INTERFACIAL TENSION BETWEEN INJECTING FLUID AND RESERVOIR OIL AT ELEVATED PRESSURE AND TEMPERATURE

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ABSTRACT

An important parameter of surfactant flooding in enhanced oil recovery (EOR) processes is the interfacial tension (IFT) reduction between the injecting fluid and the reservoir oil. To measure the IFT precisely and accurately at high pressure and temperature, Pendant Drop Apparatus had been set up. IFT between surfactant solution and reservoir oil have been investigated at several different pressure and temperature. The working pressure ranged from 0 psig up to 5000 psig, and the temperature varied from ambient condition to 80^{o}C.

The results indicated that the interfacial tension behavior of surfactant solution and reservoir oil was very unique characteristics as the pressure and temperature increase. However, some conclusion can be withdrawn from these experiments. Increasing pressure causes relatively minor change in IFT. On the other hand the rise of temperature tended to raise the IFT much more significant. Since the surfactant solution having unique behavior therefore it is recommended that IFT must be measured in laboratory at the reservoir condition before injecting in to a reservoir.

Key words: Interfacial tension, injecting fluid, EOR

I. INTRODUCTION

During this high oil price condition, the oil industries have been heavily interested to use EOR technology to increase their oil production. Chemical injection may become the best option in many cases compare to gas injection. Gas injection is normally suitable for deep reservoirs in order to achieve the minimum miscibility pressure and also to prevent the fracture formulation.

Basically chemical injection includes alkaline, surfactant, polymer injection. They can be arranged to be injected into a reservoir in a series of order injection fluids but also possibly injected separately. Nowadays this technology has become simpler by introducing the new injection technique, mixing those chemicals in the surface and injected into a reservoir all together. This categories consist of AS (alkaline-surfactant mixture), SP (surfactant-polymer mixture), and ASP (alkaline-surfactant-polymer mixture) injections.[1]

Surfactant flood has been successfully implemented in some oil field to increase the recovery factor of oil during tertiary stage. Even though in the laboratory scale surfactant injection has been proven to be very promising to enhance the oil production, in field scale still have some uncertainty. Therefore, detail laboratory works should be done before bringing into pilot field scale project. In this papers will be discussed very detail the influent of elevated pressure and temperature to the value of IFT of injected fluid and reservoir oil.

II. SURFACTANT SCREENING

In order to increase the optimum oil recovery, experiments in laboratory should be done not only to measure the IFT as the importance parameter, but also the other parameters such as phase behavior, compatibility test with formation water, injectivity, and rock adsorption, before implementing the surfactant injection in a pilot field.[2]

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IFT measurement: surfactant injection should create ultra low interfacial tension (<10^{-3} dyne/cm) to increase the displacement efficiency. The fundamental effect of surfactant used is to reduce the interfacial tension between oil and displacing fluid so as to displace the residual oil in porous media. Basically, the relationship between capillary number and residual oil saturation should be prepared in the laboratory. The value of capillary number represents the ratio of driving force to capillary resistance force. Increasing the capillary number to the level above of 10^{-4} will consequently reduce the residual oil saturation drastically.

Compatibility tests: mixture of the injection water or formation water with surfactant should produce a clear solution and no precipitation. However, there is some hazy solution, a good micellar fluid of surfactant mixtures can be translucent and whitish and opaque in appearance. This solution still can be injected into the reservoir if it is a stable solution and thermodynamically also stable. Run a filtration test using 0.2 micron filter paper of finer and make sure the filterability is good.

Phase behavior: Normally, middle micro-emulsion is the best solution to be injected into the reservoir. However, the lower phase or water phase is still can be injected into the reservoir as long as the optimum IFT can be achieve. On the other hand, the upper phase should not be used in EOR.

Injectivity test: this test is to measure the capability a solution to be pumped into a reservoir. This work is done to evaluate also the possibility of surfactant “filtered” on the sand-face during injection. Measure the RF (resistance factor) and RRF (residual resistance factor) and compare the values to the industrial standard which is tolerable.

Adsorption test: the adsorption of surfactant on the surface of sandstone normally is lower compared to carbonate rock. To prevent high adsorption of surfactant some chemical such as alkaline may be added into the solution. Some studies reported that adsorption surfactant of 0.46 mg/g rock was acceptable. Using mg loss/gm of rock can be misleading in the design of a micellar process. The measurement of adsorption should be expressed in lbs (or kg)/ bbl of pore volume. Typically, if the adsorption loss is > 1.0 lb/bbl of, it is considered high. By knowing the adsorption loss number, then the total surfactant amount required to satisfy the adorption loss in the reservoir (adsorption loss x bbl of pore volume in the reservoir) can be measured.

III. EQUIPMENT FOR IFT MEASUREMENT

High pressure high temperature pendant drop interfacial tensiometer (Drop Shape Analysis DSA PD-700) was used in this experiment. This equipment can handle temperature up to 200°C and pressure

Figure 2
Image bubble

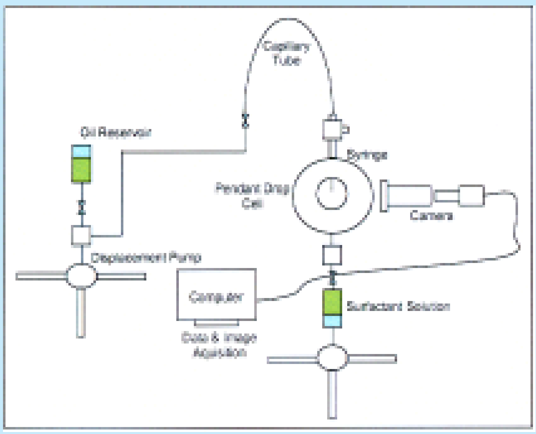

Figure1
Schematic of pendant drop apparatus

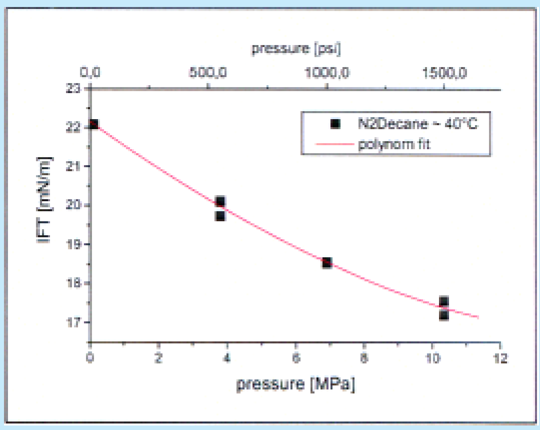

Figure 3
Calibration result

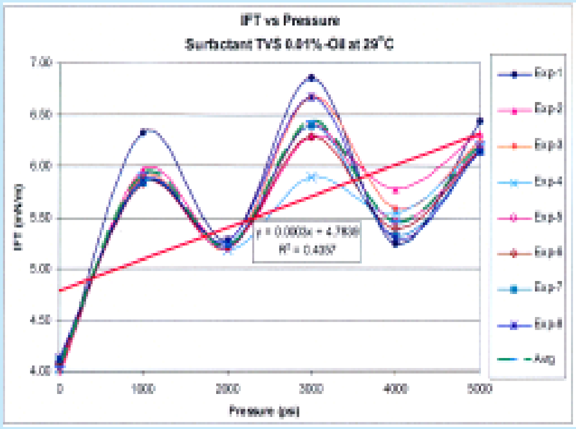

Figure 4
IFT of 0.01%TVS-oil at 29°C

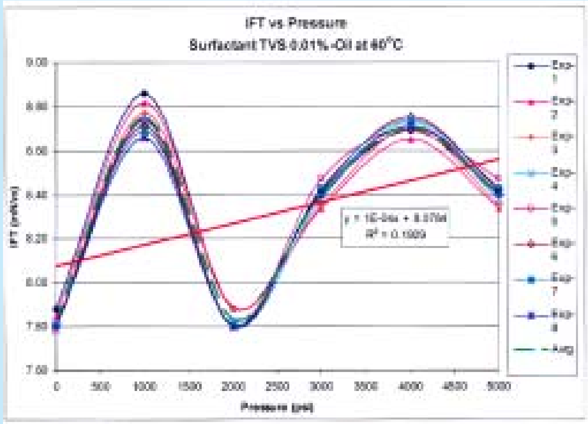

Figure 6
IFT of 0.01%TVS-oil at 60°C

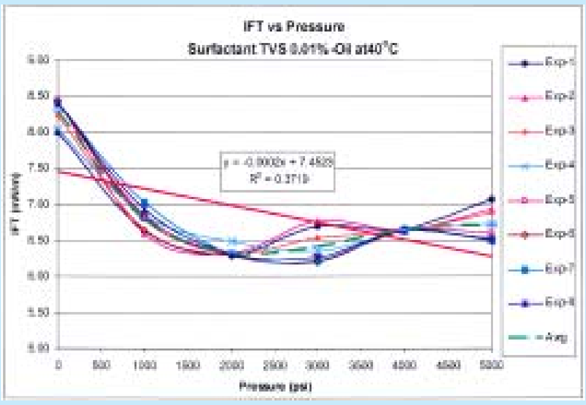

Figure 5
IFT of 0.01%TVS-oil at 40°C

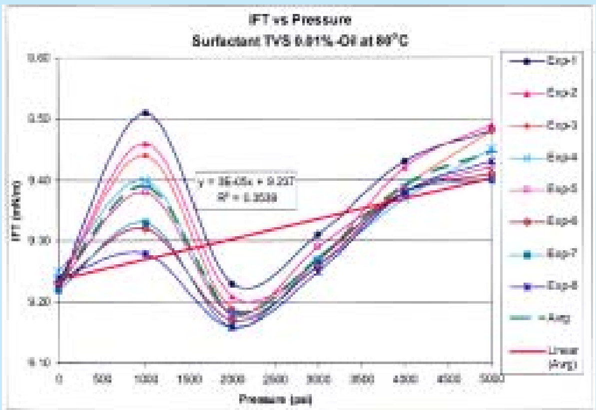

Figure 7
IFT of 0.01%TVS-oil at 80°C

of 10.000 psig. Pendant drop method is used to measure the interfacial tension of liquid-liquid system and liquid-gas system as long as there is density difference exists between two phases, and the one phase is transparent.

DSA PD-E700 is new generation of pendant drop interfacial tensiometer. Basically, this equipment consists of windowed cell that is capable of withstand at high pressure and temperature, 2 high pressure pump to arrange the injection pressure and to develop the liquid or gas bubble. A microscope is put in front of the windowed cell to snap the image bubble, and send it into the computer. Drop Shape Analysis Software has been installed in this computer which is capable of calculating the value of IFT directly from the image bubble. Figure 1 is schematic picture of DSA PD-E700.[3, 4]

Initially this equipment should be run in a calibration processes using decane and nitrogen. Measurements were done at temperature of 40°C and pressure in the range of 15 psig up to 1500 psig. The results are shown in Figure 2 and the bubble image in Figure 3. The results indicated that the equipment have measured the IFT accurately.

IV. IFT OF OIL AND TVS-SURFACTANT

TVS is an amphoter surfactant which has a high surface active agent and soluble in the water. This surfactant is normally prepared for EOR project in some oil field in the world. Formation water from oil

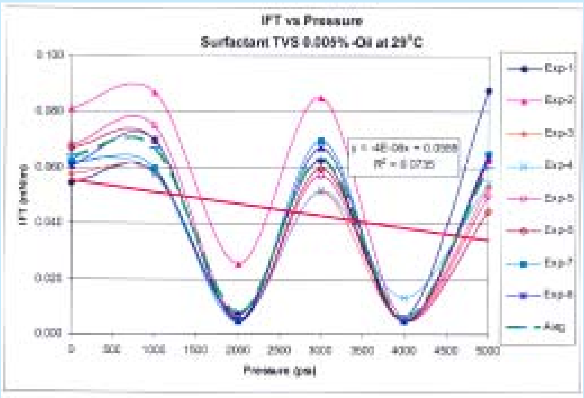

Figure 8
IFT of 0.005%TVS-oil at 29°C

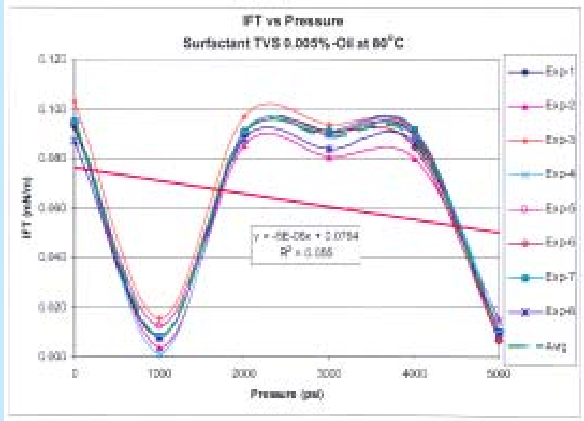

Figure 11
IFT of 0.005%TVS-oil at 80°C

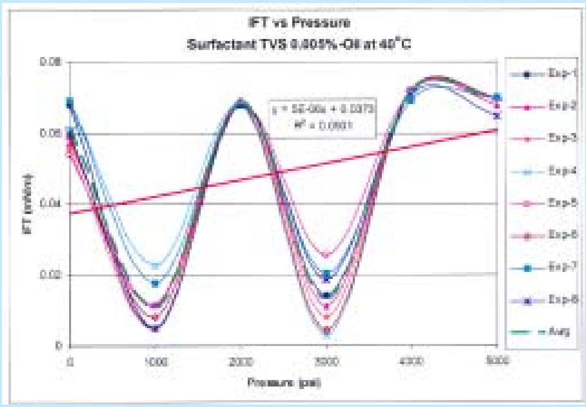

Figure 9
IFT of 0.005%TVS-oil at 40°C

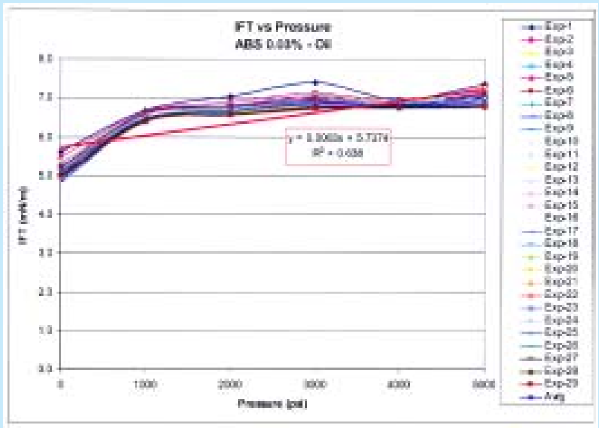

Figure 12
IFT of 0.03%ABS-oil at 29°C

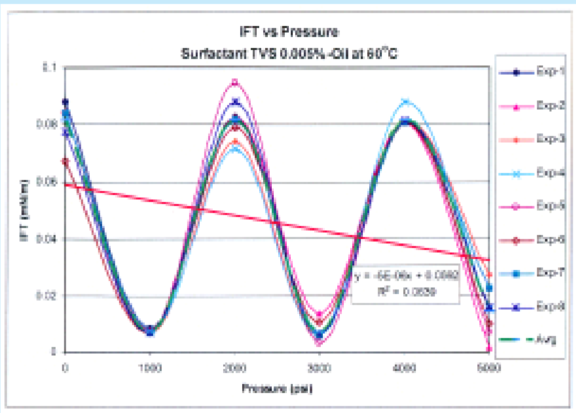

Figure 10
IFT of 0.005%TVS-oil at 60°C

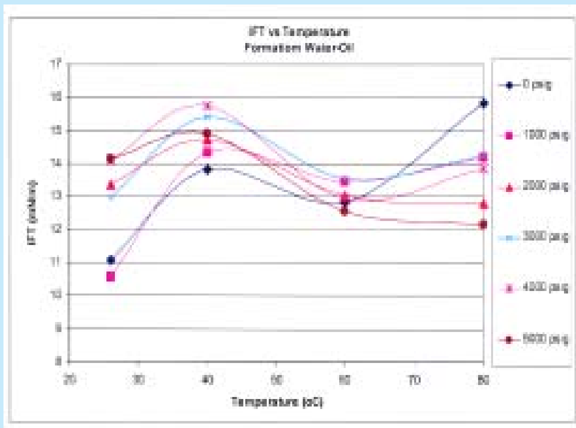

Figure 13
IFT of Water-oil at 29°C

Table 1
IFT change due to pressure

Fluid and temperature	IFT change/ 1000 psig	Fluid and temperature	IFT Change/ 1000 psig
TVS-0.005%-Oil		Form. Water-Decane	
29°C	-7.77%	29°C	0.97%
40°C	11. 82%	40°C	2.95%
60°C	-9.23%	60°C	0.31%
80°C	-7%	80°C	0.94%
TVS-O.OI %-Oil		Form. Water-Oil	
29°C	5.90%	29°C	
40°C	-2.76%	40°C	2.08%
60°C	1.22%	60°C	-0.53%
80°C	0.32%	80°C	-3.41%
ABS-0.03%-Oil			
29°C	4.97%		
- = decrease			
+ = increase			

Table 2
IFT change due to temperature

Fluid and pressure	IFT change/20^{o}C	Fluid and pressure	IFT Change/20^{o}C
TVS-0.005%-Oil		Form. Water-Decane	
0 psig	17.78%	0 psig	1.53%
1000 psig	-51. 72	1000 psig	1.37%
2000 psig	58.46%	2000 psig	0.44%
3000 psig	26.81%	3000 psig	3.85%
4000 psig	57.27%	4000 psig	3.85%
5000 psig	-48.19%	5000 psig	-1. 80%
TVS-O.OI %-Oil			
0 psig	20.29%	0 psig	11.36%
1000 psig	28.76%	1000 psig	8.09%
2000 psig	23.80%	2000 psig	-2.99%
3000 psig	31.05%	3000 psig	1.13%
4000 psig	31.08%	4000 psig	-3.05%
5000 psig	25.05%	5000 psig	-6.78%
- = decrease			
+ = increase			

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field was also prepared for this experiment. The water contain approximately 15,552.6 mg/L NaCl equivalent and ions divalent content such as Ca^{2+} and Mg^{2+} are around 296.6 and 41.3 mg/L correspondingly. This water is categorized as very hardness and high Salinity. Many surfactants are very sensitive to the present of divalent ions and decreasing their performance. Besides, reservoir oil was also taken from the same reservoir as the formation water. The reservoir oil is classified as light oil with a gravity of 43.8°API.

Two surfactant solutions were made up with concentration of 0.005 and 0.01%. IFT between these surfactant and the reservoir oil were examined at various temperatures such as 29°C (room condition), 40°C, 60°C, and 80°C. The investigation pressure were initiated at the level of 0 psig and after that it was increased steadily to the level 1000, 2000, 3000, 4000, and finally 5000 psig. Each IFT reading was repeated at least 8 times at the same pressure and temperature level, to make sure the investigated IFT was taken as accurate as possible. The results of these experiment are presented in Figure 4 to Figure 7 for 0.01% TVS and Figure 8 to Figure 11 for 0.005% TVS.

All of the results indicate that the curves have developed with irregular trends. For example, the experimental temperature condition of 29°C and pressure range of 0, 1000, 2000, 3000, 4000, 5000 psig, IFT of 0. 01% surfactant and reservoir oil came up with such random numbers, i.e. 4.16, 5.87, 5.31, 6.35, 5.31, 6.15mN/m correspondently. Similarly, at the experimental temperature of 80°C IFTs of the fluid are in the range of 9.25, 9.29, 9.13, 9.25, 9.37, and 9.40mN/m.

V. IFT OF OIL AND ABS-SURFACTANT

ABS stands for Alkyl Benzene Sulfonates, which is normally used as a raw material of detergent. This surfactant is perfectly soluble in a low salinity water and becoming precipitate if the salinity increases to the level of above 5000ppm. If the salinity of the water increases then the solubility of ABS drops gradually. Alcohol need to be added to improve the solubility of ABS. Experiments using ABS solution was performed only at one temperature of 29°C and combining with various pressure levels. The result is shown in Figure 12, in which the influence of pressure on IFT is very minor. IFT at 1 psig is 5.10mN/m and small increase at 5000 psig to the level of 6.94mN/m.

In addition to the above experiments, IFT between reservoir oil and formation water were also investigated at various temperatures in this course of the study to simulate IFT value of water flooding condition. The results are illustrated in Figure 13. In addition to that, IFT between Decane and formation water also was performed to acquire some more data.

VI. EFFECT OF PRESSURE AND TEMPERATURE

Table 1 and Table 2 are summary of the experimental results of the effect of pressure and temperature on the IFT. In the range of experiment, the rising pressure tends to increase the IFT from 0.31% up to 11.82%. On the other hand the elevated temperature may expand the IFT in between 0.44% and 31.80%. So, the effect elevated temperature is much pronoun than increasing pressure.

VII. CONCLUSIONS

1. DSA PD-E700 is sophisticated instrument to measure IFT of injected fluid surfactant and reservoir oil at elevated temperature and high pressure condition
2. The effect of increasing pressure on IFT is very minor
3. The effect of elevated temperature on IFT is much more pronoun than pressure
4. Basically, each type of surfactant have a specific behavior at reservoir condition
5. Therefore, it is suggested to continue this research to use variety of surfactant such as: different types, composition, and molecular weight.

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