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The Effects Between Interfacial Tension and Viscosity Reduction in Viscous Crude Oil Through the Addition of Surfactant Sodium Lignosulfonate (SLS) for EOR Purpose

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Abstract: Surfactant injection is one of chemical EOR methods by injecting a special substance as a surface-active agent (surfactant). The purpose is to reduce the interfacial tension (IFT) and the viscosity value of crude oil. This research was conducted to analyze the effect of adding anionic surfactant sodium lignosulfonate (SLS) on a laboratory scale. The sample of crude oil samples are obtained from Wonocolo field, Indonesia. The surfactant was obtained by almond peel extraction, developed at Laboratory Research EOR University of Pembangunan National "Veteran" Yogyakarta. SLS compositions for the experiment are 2%, 4%, 6% and 8% v/v. The test was made at 30, 40, 50, 60 and 70°C. The results showed that 6% v/v SLS solution was the best composition to significantly reduce IFT at 70°C from 32.78 mN/m to 3.22 mN/m. This composition also being the value of critical micelle concentration (CMC) for SLS. At above critical micelle concentration, the additional of surfactants will be insignificant on IFT reduction and also excess amount of surfactant in aqueous solution. With SLS 8% v/v solution gain the lowest viscosity of the fluid from 2.54 cP to 1.88 cP. In addition, the results of this study showed that when the reduction in IFT was the highest, the viscosity reduction was the highest.

Keywords: Crude Oil, Enhanced Oil Recovery, Interfacial Tension, Surfactant SLS, Viscosity

1. Introduction

In 2040 predicted that energy demand in the world is increasing up to 30% from 2010 [1]. With the depletion of petroleum reserves, increasing demand for energy, high population growth, and rapid industrial development, the increase in oil recovery is the most important [2]. In the primary phase, continuous oil drain will cause a decrease in the pressure gradient in the reservoir, and consequently, the oil production rate will decrease, according to Darcy's Law [3]. One of the ways to increase the oil production rate is by reducing the wellbore pressure (BHP). Next, the secondary phase is enforced to boost crude oil out of the reservoir using the pressure maintenance method of water flooding and gas injection [4]. However, waterflooding cannot drain all the oil in the reservoir due to two factors; first, due to reservoir heterogeneity, which causes water to flow in high-permeability rock paths found between injection wells and production wells. Second, the residual oil is covered by water and entrapped in slight crevices of the rock matrix because the oil-water surface tension stems from the oil flowing [5].

After the primary and secondary phases in the drain of oil, there is still oil that remains not drained. Then, it requires a tertiary phase well known as EOR to increase oil drain in the reservoir for oil displacement efficiency either microscopic or macroscopic scale. Surfactant is one of the components in a chemical injection that is effective to be applied to reduce the value of interfacial tension (IFT) and reduce oil viscosity so that it can increase sweep efficiency and thrust, along with a decrease in residual oil saturation value [5]. Then, it can be used to form a stable oil-in-water emulsion and reduce the viscosity of viscous crude oil.

Chemical injection is one of the advanced oil recovery (EOR) methods using chemicals as an injection fluid. This injection aims to increase the effectiveness of the water injected into the reservoir draining the oil. Chemical injection methods are polymer injection, surfactant injection, and alkali injection. Surfactant injection is a chemical injection by injecting a special chemical substance as a surface-active agent (Surfactant). The main purpose of being injected with these substances has two main reservoir mechanisms [6]. The first is the reduction in the value of the interfacial tension (IFT), and the second is the wettability alteration (wet change). As a result, there will be an increase in the value of oil recovery.

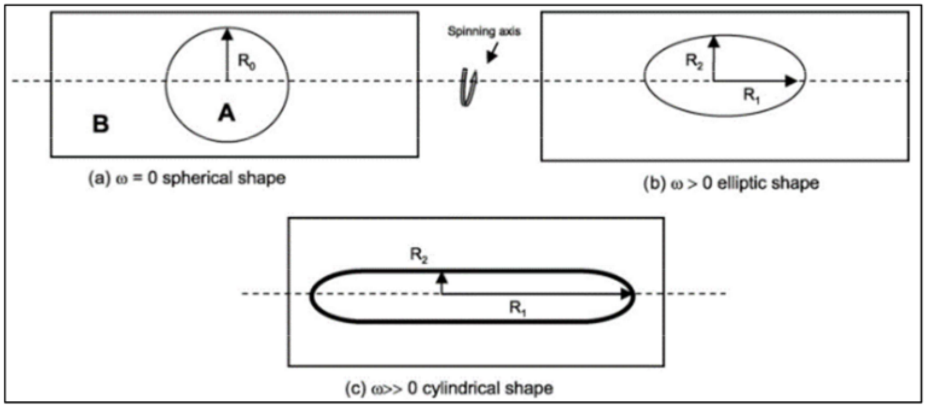

Figure 1. *Bubble Shape of IFT Measurement [7].*

In that solution, dissolved surfactant molecules were dispersed on the interface. At this moment, surfactants become monomers while decreasing the surface free energy. The addition of surfactant concentration will reach a critical micelle concentration (CMC) value, and then surfactant starts forming micelles. With a higher concentration above CMC, the surfactant will be negligible to IFT reduction. Anionic surfactants such as sodium lignosulfonate (SLS) are well known to decrease the oil-water IFT [8].

The higher viscosity and poor fluidity are the most challenging parameters when developing and applying crude oil production [9]. Reducing crude oil viscosity in the reservoir has always been vital in oil field development. Surfactants form a stable oil-water emulsion and reduce the viscosity of crude oil [10]. Applying surfactant needs the right choice to determine the viscosity reduction effect. Sodium lignosulfonate (SLS) was investigated as a cheap natural surfactant in stabilizing water emulsion in the fluid to reduce the vale of IFT. Anionic surfactant has high sensitivity through water salinity with high surfactant concentration. It has been found that the dynamic shear viscosity ofthe crude oil decreases substantially when it is emulsified with water in the form of an oil-in-water type of emulsion that stabilized by SLS [11].

This research analyzed the effect of adding natural surfactant sodium lignosulfonate (SLS) to crude oil. Therefore, this aims to examine the relation between IFT and fluid viscosity. The procedure is conducting surfactant system tests on SLS, determining the optimum concentration of SLS for the EOR purpose.

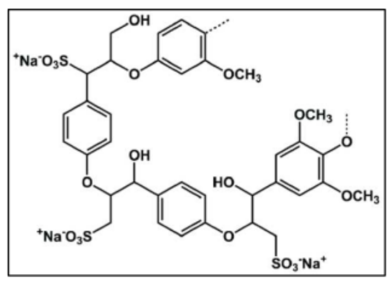

Figure 2. *Structure of Sodium Lignosulfonate (SLS) [12].*

2. Material and Methods

2.1. Chemical Sample

The crude oil sample used is from the oilfield in Wonocolo field, Cepu, Middle of Java, Indonesia with a density of 0.903 gr/cc. SLS is obtained from Laboratory Research EOR UPN "Veteran" Yogyakarta. Brine is obtained in the exact location as the crude oil with the salinity value is 8014 ppm.

2.2. Experimental Procedures and Instruments

A spinning drop tensiometer is set up to run the IFT test as seen in Figure 3. First, measuring density and concentration of the solution were carried out to measure the IFT value. This test aims to determine the effect of the addition of SLS on the oil-water contact in reducing IFT [13]. Lower the IFT concluded in a lower angle from the droplet (see Figure 2.). Procedures to measure the IFT are injecting 2 μL of crude oil into 2 ml of brine in the tube. Then, set the temperature according to what will be used for measurement. Running the spinning drop tensioner at 6000 rpm. Finally, The IFT value will appear on the monitor screen.

Figure 3. *Spinning Drop Tensiometer.*

The viscosity of the fluid is measured with brookfield viscometer (see Figure 4.). The viscosity testing procedure is as follows. First, turn on the water bath to set the temperature at the measurement time. Then, install a spindle to measure the sample's viscosity, insert the sample into the cylindrical tube, and attach it to the viscometer. Ensure the sample height level is under the height limit on the spindle. Next, perform viscosity measurements at several temperatures and input the sample density data measured on the monitor. And choose the start button on the monitor. Finally, the viscosity value will be displayed on the brookfield viscometer screen.

Figure 4. *Brookfield Viscometer.*

The parameters will be varied according to IFT and viscosity test. First, the surfactant concentrations are prepared at 2%, 4%, 6% and 8% v/v. Second, the salinity is set at 8014 ppm. Then the temperature varied at 30°C, 40°C, 50°C, 60°C and 70°C. The operating conditions for this study are shown in Table 1.

Table 1. *Operating Conditions of IFT and Viscosity Measurement.*

Parameter	Operating Conditions
Surfactant	Sodium Lignosulfonate (SLS)
Concentration (%)	0.0, 2.0, 4.0, 6.0, 8.0 v/v
Oil density	0.903 gr/cc
Brine salinity	8014 ppm
Temperature (°C)	30, 40, 50, 60, 70

3. Result and Discussion

Sodium lignosulfonate is used as a type of SLS made from natural chemicals. This SLS is sourced from chemical content in the form of lignin obtained from Ketapang through the EOR research laboratory of UPN "Veteran" Yogyakarta, the lignin content in almond's peel is extracted through the process of extraction, delignification, and sulfonation. In the early stages, the almond is dried for 7-14 days in the sun to reduce the water content in the almond's peel. The almond's peels are ground to a mesh size of 50 into powder, and this process is carried out to create a powder for the lignin content to be extracted. The extraction process uses ethanol and toluene. In the extraction process, the chemical contents that are not needed will be lost and dissolved in the added organic solvent. Furthermore, the delignification and sulfonation processes are carried out with the aim of binding lignin from the extracted powder and converting the lignin into lignosulfonate. The final result is a surfactant solution of sodium lignosulfonate type. Sodium lignosulfonate is a type of SLS made from natural chemicals, namely vegetable ingredients; the advantages of this material are biodegradable, cheap, and environmentally friendly manufacturing process. The content of the developed SLS is shown in the following Table 2.

Table 2. *Sodium Lignosulfonate (SLS) Characteristic.*

Characteristic	Operating Conditions
Color	Brownish yellow
pH	5
Smell	Acid sulfuric
Solubility in water	Soluble

The steps taken in making surfactant SLS made from almond's peel can be seen in Figure 5. below.

(a) Almond's peel extraction. *(b) Synthesis of SLS*

Figure 5. *The synthesis process of SLS from almond's peel.*

Figure 6. *SLS Solubility Test Result.*

All SLS concentrations were tested without any formulations in them. Where the concentration of SLS used is 2%, 4%, 6% and 8% v/v. Surfactants with good solubility in brine are needed because the reaction will form a uniform distribution. Hence, the performance of the surfactant will be the same in every part of the rock when it is injected. Based on the solubility test results, SLS dissolved clearly in brine (see Figure 6.).

The IFT test results display that the highest IFT value of the sample crude oil after being added by SLS is found at a temperature of 70°C with a concentration of 2% equal to 25.9 mN/m. Meanwhile, the lowest IFT value was found at a concentration of 6%, which was 3.22 mN/m (Figure 7.).

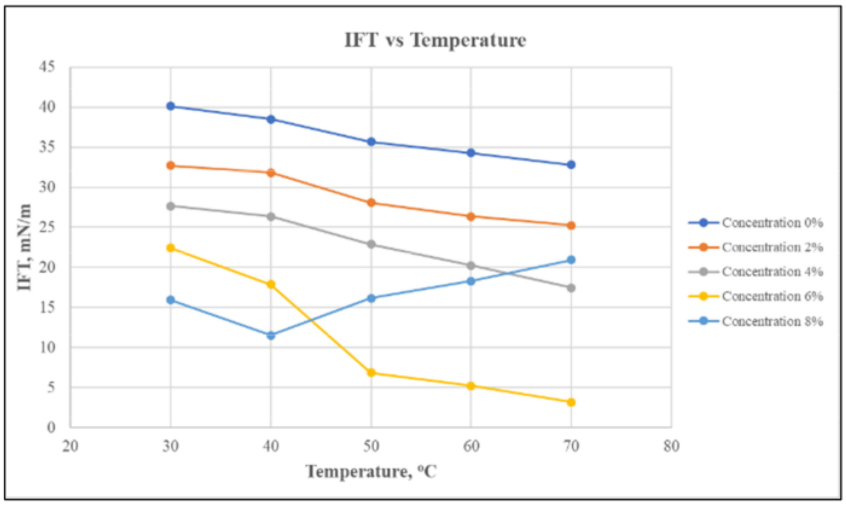

Figure 7. *Interfacial Tension (IFT) Test Result.*

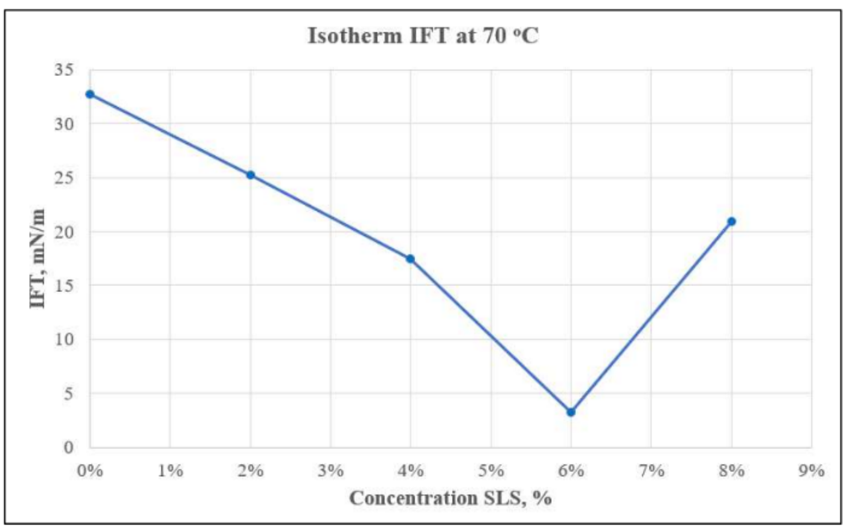

Figure 8. *Critical Micelle Concentration (CMC) Test Result.*

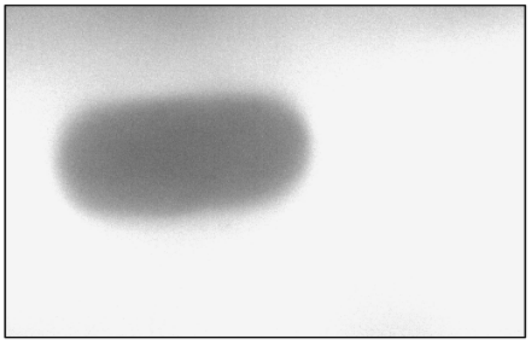

Figure 9. SLS 6% IFT Test Result.

After obtaining IFT prices on various concentrations, the value of critical micelle concentration (CMC) on SLS can be determined as seen in Figure 8. CMC is used to determine the smallest concentration of surfactant in brine as the basis for determining the surfactant concentration to be applied to EOR. Hence, the CMC value was obtained at a concentration of 6%.

Based on Figure 10. Below known that the viscosity of SLS 3 relatively constant with increasing temperature. Then SLS can reduce the viscosity of the sample crude oil relative to the increase in temperature (see Figure 10.). The lowest viscosity values were located at 8% SLS solution with a temperature of 70°C with the value of 2.54 cP to 1.88. It has shown adding SLS to crude oil can reduce the viscosity value with a constant increase in SLS concentration.

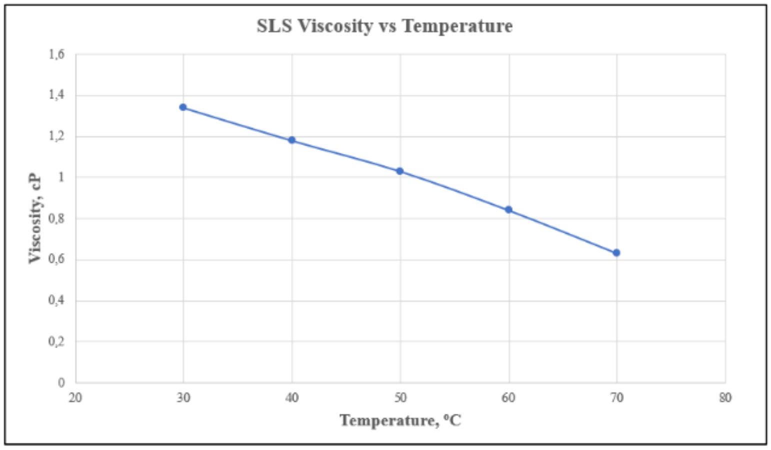

Figure 10. SLS Viscosity Test Result.

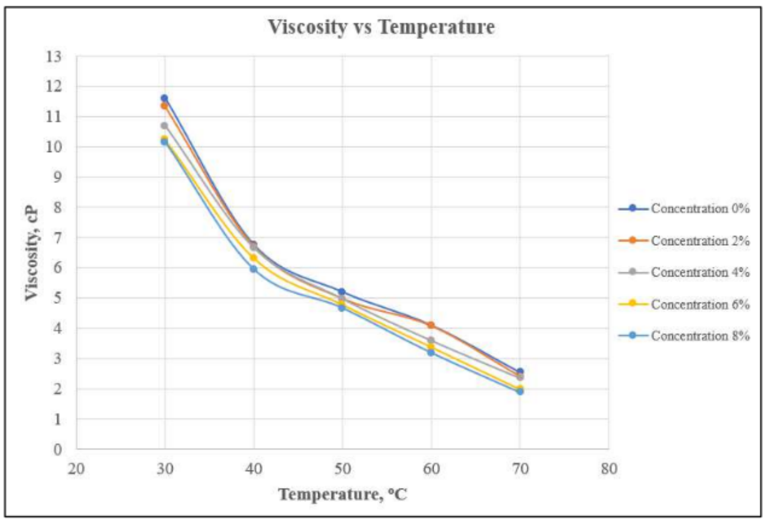

Figure 11. Viscosity Test Result.

Figure 7 shows the IFT variation with temperatures for various systems at the optimized ratio. IFT at the oil-water interface formed by SLS surfactant is in the order of magnitude of 10^{-0} mN/m. When the reduction in IFT was the highest, the viscosity reduction was the highest [14]. The minimum value of IFT of surfactant on the oil-water interface is 10^{-3} mN/m [15]. This study needs development on the formulation of this type of surfactant to gain the minimum value from the criteria of EOR.

4. Conclusion

Anionic surfactant sodium lignosulfonate (SLS) based almond peel that is developed from Laboratory Research EOR UPN "Veteran" Yogyakarta able to reduce IFT and viscosity of crude oil significantly. In the solubility test, SLS can be dissolved in water to improve the performance of surfactants during experiments. The most optimal SLS concentration that reduces the viscosity value in the viscosity test is SLS 8% v/v solution to the lowest value from 2.54 cP to 1.88 cP. Hence, SLS can be used to form a stable oil-in-water emulsion and reduce the viscosity of viscous crude oil. In the IFT test, the 6% SLS is optimal because it reduces the lowest IFT to 3.22 mN/m. Besides, after CMC observation at a Temperature 70°C, the optimal CMC is obtained at 6% SLS. This study showed that when the reduction in IFT was the highest, the viscosity reduction was the highest. SLS needs some developments in the formulation to gain the magnitude order in the value of IFT to 10^{-3} mN/m for the EOR process criteria from surfactant injection.

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