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THE SYNERGIZATION OF SILICA NANOPARTICLE AND SODIUM DODECYL SULFATE FOR CHEMICAL FLOODING APPLICATION

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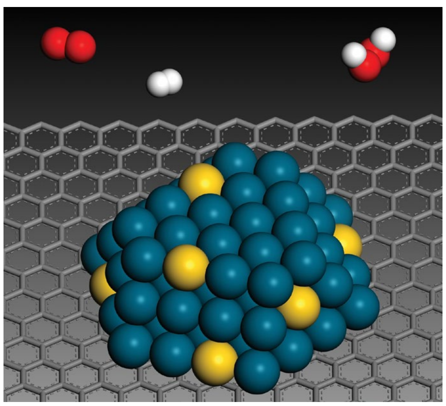
Graphical abstract



Abstract

Nowadays, enhanced oil recovery is vital in improving the oil recovery. However, the oil productions keep depleting due to production problem such as high surface tension and interfacial tension reservoirs. Therefore, chemical flooding is one of the methods used in enhanced oil recovery. The synergy between Silica nanoparticle and Sodium Dodecyl Sulfate has been proposed as a compound for chemical flooding in enhanced oil recovery in this project. The major aim of this study was to measure the effectiveness of synergization between Silica (SiO_2) nanoparticles SDS with different injection ratio by measuring the oil recovery using chemical flooding. After the synergization of surfactant with nanosilica solution take place, the surface tension and interfacial tension test have been conducted to identify the optimum concentration. The results showed that the optimum concentration for SDS is 2000 ppm with surface tension (ST) and interfacial tension (IFT) are 33.5 and 36.0 mN/m respectively. When the SiO_2 nanoparticles were added, it showed that 6000 ppm was the optimum concentration with reduction in surface tension and IFT to 31.0 and 34.5 mN/m respectively. The 20,000 ppm brine and paraffin oil have been injected into the sandpack followed by waterflooding and chemical flooding. The results from the experiment presented that the oil recovery for waterflooding were in between 23% to 28% therefore, more oil left in the sandpack. Then, surfactant with nanosilica solution was injected with 20,000 ppm of brine as a slug with injection ratio in between 0.1 to 0.5 as tertiary recovery. It showed that the oil recovery increases up to 48% for 0.1 of injection ratio and 64% for 0.5 injection ratio. As a conclusion, it is proved that the synergization of SiO_2 nanoparticle and SDS is applicable for chemical flooding as tertiary recovery because in can recover up to 64% of oil production.

Keywords: Silica, Sodium Dodecyl Sulfate, Enhanced Oil Recovery, Surface Tension, Interfacial Tension time video

1.0 INTRODUCTION

Fuel energy is one of the major energy sources in the world such as oil, coal and natural gas. Currently, oil supply 80% of the world's energy needs and its demand projected to be higher for about 40% in 2035 than in 2010 even if current policy commitments and pledges by governments to tackle the climate change are all implemented [1]. The influential thinkers have predicted that global oil demand as fuel energy will peak in 2023. Anyway, there is no sufficient energy source that broadly integrated to replace the crude oil energy. The needs of 97 million barrels per day of new oil to meet the oil demand everyday [2]. However, the remaining resources of the oil energy getting decline throughout the years.

The way to increase the oil production is through tertiary oil recovery known as enhanced oil recovery (EOR) works by altering its fluid's properties to make it more conducive for extraction. Even though this technique is more expensive to directly implement into the well, but it promised can increase the production up to 75% of the recovery. The polymer flooding presented as one of enhances oil recovery (EOR) technique helps to free trapped oil within the reservoir. It will introduce long chained molecules to improve the properties of the reservoir make it easy to flow to the production wellbore. The fascinating and valuable property of these nanoparticles is it creating massive diffusion driving force due to large surface area especially at high temperatures which Negin et al [3] have shown it ability to shifting reservoir wettability toward more water-wet and interfacial tension. However, the interfacial tension between the molecules of reservoir increases at deeper depth and the reservoir wettability turn to low water-wets when the reservoir pressure drops thus resulting the low oil production. Deeply study is required to settle the reservoir properties problems, hence enhance the oil recovery expecting the high oil production.

Ravera et. al.[4] studied the liquid-air and liquid-liquid interfacial tension of nanosilica dispersions in the presence of a cationic surfactant. They have assigned the interfacial tension behavior to the formation of a mixed layer that is composed of attached nanoparticles and surfactants in diluted particle concentrations, and to the adsorption of the particles above a specific concentration. The silica nanoparticles have a negligible effect on the surface and interfacial tension of nonionic surfactant systems, while increases the surface activity of the anionic surfactant solution, and accordingly decreases the interfacial and surface tension

Besides, surfactants and polymers become an attention because of their characteristics. They have an amphilic structure consists of hydrophobic and hydrophilic head group [5] and polymerized vinyl double bonds in their molecules structure. The objectives of this study are to synergize the silica oxide nanoparticles and sodium dodecyl sulfate with different concentrations in determination of oil recovery in the reservoirs and evaluate the surface tension and interfacial tension of silica oxide and sodium dodecyl sulfate in identifying its optimum concentration.

2.0 METHODOLOGY

The sand pack was prepared as a testing medium for characterization analysis of synergy between the silica nanoparticles and Sodium Dodecyl Sulfate (SDS) surfactant. The glass bid sizes were in range of 150 - 250 micron meter. The smaller the sizes, more similar in with sandstone core. The glass bead was packed in PVC pipe with 0.32 cm of inner diameter and 30.48 cm length. The sand pack was a wet sand pack.

In addition, a few samples were required in these studies which are Sodium Dodecyl Sulfate (SDS) solution, Silica (SiO_2) nanoparticle and the synergization of both samples. Firstly, defined the number of samples required to prepare the required concentration. Then, the samples have been stirred in the magnetic stirrer to ensure the samples disperse evenly for about 30 minutes. After that, the steps were repeated at different concentration of SDS in range of 1500 ppm to 3000 ppm until the critical micelle concentration achieved through the surface tension test.

Surface Tension and Interfacial Tension Test

Krüss Tensiometer has been used to measure the surface and interfacial tension (liquid-air tension) for this study. Firstly, the clean ring attached to lever arm. 40 ml of 1000 ppm SDS added into the glass container and placed it at the centred of sample table. Then, screwed it up until the ring immersed into the sample and further lowered by means of the ring and sample was just attached at the surface of the sample. Next, rotated the knob until the ring detached from the sample and recorded the reading. Repeated the samples with different concentration of SDS (1500 – 3000 ppm) and the synergy of SDS and SiO_2 (2000 ppm of SDS and 1000 – 10 000 ppm of SiO_2). Lastly, plotted the graph surface tension and interfacial tension versus concentration to find the trend of the result and to identify the optimum concentration of SDS and synergization of SDS with SiO2.

Oil Recovery Test

In identifying the oil recovery, the recovery test has been done by using sand pack column. The steps and experiments were set up as Figure 1 below. The sand pack was saturated with paraffin oil. Followed by water flooding where 20 000 ppm of brine was injected at 2.0 cc/min into the sand pack. The amount of oil produced from the outlet was recorded. Then, the synergization of 2000 ppm of SDS with 6000 ppm of SiO_2 was slug with 20 000 ppm of brine were injected at 2.0 cc/min with injection ratio of 0.1. The amount of oil in the beaker was recorded. The amount of oil in the beaker was recorded at every 10 minutes. Furthermore, the steps were repeated at different injection ratio, 0.2, 0.3, 0.4 and 0.5. The oil recovery factor was calculated by using the Formula 1. Lastly, plotted the graph oil recovery versus time with different types of flooding and injection ratio.

$$Oil\ Recovery = \frac{Amount\ of\ Oil\ Recovered}{STOIIP} \quad (1)$$

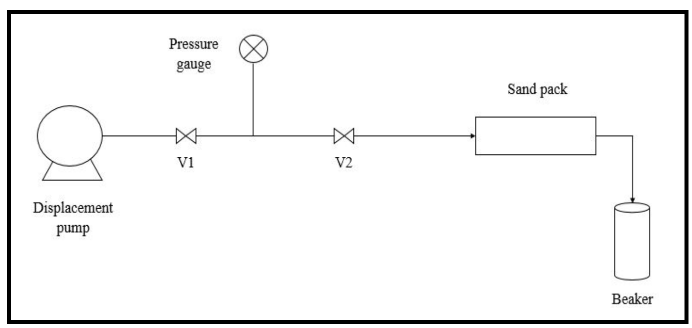


Figure 1. Experiment set up for the oil recovery test

3.0 RESULTS AND DISCUSSION

The properties that have been identified in this experiment are porosity, permeability and bulk volume. The porosity of the sand packs is 32.55 with permeability of 2.16 darcy. Following with the static characterization tests which are the surface tension test and interfacial tension test. In the surface tension test, the SDS surfactant concentrations used in range of 1000 ppm – 3000 ppm to identify the optimum concentration through the critical micelle concentration. After that, the interfacial tension test took place.

Surface Tension

Surface tension is a property of the liquid surface allows it to resist an external force due to cohesive nature of its molecules. In simple words, surface tension involved the tension between the liquid and air resistance [6]. At first, the SDS surfactant was dissolved in 20,000 ppm brine. The concentrations that have been prepared were plotted in graph of surface tension versus different concentrations in Figure 2.

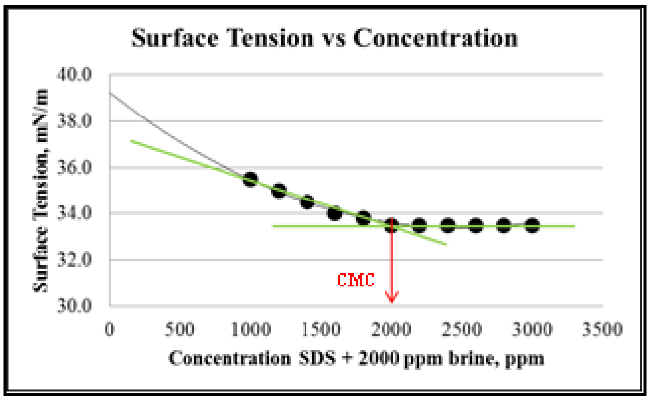


Figure 2. Graph of surface tension versus concentrations of SDS in range of 1000 ppm to 3000 ppm

Silica (SiO2) helped in reducing of displacement efficiency such as surface tension and interfacial tension [8]. After defined the optimum concentration of SDS through CMC point, Silica nanoparticle have been introduced in this study.

The 2000 ppm of SDS surfactant was dissolved in 20 000 ppm of brine solution and stirred by using magnetic stirrer. The SiO2 concentrations were added in range of 1000 ppm to 10 000 ppm to identify the best concentration of the synergization between the SDS surfactant and Silica nanoparticle. The solution was stirred for about 30 minutes to ensure they evenly dispersed.

Then, the surface tensions of synergization of both chemicals were measured. Figure 3. below showed the table and graph of surface tension of the synergization of 2000 ppm of SDS surfactants with different concentrations of Silica (SiO2) nanoparticle. The results presented that the higher the concentrations of SiO2 added into the 2000 ppm of SDS surfactant solutions, the lower the surface tension until 6000 ppm. At that concentration, the critical micelle concentration was achieved its optimum.

Above the 6000 ppm SiO2, there was no more surface tension reduction due to the solution already reached its micelle condition. Micelle condition means the solution already became saturated. The additional reduction of surface tension can be accomplished by applying the temperature or pressure to the system.

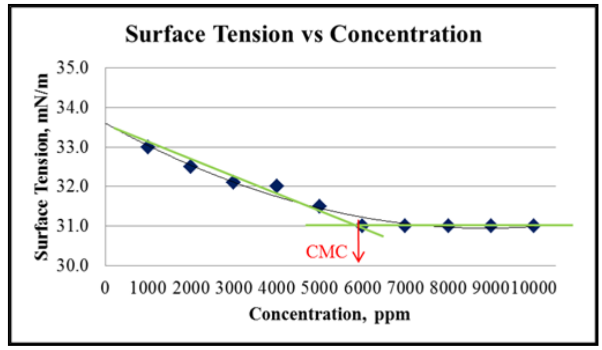


Figure 3. The surface tension versus concentration of synergization of 2000 ppm SDS surfactant with different concentrations of SiO2 nanoparticle

Interfacial Tension

In this study, a few concentrations have been used to investigate the ability of SDS surfactant to reduce the interfacial tension. The concentrations were in range of 1000 ppm to 3000 ppm of SDS surfactants.

The Figure 4 below showed the result of interfacial tension of SDS surfactant that have been dissolved in 20 000 ppm of brine. The higher the concentration, the lower the interfacial tension properties [10]. The graph shows that the reduction of interfacial tension with the increasing of SDS surfactant concentrations. At 1000 ppm of SDS surfactant, the interfacial tension was 40 mN/m while the increasing the SDS surfactant concentration to 2000 ppm, the interfacial tension reduced to 36 mN/m.

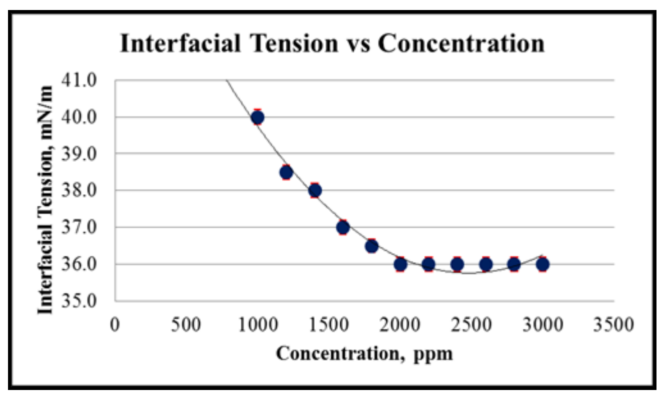


Figure 4. The graph of interfacial tension versus concentrations for SDS surfactant.

The Silica (SiO2) nanoparticles contain solid nanoparticles dispersed in aqueous phase of Sodium Dodecyl Sulfate [11]. These nanoparticles aggregated during mixing and show significant settlement with time.

The uses of SiO2 nanoparticle in reducing IFT of paraffin oil are advantageous for EOR applications where conventional surfactant may be subjected to degradation and not economical. The Figure 5 showed the graph of interfacial tension of 2000 ppm of SDS with different concentration of Silica (SiO2) nanoparticle. When the Silica nanoparticle was introduced into the SDS surfactant solutions, it showed a reduction in interfacial tension. With addition SiO2 nanoparticle, the IFT was reduced to 34.5 mN/m instead of the IFT for 2000 ppm of SDS only which is 36 mN/m.

The higher the addition of SiO2 into the SDS surfactant solutions, the higher the concentration hence the higher the interfacial reduction to the paraffin oil. It made the oil easy to flow thus increasing the oil recovery. The result indicated that SiO2 exhibited better surface adsorption in SDS surfactants solutions [12].

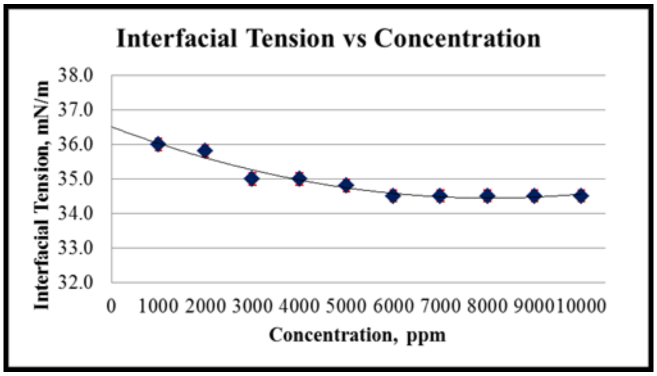


Figure 5. The graph of interfacial tension of 2000 ppm of SDS surfactant with different concentration of Silica (SiO2) nanoparticle

Oil Recovery

In this section, the 20,000 ppm of brine and paraffin oil was the constant variable in this study. The recovery factor of the synergization of both samples has been calculated at the end of experiment. The samples were injected at 2 cc/min of injection rate however different injection ratios were the manipulated variables in this study.

The ratios indication was the amount of synergization of SDS surfactant with Silica nanoparticle have been injected to the amount of injected brine as slug. The injection ratios used in this study were 10:90, 20:80, 30:70, 40:60 and 50:50. The 20,000 ppm of brine used as slug because it assisted the SDS with SiO2 to push the oil and for economy concern. It reduced the amount of chemicals required for this study thus reducing the cost.

At first, the water flooding technique has been done to measure the amount of oil recovery during the first stage of production. Then, a comparison between the surfactant flooding and surfactant with nanoparticles have been introduced to compare the recoverable amount based on different approached. Figure 6 below shows the results of recovery for three different methods.

From Figure 6, it is presented that water flooding can only recover about 25% of oil recovery during primary recovery. Regarding to that, chemical flooding has been introduced and tested in this study. SDS with SiO2 flooding has more oil recovery compared to SDS flooding only. It recovered about 48% of oil recovery compared to only 34% oil recovered for SDS flooding. Both method was injected with same injection ratio which is 0.1 of chemical flooding to the 0.9 of 20 000 ppm of brine as slug.

Through the synergization of SDS with SiO2, it showed that SiO2 can change the properties of the reservoir. SiO2 helped SDS reduced the surface tension and interfacial tension of the reservoir more compared to the SDS flooding and water flooding. Hence, it can produce more oil recovery during the production period.

Moreover, there were presented a same result when different injection ratio introduced in this study. The higher the injection ratio, the higher the oil recovery as shown in Figure 7. When more amount of SDS with SiO2 has been injected into the sand pack, it shows an increasing of oil produced in the measuring cylinder. In the injection ratio 10:90 of the SDS with SiO2 to the brine as slug, the amount of oil recovery was 48% after the water flooding has been done.

Besides that, the oil recovered up to 64% when the injection ratio 50:50 of synergization of SDS and SiO2 with brine as slug have been implemented. When higher of SDS with SiO2 injected into the sand pack, more amount of chemical to displaced and push the oil thus, increased the oil production. It showed that, 50:50 injection ratio of synergization of SDS with SiO2 and the slug with brine was the best ratio in this study because it can recover the highest oil recovery.

When more volume of synergization of SDS with SiO2 injected into the sand pack, it means more reduction of surface tension and interfacial tension occur to the oil properties in the sand pack. The SDS with SiO2 displaced the oil in the sand pack and making the oil easy to flow thus resulting more oil recovered compared to the low volume injection of the SDS with SiO2. The brine as slug was important in the economic concerns. The brine helped to reduce the volume of chemicals required during injection thus reducing the cost required.

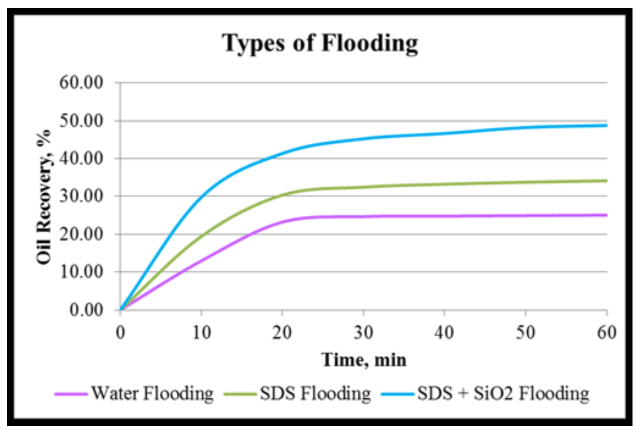


Figure 6. The oil recovery graph based of different methods of flooding

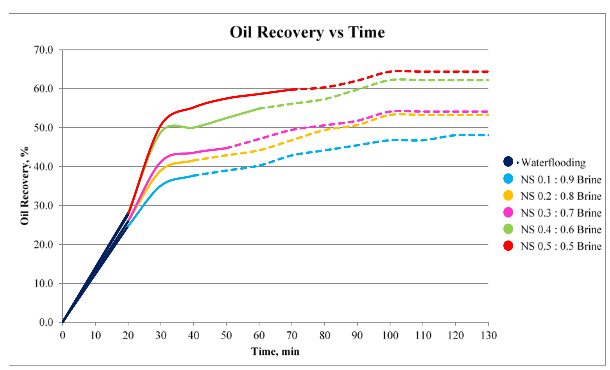


Figure 7 :The oil recovery with different injection ratio

4.0 CONCLUSION

Conclusion, the synergization of sodium dodecyl sulfate (SDS) and Silica (SiO_2) nanoparticles able to reduce the surface tension of the oil. From the surface tension results, the optimum concentration has been identified which is 2000 ppm for SDS concentration and 6000 ppm after the synergization with SiO_2.

In addition, this study presented that the Silica nanoparticles helped the SDS surfactant in reducing the interfacial tension of the paraffin oil in the sand pack. It was proven by oil recovery test. It showed that, the oil recovery increased up to 64% with the injection ratio 0.5 of synergization of SDS with SiO_2 over the 0.5 of 20 000 ppm of brine as slug. Overall, the chemical flooding by using the synergization of SDS with SiO_2 enhanced the oil recovery up to 64%.

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