SURFACTANT MIXTURE IN PARTIALLY HYDROLYZED POLYACRYLAMIDE POLYMER FOR ENHANCED OIL RECOVERY

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ABSTRACT

Chemical EOR has won significant interest in the oil and gas industry over decades. The use of nanoparticles, alkaline, foam and most importantly polymers and surfactants, have been widely explored. Surfactants have achieved great interest because it can reduce IFT and subsequently improve oil recovery. Polymers on the other hand have gained significant importance due to their ability to increase the viscosity of the injected fluid by rendering oil at the oil-water interface less viscous than water and increasing its mobility, yielding a higher oil recovery. In this work, the surface tensions of AOS and SDS were investigated using a ring experiment method at different salinities, followed by their respective IFTs until the critical micelle concentrations were observed. The SDS and AOS were then mixed at a ratio of 1:1 and the IFT measured accordingly. A blend of AOS, SDS and HPAM was made and the IFT measurement was repeated. The viscosity of the HPAM was made, followed by the displacement test in a sand pack flooding setup and the results recorded. The IFT values of 6.6 mN/m for SDS at 0.1% wt, 7.7 mN/m for AOS at 0.1 %vol. were achieved. Nonetheless, a blend of AOS, SDS and HPAM, gave an IFT at CMC of 8.5 mN/m at 1000ppm of polymer while viscosity proved contrary that the solution with 2000 ppm was the most stable. Finally, 73% of oil was recovered using water flooding, 78% was further obtained using HPAM and finally 83% using SDS, AOS and HPAM in a hybrid system. This therefore concludes that the combination of HPAM and a blend of SDS and AOS, can impact meaningfully to EOR applications.

Key words: EOR, surfactants, polymers, HPAM, SDS, AOS.

ABSTRAK

Perolehan minyak tertingkat (EOR) kimia telah mendapat pertimbangan yang besar penggunaannya dalam industri minyak dan gas bagi beberapa dekad ini. Penggunaan nanopartikel, alkali, busa dan terutamanya polimer dan surfaktan telah diterokai secara meluas. Surfaktan telah mendapat pertimbangan yang besar kerana ia dapat mengurangkan IFT dan seterusnya meningkatkan perolehan minyak. Polimer pula berkemampuan untuk meningkatkan kelikatan bendalir yang disuntik dengan menjadikan minyak di antara permukaan minyak-air menjadi kurang likat daripada air, dan dengan itu meningkatkan alirannya bagi menghasilkan perolehan minyak yang lebih tinggi. Dalam kajian ini, ketegangan permukaan bagi AOS dan SDS diukur menggunakan kaedah eksperimen gelang pada saliniti yang berbeza, diikuti oleh ukuran ketegangan antara permukaan (IFT) sehingga mencapai kepekatan kritikal misel (CMC) diperolehi. Campuran SDS dan AOS pada nisbah 1: 1 dihasilkan dan IFT diukur dengan sewajarnya. Bagi sistem HPAM dan campuran AOS dan SDS, nilai IFT juga diukur. Ujian kelikatan bagi HPAM dilakukan, dan diikuti dengan ujian sesaran dalam ujian banjiran menggunakan teras padat pasir untuk menilai perolehan minyak. Nilai IFT sebanyak 6.6 mN/m untuk SDS pada 0.1% berat, 7.7 mN / m untuk AOS pada 0.1% isipadu telah direkodkan. Bagimanapun, campuran AOS, SDS dan HPAM telah memberi IFT 8.5 mN/m pada nilai CMC pada 1000 ppm polimer. Bagi kelikatan, keputusannya adalah bertentangan bahawa larutan pada 2000 ppm campuran adalah yang paling stabil. Bagi ujian banjiran, 73% minyak diperolehi dengan menggunakan banjir air, 78% dengan banjiran HPAM, dan 83% dengan menggunakan campuran SDS, AOS dan HPAM. Dengan itu, sistem HPAM dan campuran SDS dan AOS memberi kesan yang bermakna dalam aplikasi EOR.

KATA KUNCI: EOR, SURFAKTAN, POLIMER, HPAM, SDS, AOS.

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LIST OF ABBREVIATIONS

AOS	Alfa olefin sulfonate
ASP	Alkaline surfactant-polymer
CEOR	Chemical Enhance Oil Recovery
CMC	Critical Micelle Concentration
EOR	Enhance Oil Recovery
IFT	Interfacial Tension
IOS	Internal Olefin Sulfonate
K	Kelvin
HPAM	Hydrolysed Polyacrylamide
PSD	Particle Size Dispersion
PV	Pore Volume
SDS	Sodium Dodecyl Sulphate

CHAPTER 1

INTRODUCTION

1.1 Background of Study

For many years, the oil and gas industry has recognized the end of the "easy oil" age. Many of the world's biggest production fields are facing exhaustion, and much of the existing stocks are thought to be impossible to restore. It fact pushes the industry to create and introduce novel EOR strategies to boost recovery performance (Alvarado and Manrique, 2010).

EOR processes can be divided into three main categories: thermal, miscible and chemical. In thermal recovery, hot fluids, such as steam or heat water, are injected into the structure to which the viscosity of the oil and enable it to float. Thermal recovery consists of steam flooding, cyclic steam stimulation, in-situ combustion and modification. Chemical EOR seeks to use chemical agents to enhance the microscopic and macroscopic quality of immiscible displacement in order to maximize the recovery of oil. There, microscopic displacement capacity refers to the displacement or mobilization of hydrocarbons at the pore size, while macroscopic displacement performance characterizes volumetric displacements at the reservoir stage. There are three main types of chemical EOR methods: polymer, surfactant, and alkali.

The main mechanisms of these methods are as follows:

During surfactant storms, surfactants are used to greatly decrease IFT, which helps release capillary trapped oil.

Polymer flood increases the mobility ratio by improving the viscosity of the injected fluid; Alkali flood often decreases IFT, but surfactant is produced in situ by the addition of a high pH solution to crude oil.

Sodium dodecyl sulfate (SDS), synonymous with sodium lauryl sulfate (SLS) or sodium lauryl sulfate, is a synthetic organic compound containing the formula CH3(CH2)11SO4 Na. It is commonly used as anionic surfactant. Alpha olefin sulfate is an ionic surfactant containing a hydrophobic hydrocarbon group associated with one or more hydrophilic groups which dissociates into a positively charged cation and a negatively charged anion in an aqueous solution.

Applications for polymers have steadily grown in science and engineering, including chemistry, pharmacology, and chemical and petroleum engineering, owing to their attractive properties. Among all types of polymers, partially Hydrolyzed Polyacrylamide (HPAM) is one of the polymers widely used, especially in chemical and petroleum engineering. The potential to improve the viscosity of HPAM solutions is the main parameter for efficient applications (Alireza *et al.,* 2018).

By stabilizing the moving front by control over the viscosity of injected water, polymers contribute to the CEOR and thus improve macroscopic sweeping performance. Alkaline-surfactant-polymer (ASP) flood uses the above-mentioned chemicals, and by combining the injection of surfactant and in-situ surfactant generation with the controlled mobility of polymer oil, ASP floods have a potential benefit over other CEOR methods. The association of these three chemical components is one of the most exciting in the history of CEOR science and field trials (Olajire, 2014).

Satish and Ahluwalia (1996) measured the density of the solutions of surfactants and their mixtures with a vibrating tube densimeter at 298.15 K and observed that the mixed-surfactant system exhibits synergy in all aspects when the mole fraction of alpha-olefin sulfonate in the mixture is 0.2. Volumetric properties were well correlated, as the partial molar volumes also showed a minimum at the same mixture composition. The choice of a multi-purpose surfactant system, from tissue detergent to tertiary oil recovery, is a serious step. In action, mixtures of surfactants are used as a single surfactant never satisfies all specifications.

Mixed-surfactant structures are often considered to show coordination, resulting in improved efficiency properties. While various studies of mixed-micelle structures in nonionic surfactant solutions, there have been few records of mixtures of industrially significant, non-homological, ion-surfactant systems. It would be interesting to study a mixed-surfactant system containing two anionic surfactants with similar hydrophilic groups but different hydrophobic parts. Mixed-micelle structures in these systems would be primarily attributed to the hydrophobic impact of the alkyl chains and steric constraints, as there is absolutely no positive activity between the groups charged.

1.2 Problem Statement

A variety of studies on the mechanisms and parameters of the displacement affected ultimate recovery during phases of chemical regeneration were conducted. In most of these studies, porous substances containing heavy oil have been flooded with water to recover water flood, followed by a water-assisted chemical flood to reduce water cutting through microemulsions and traps on the porous medium by blocking prefigured water channels. This increases the microscopic sweeping capacity of the transportation systems, which results in a greater recovery than floods alone (Omid *et al.*, 2018).

Nevertheless, effects and concentrations of surfactants that function with polymers have not been properly evaluated for incremental oil recovery. Although the use of surfactant flooding for oil recovery has been extensively worked on, many factors are still needed to explain differences in recovery and displacement mechanisms associated with surfactants and polymer interactions with petroleum.

This research focuses on the application of partially hydrolyzed polyacrylamide (HPAM) of the mixture of sodium Dodecyl sulfate (SDS) and alpha olefin sulfate. HPAM is a widely used oil displacement agent but it is not used in high-temperature and high-salinity oil storage tankers due to low thermal stability, salt resistance, and mechanical degradation.

In order to overcome HPAM deficits, HPAM must complicate a new viscoelastic mix of surfactant, SDS and olefin sulfate with increased thermal stability and salinity tolerance. The samples for HPAM / surfactant in synthetic sauna were studied for their rheological behavior as compared to HPAM and flooding experiments in laboratory ambient conditions. Synergy exhibited in all aspects in the mixed- surfactant system (Marlene *et al.*, 2018).

Nevertheless, the effects and concentrations of polymers on incremental oil regeneration surfactants have not been well tested. Furthermore, anionic surfactants (SDS) precipitate between 10 and 20oC at a lower temperature and thus have a lower effect on the reduction of IFT, while non-ionic surfactants (AOS) and especially sulfonated surfactants are particularly sensitive to high temperatures above 120oC and hydrolyze or degrade the molecule to a non-reactive form permanently. (Hirasaki *et al.*, 2011) Sulfur-containing surfactants are also not appropriate for training at temperatures higher than the critical temperature of the formation. A mixture of this surfactant and anionic surfactant has neither a significant nor a less important effect on the synergy temperature (Chegenizadeh *et al*., 2016., Hirsaki *et al.,* 2011). This is because mixed micelles appear to have negative interacting parameters that cause a decrease in surface tension (Yuan and Milton 1982). In the same manner sulfonated tensioners stabilize the system in cases of salinity of approximately 6000 ppm, although as stated by Hirasaki *et al*., (2011) the optimum salinity is expected to be 4500 ppm, while anionic surfactants in salinities over the optimum value are not successful (Sharma and Gao, 2014).

Polymers are known for their effectiveness in rising the viscosity of the injected material, which makes it more viscous than gasoline. On the other hand, the addition of polymer molecules to surfactants also proved to be of considerable importance in lowering IFT between oil and water resulting in a greater oil recovery (Pablo and Francesco 2018). This therefore has a positive impact on oil recovery during EOR, which was the main objective of this project, through the combination of SDS and AOS and HPAM.

1.3 Objectives

The objectives of this study were:

1. To determine the IFT and viscosity of the SDS, AOS and polymer mixtures at different salinities.
2. To determine the oil recovery in a sand pack experiment for the hybrid solutions of AOS, SDS and HPAM

1.4 Scope of Study

The scopes of this study were:

- This work was carried out under ambient temperature 30ºC and under atmospheric pressure 14.7 psia.

- Fluid of sodium dodecyl sulfate (SDS) with 0.1 – 1.5 wt% , alpha olefin sulfonate with 0.1- 1.5 vol% and partially hydrolyzed polyacrylamide (HPAM) 2888.38 g / mol of molecular weight from(1000-5000) ppm preparation and stirring with the use of magnetic stirrer at different salinities (1000-6000) ppm.

- IFT measurement at varying concentrations of salt (salinities) of the hybrid solution in a ring experiment by using the tension meter device.

- Measurement of the rheological properties with the use of a Brookfield RST Rheometer.
- Sand pack flooding experiment with the use of glass beads of 200 µm using an ISC Teledyne pump for fluid injection.

1.5 Significance of The Study

Information regarding the blend of surfactants and polymers was achieved. In addition, the combination of surfactants and polymers could benefit the oil and gas industry in areas like drilling operations, cement slurries, demulsification, corrosion inhibition, transportation, cleaning, and water flooding jobs. The fluid system could reduce the residual oil saturation to appreciable values by increasing the oil recovery.

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