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Interfacial Tension Test Analysis as Injection Fluid on Reservoir Core

Orlando Firdaus [a]
Rini Setiati [b]
Muh. Taufiq Fathaddin [c]
Pri Agung Rakhmanto [d]
Suryo Prakoso [e]
Dwi Atty Mardiana [f]

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Abstract

In the petroleum industry, Enhanced Oil Recovery (EOR) technology has been developed to obtain increased oil recovery from reservoirs. One of the EOR methods is chemical EOR using a surfactant known as the surfactant flooding method. Surfactants have the ability to reduce the interfacial tension between oil and water in the rock matrix so that residual oil can be produced. There are several parameters that affect the performance of surfactants, among which will be discussed in this discussion, namely the middle phase emulsion obtained from the phase behavior test and the results from the Interfacial Tension (IFT) test. Based on the literature review, the method used in IFT uses the spinning drop method. Compatibility test of Fir wood SLS surfactant solution used with a concentration of 0.5% - 3% and a salinity of 4,000 - 110,000 ppm. The results of the study obtained the best results in the behavior test of the middle phase, at 90,000 ppm salinity with a concentration of 1.5%, salinity 110,000 ppm with a concentration of 2.5% and salinity 110,000 ppm with a concentration of 3%. From the best selected, only one will be tested further, at a concentration of 2.5% and a salinity of 110,000 ppm. The results of the thermal stability test showed that it was stable at 4.27 mN/m. Based on the literature review, it was found that the greater the percentage of the middle phase emulsion, the greater the IFT results obtained.

Corresponding author:
Rini Setiati
Master of Petroleum Engineering Study Program, Faculty of Earth and Energy Technology,
Universitas Trisakti, Jakarta, Indonesia.
Email address: rinisetiati@trisakti.ac.id

[a] Master of Petroleum Engineering Study Program, Faculty of Earth and Energy Technology, Universitas Trisakti, Jakarta, Indonesia
[b] Master of Petroleum Engineering Study Program, Faculty of Earth and Energy Technology, Universitas Trisakti, Jakarta, Indonesia
[c] Master of Petroleum Engineering Study Program, Faculty of Earth and Energy Technology, Universitas Trisakti, Jakarta, Indonesia
[d] Master of Petroleum Engineering Study Program, Faculty of Earth and Energy Technology, Universitas Trisakti, Jakarta, Indonesia
[e] Master of Petroleum Engineering Study Program, Faculty of Earth and Energy Technology, Universitas Trisakti, Jakarta, Indonesia
[f] Master of Petroleum Engineering Study Program, Faculty of Earth and Energy Technology, Universitas Trisakti, Jakarta, Indonesia

1 Introduction

EOR screening is vital to be conducted on initial stage of valuation to explain EOR evaluation appropriateness (Hartono et al., 2017). Capillary pressure is one of the most important parameters because of its ability to show differences in pressure level on the interface between two unmixable fluids; one fluid wet another rock surface. Interfacial Tension (IFT) can affect capillary pressure, and further disrupt fluid distribution (Azad, 2021). IFT is also a guidance to measure miscibility, where high IFT level indicates that the fluid is immiscible, meanwhile low IFT level indicates that the fluid is miscible. Phase behavioral test is conducted to determine surfactant IFT description of formed microemulsion in a system consist of surfactant, salt water, and oil. This subject is tightly connected to IFT which is an important factor in oil recovery with microemulsion formed of chemical flooding process (Fattahanisa et al., 2018; Gbadamosi et al., 2019). Characteristic test is a complimentary test needed to produce an interpretation of surfactant performance success on injection fluid in reservoir rock. According to Kayali et al. (2010), phase behavioral test is conducted to understand IFT information on surfactant from a formed microemulsion in surfactant, brine and oil. This is highly connected with IFT which is an important factor in oil production with microemulsion formed on chemical flooding process. Based on IFT test, salinity and surfactant concentration influence IFT value. The higher surfactant concentration, the lower IFT value will be on certain level (Azad, 2021; Andriyan et al., 2015). Similarly, for salinity, the higher the salinity level of a surfactant, the smaller the IFT value will be. On higher salinity level, IFT is detected to be higher (Khouw et al., 2021).

2 Materials and Methods

Method utilized in this research is an experimental laboratory and analytic research methods. This research implements laboratory analysis method adjusted to reservoir condition. The utilized Fir wood SLS surfactant concentration in this research is at 2.5% and 110,000 ppm salinity. Surfactant solution will be measured on 60°C temperature. The type of oil used in this research is intermediate crude oil. Interfacial tension test between crude oil and brine samples shows that IFT on oil with formation water (without surfactant) is at IFT = 12.43 (mN/m) with formation water salinity on the sample point at 8,110 ppm (Swadesi et al., 2015). Thermal stability test is conducted to acknowledge surfactant endurance against certain temperature level. A decent surfactant will be in stable condition after thermal stability test (Druetta & F. Picchioni, 2020). This test was conducted in 3 months of observation period inside a 60°C oven. This observation is conducted to acknowledge the tendencies of interface tension (IFT) value change that occurs during warming process within reservoir temperature (Karnanda et al., 2012). Stable IFT value measurement shows that surfactant is undamaged by heat and still has the ability to lower IFT level. Figure 1 shows the implemented flow chart of this research (Gutiérrez et al., 2008; Solans et al., 2005).

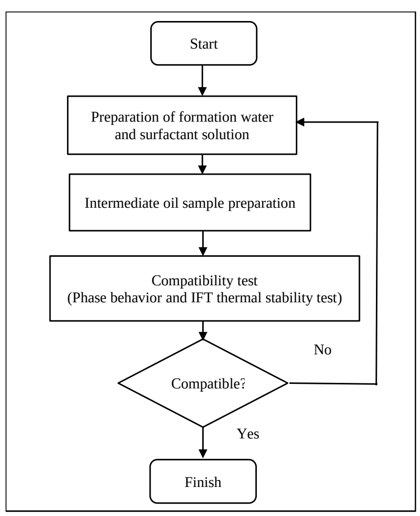
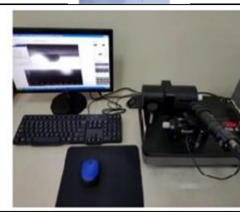


Figure 1. IFT Measurement Flow Chart

The test was conducted by utilizing Spinning Drop Tensiometer – Series TX 500D. IFT value was obtained by measuring 2μL crude oil droplet diameter injected in chemical EOR solution on reservoir temperature (in this case is at 60°C) with 6000 rpm angular velocity for 30 minutes of testing period. Table 1 below shows the tools and equipment used in this IFT test with spinning drop tensiometer series TX500D.

Table 1
Tool and Equipment (LAPI ITB, 2022)

No.	Tools/Equipment	Image
1.	Sample preparation (Capillary tube and syringe)	
2.	Spinning Drop Tensiometer Kit (TX-500D Series)	

3 Results and Discussions

Based on the previous phase behavioral test, we managed to discover the formation of middle phase emulsion. That is why, the selected compound composition is 2.5% concentration and 110.000 ppm salinity. This composition will be further involved in IFT and thermal stability tests. The measurement is conducted for 90 days of observation in a 60°C oven. Observation was only implemented on five points with day 0 as IFT value measurement before thermal. Measurement was started from day 0, week 1, up to week 14 by using Spinning Drop Tensiometer TX500D tool to obtain IFT value (Cheng et al., 1990; Rao, 1997; Meza et al., 2018). The IFT value will become a reference to acknowledge surfactant endurance in reservoir temperature at certain period of time marked with its stability. Stable IFT measurement result shows that surfactant was undamaged by heat with relatively stable IFT value. IFT test results in this research is 4,271 mN/m on day 0 and 4.161 mN/m on week 14. Besides using Fir wood SLS surfactant, this research also compares results obtained from previous research that uses sugarcane bagasse SLS surfactant with similar concentration and salinity levels, namely at 2.5% concentration and 110,000 ppm salinity. IFT test result with sugarcane SLS surfactant is at 6.6995 mN/m on day 0 and 7.3322 mN/m on week 14. Table 2 shows comparative results between thermal stability test results on Fir wood SLS surfactant and sugarcane bagasse SLS surfactant conducted from day 0 up to week 14 (Austad & Strand, 1996; Suljanović et al., 2004).

Table 2
IFT results of thermal stability test on surfactant solution

Concentration and Salinity	Time (week)	IFT (mN/m)	
		SLS Fir wood	SLS bagasse [12]
2.5% - 110,000ppm	0	4.27105	6.6995
	1	4.62167	7.3511
	3	4.37053	7.6313
	7	4.86194	7.7987
	11	4.72540	7.5321
	14	4.16147	7.3322

Based on the comparation of the 2 surfactant types in IFT test, we can see the stability level of these commercial surfactants. The average IFT value after 3 months of measurement is at:
On Fir wood SLS surfactant, the average IFT valuation is as follows:

$$IFT = \Sigma \, IFT_{0} - IFT_{6} = (4.271 + 4.621 + 4.370 + 4.861 + 4.725 + 4.161) / 6 = 4.501 \text{ mN/m}$$

Meanwhile for sugarcane bagasse SLS surfactant, the average IFT valuation results is as follows:

$$IFT = \Sigma \, IFT_{0} - IFT_{6} = (6.6995 + 7.3511 + 7.6313 + 7.7987 + 7.5321 + 7.3322) / 6 = 7.390 \text{ mN/m}$$

From table 2, we obtained IFT results graphic on relatively stable nature from day 0 up to week 14 with 5 measurement points on both sugarcane bagasse SLS surfactant and Fir wood SLS surfactant as shown in Figure 2. The objective of this thermal stability test is to acknowledge surfactant endurance level against certain level of temperature (Tavakkoli et al., 2022; Sofla et al., 2016).

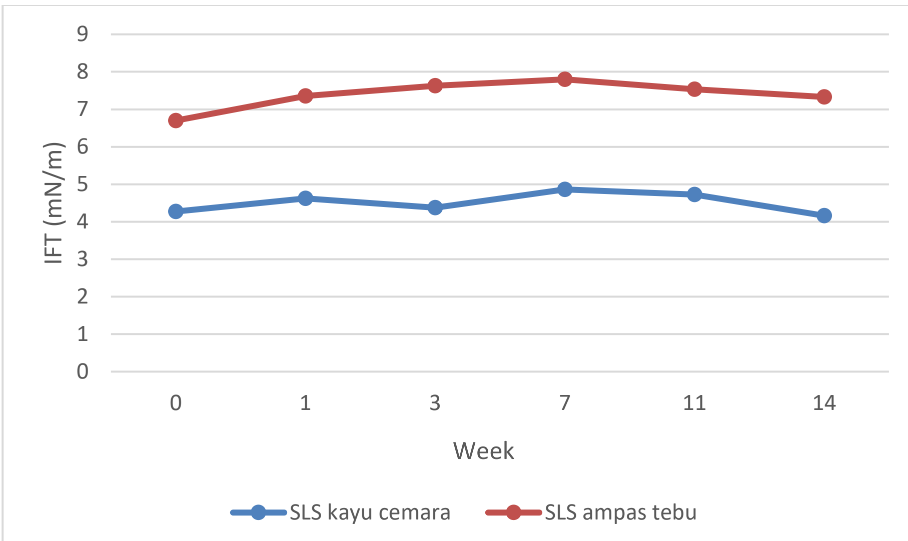


Figure 2. IFT thermal stability results graphic

Based on the graphic above, similar results were obtained on 10^0 order between Fir wood SLS surfactant and sugarcane bagasse SLS surfactant. IFT result on the previous research shows that the utilization of sugarcane bagasse SLS surfactant with similar concentration and salinity levels was able to generate stable IFT value of 4.501 mN/m for Fir wood SLS surfactant and stable IFT value of 6.6995 mN/m for sugarcane bagasse surfactant. IFT test results has proven that sugarcane bagasse NaLS surfactant and Fir wood surfactant was able to lower IFT value on sampled oil and formation water (without surfactant) with IFT value of 12.43 (mN/m) with formation water salinity of 8,110 ppm (Swadesi et al., 2015). Fir wood surfactant is able to lower IFT as much as 7.929 mN/m or 63.78% of the initial IFT value, meanwhile sugarcane bagasse surfactant is able to lower IFT as much as 5.6305 mN/m or 46.10% of the initial IFT value (Chattopadhyay & Webster, 2009; Kosmulski et al., 2004; Meza et al., 2018).

4 Conclusion

Conclusions generated from IFT and thermal stability tests on 2.5% SLS and 110,000 ppm salinity shows that surfactant is quite stable because it generates similar value than the average IFT measurement within 3 months of observation. Fir wood surfactant has the ability to lower 63.78% of IFT value from the initial value, meanwhile sugarcane bagasse surfactant is able to lower 46.10% of IFT value from the initial IFT value. Based on that, these organic surfactants are able to function as interfacial tension (IFT) reducer. The ability to lower IFT shows that Fir wood and sugarcane bagasse SLS surfactants can be utilized as injection fluids. That is why, IFT test is useful to determine whether a surfactant can be utilized as injection fluid in Enhanced Oil Recovery process.

Conflict of interest statement
The authors declared that they have no competing interest.

Statement of authorship
The authors have a responsibility for the conception and design of the study. The authors have approved the final article.

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