type alkyltrimethylammonium bromide or chloride was injected [Standnes & Austad, 2002]. The cationic surfactants are most likely dissolved in the oil phase as aggregates between the surfactant and the carboxylates, under creation of ion pairs. In this way the surface becomes more water-wet, thus the aqueous phase can better imbibe by capillary forces.

1.2.3 Single Component Surfactant Flooding

To obtain the optimal conditions for creating and maintaining the desired microemulsion phase during a surfactant flood, co-surfactants, such as low molecular alcohols as propanol and hexanol, are usually added to the surfactant solution, [Austad et al., 1996]. Chromatographic separation of the injected surfactant solution makes the operation challenging to control, as the original chemical composition in the surfactant solution will change in the reservoir and in consequence poor oil recovery may be experienced. A way to eliminate this problem is to reduce the amount of, co-surfactants, or even to omit them altogether. A few single component surfactants have been proposed in literature.

Austad et al. (1996) propose branched ethoxylated sulfonates, sulfate mixtures containing both ethoxy and propoxy groups in the same molecule, mixtures of ethoxylated and secondary alkane sulfonates and alkyl-o-xylene sulfonate. However, the ideal surfactant solution or combination will differ from one residual crude oil and reservoir to another. Austad et al. (1996) have examined the multiphase behavior of a single component alkyl-o-xylene sulfonate/brine/oil system at

temperatures from 40 °C to 180 °C and pressures from 200 bar to 1000 bar with different crude oil, fractions of crude oil and model oil. The phase behavior observed with the increase in pressure was the same in all cases to III to II-). Regarding the increase in temperature, in the case of the crude oil the phase behavior showed II- to III to while the opposite phase behavior to III to II-) was observed in the case of the model oil and the fraction of crude oil. It is suggested that the effect of temperature on the phase behavior is related to the interaction between the surfactant and the resin type material in the crude oil present at high temperatures.

Zhao et al. (2006) study IFT behavior of crude oil/single component surfactant/brine systems. Heavy alkyl benzene sulfonates have been found to be good surfactants for enhanced oil recovery in Chinese oil fields. On the basis of previous experiences Zhao et al. (2006) suggest alkyl methylnaphthalene sulfonates (AMNS) as surfactants for EOR. Different synthesized AMNS surfactants have been investigated; hexyl methylnaphthalene sulfonate, octyl methylnaphthalene sulfonate, decyl methylnaphthalene sulfonate and tetradecyl methylnaphthalene sulfonate. Zhao et al. (2006) reported that some synthesized single component surfactants of AMNS possess higher capacity and efficiency for lowering the surface tension than similar long-chain alkyl benzene sulfonates (LAS), when surfactants of the same chain length are compared. The structure of both AMNS and LAS is shown in figure 1.7.

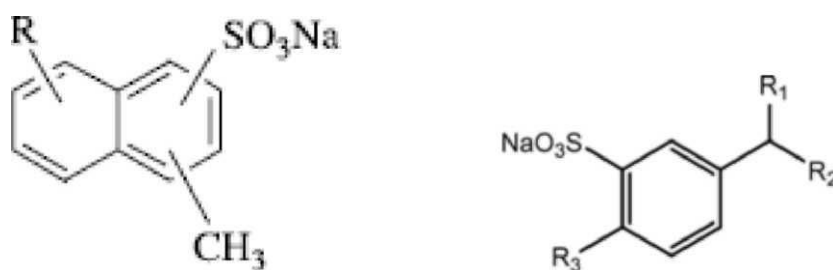


Figure 1.7. The structural formula of the alkyl methylnaphthalene sulfonates (AMNS), left, and alkyl benzene sulfonates (LAS), right.

The different AMNS were studied with respect to the IFT and the optimum salinity. It was concluded that the AMNS tetradecyl methylnaphthalene sulfonate was the most efficient in reducing the IFT. The surface tension of the crude oil/water

IFT was reduced to 0.001 mN/m (ultra low) at low surfactant concentrations, 0.002 mass %, without addition of alkali or other additives. Surfactants with the longest chain length reduced IFT the most. This is in agreement with the expected behavior, as it is in general understood that IFT reduction increases with the increase in the chain length of the surfactant molecules. Zhao et al. (2006) conclude that both the chromatographic separation and the breakage of stratum are avoided effectively.

As mentioned earlier Wu et al. (2005) carried out a study with branched alcohol propoxylate sulfate surfactants and the influence of single component surfactants. They concluded that using only branched alcohol propoxylate surfactant in the formulation at low concentrations can create low IFT between brine and either *n*-octane or crude oil. The optimal salinity depended on the number of propoxy groups and decreases with an increase in propoxy groups. Adsorption experiments were carried out in this study as well. Adsorption of these surfactants on kaolinite clay decreases with an increase in the number of propoxy groups.

Заключение

В ходе выполнения диссертационной работы получены следующие результаты:

1. Дополнительная добыча нефти от анализируемых мероприятий составляет 11,8% накопленной добычи нефти месторождения. Это свидетельствует о более возрастающей роли мероприятий по интенсификации добычи нефти для повышения нефтяной отдачи пластов и дальнейшей разработки месторождения.

2. Высокую технологическую эффективность показало применение боковых стволов на различных объектах разработки. Помимо поддержания регулярной сетки скважин, бурение боковых стволов и боковых горизонтальных стволов способствовало отбору нефти из зон, слабодренируемых основными стволами скважин. Дополнительная добыча нефти только от бурения боковых стволов и боковых горизонтальных стволов составила 576,9 тыс.т. В перспективе бурение боковых горизонтальных стволов позволит продолжить эксплуатацию объектов разработки в условиях добычи высокообводненной продукции.

3. Проведение гидравлического разрыва пласта по-прежнему остается основным инструментом интенсификации добычи нефти в скважинах объектов АВ₁³, АВ₄ и особенно БВ₁₇₋₂₁. Его применение будет оправдано как при вводе скважин из бурения (или переводе на объект), так и в процессе эксплуатации. Всего от проведения 340 гидравлических разрывов пласта дополнительно получено 2 млн 724,4 тыс.т нефти.

4. Продолжение работ по дострелу и перестрелу пластов, физико-химических обработок призабойной зоны пласта позволит удержать от падения дебиты нефти скважин. От проведения перфорационных работ дополнительно получено 2 млн 559,6 тыс.т нефти. Всего за период разработки месторождения было проведено 273 обработок призабойной зоны пласта, дополнительная добыча нефти составила 234,2 тыс.т нефти.

5. В перспективе потребуется значительное увеличение объема

проведения водоизоляционных работ, связанного с закономерным увеличением обводненности добываемой продукции. При анализе были учтены результаты 329 мероприятий по ремонтно-изоляционным и водоизоляционным работам, в результате которых было дополнительно получено 1 млн 363,1 тыс.т нефти.

6. Несмотря на снижение в последние 3 года эффективности работ по выравниванию профиля приемистости, целесообразность дальнейшего проведения этих работ не вызывает сомнений. Системное проведение мероприятий по выравниванию профиля приемистости даже при условии не высокой дополнительной добычи нефти позволяет удерживать обводненность продукции и снизить объем попутно добываемой воды. Всего от проведения 1419 работ по выравниванию профиля приемистости дополнительно получено 457,2 тыс. т нефти.