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Interfacial Tension Measurement for Alkaline-Polymer Flooding Application for Oil from Fang Oilfield, Thailand

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With the high demand of oil and gas consumption, oil is required for more production. Fang oilfield is one of the main oilfields in Thailand. An enhanced oil recovery method especially alkaline-polymer flooding is an essential technique to improve oil production. It involves an injection of alkaline to lower the interfacial tension (IFT) between oil and water and polymer for improving the mobility ratio to produce more oil. In Fang oilfield, a light oil recovery is improved by using the solution to reduce IFT of oil and water. In this study, sodium hydroxide (NaOH) and hydrolysed polyacrylamide (HPAM) are used as alkali and polymer to lower the IFT with different conditions. The aim of this work is to measure the IFT and to assess the effects of pressure, temperature, concentration and salinity on IFT reduction for oil from Fang oilfield. The results present that the concentration of the chemical plays a key role for IFT reduction accounting for 99.49 %. IFT decreases with an increase in temperature up to 49.30 %. The effect of pressure is insignificant for IFT reduction. Salinity can increase IFT for 94.74 % at the low alkali concentration while HPAM could be more benefit in other aspects such as the mobility control process. The outcome of this work can be used as a fundamental data to enhance more oil recovery with the new technique for Fang oilfield.

1. Introduction

With the high demand of energy consumption, the fossil fuels such as oil and gas are required for the higher production. For oil production, water-flooding is the most widely used method to increase oil recovery due to its low costs and simple operations (Sedaghat et al., 2013). A large amount of oil droplets around 70% of the original oil in place or OOIP which is the initial amount of oil in the reservoir before the production are trapped by capillary forces (Doscher and Wise, 1976). Using some new and more advanced techniques like gas injection (Yoosook and Maneeintr, 2018) or chemicals injection (Husein et al., 2018) can produce more oil. The chemicals such as alkaline, surfactant and polymer injected into the reservoir can bring those residual oil to the surface. Due to the high viscosity of the polymer solution, polymer flooding helps increase oil productivity by decreasing the mobility ratio of water to oil and increases the sweep efficiency. With the long chain structure of polymer molecules, they are capable of dragging the residual oil out of the retention area and create steady oil channels to increase oil recovery (Wang and Liu, 2014). Another interesting mechanism is that the adsorbed polymer molecules resist the flow of aqueous phase, thereby decreasing the water relative permeability (Wang and Liu, 2014). Polymer that has been used widely is hydrolysed polyacrylamide (HPAM) because of its price and large-scale production (Sheng, 2013).

Another technique that has been used to enhance oil production is the alkaline-polymer (AP) flooding. It relates with the alkaline injection that reacts with the organic acid in oil to generate an in-situ surfactant. This surfactant can lower the interfacial tension (IFT) between oil and water and decrease the residual oil saturation, leading to the higher value of both sweep efficiency and displacement efficiency to produce more oil (Chen et al., 2015). Several operating mechanisms on alkaline flooding are proposed. Johnson (1976) summarized the mechanisms into the following categories: (1) emulsification and entrainment, (2) emulsification and entrapment, (3) wettability reversal (oil-wet to water-wet), (4) wettability reversal (water-wet to oil-wet), and (5) emulsification and coalescence. The occurrence of each mechanism depends on various

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parameters of the system such as pH, acid number, salinity, pore structure, etc. At least, the in-situ surfactant generation and emulsification appear on most of the mechanisms.
Polymers are believed to have little impact on the IFT (Sheng, 2011). However, when the polymer is added to the alkaline solution, they would work together to achieve the better performance.
Although the use of alkali for flooding seems interesting, it can cause a serious scaling problem during the production. Alkalis can react with divalent ions such as calcium and magnesium to form precipitates (Zhu et al., 2013). Scale inhibitor could be added in order to prevent scaling (Liang et al., 2011). The effect of alkali concentration on the IFT is explained from the following studies. Green and Willhite (1998) observed that the minimum IFT of 0.01 mN/m could be obtained at the narrow concentration range between 0.05 and 0.1 wt%. Yang et al. (2010) conducted a pilot field test in Yangsanmu oilfield, China from 1998 to 2008. They applied alkali-polymer flooding technique with the condition of no fresh water supplied. Produced water was used to mix the chemicals. Sodium carbonate was used as an alkali while HPAM was used as a polymer. The optimum condition was at 1 % of alkali and 1,500 ppm of polymer. The amount of the chemicals used is still high compared to the huge area of injection.
In Thailand, Fang oilfield is one of the main oilfields in the North. The light oil production from this oilfield can be enhanced by applying the solution to decrease the IFT of displacing and displaced phases. In this study, sodium hydroxide (NaOH) as alkali and hydrolysed polyacrylamide (HPAM) as a polymer are used to reduce the IFT with different conditions at less amount of chemicals to fit well with the working conditions at Fang area which is the gap of this work based on the literature. The objective of this work is to measure the IFT and assess the effects of pressure, temperature, concentration and salinity on IFT reduction for oil from Fang oilfield. This studied work can be used as a fundamental data and a starting point to apply this technique in the oil production in Fang oilfield in the future.

2. Experiment

2.1 Chemicals

Oil sample is obtained from Fang oilfield, Thailand. The density of oil is 0.846 g/cm^3. The viscosity of oil is 145 mPa.s with the acid number of 0.89 mg KOH/g. The simulated brine is prepared by using distilled water with the mixture of sodium chloride and sodium bicarbonate purchased from Ajax, Thailand. The brine has the salinity of 500, 750 and 1,000 ppm. Sodium hydroxide is purchased from Ajax, Thailand. The hydrolysed polyacrylamide (HPAM) is obtained from Sigma-Aldrich.

2.2 Equipment

An interfacial tension is measured from Vinci Technologies equipment Model 700 as shown in Figure 1 taken from Vinci Technology website. The maximum working temperature and pressure of this apparatus are 180 °C (or 350 °F) and 69 MPa (or 10,000 psi). The pressure gauge inside the IFT cell is used to measure the pressure with 0.5 % of span accuracy. A sample cylinder is utilized to feed the oil to the chamber. The example of rising oil drop is generated as illustrated in Figure 2. Many pictures of oil droplet are taken to compare with the initial one. The importance of the generated drop is to investigate the change in volume and size of oil droplet to calculate the oil swelling and interfacial tension by taking the pictures with video lens system with high accuracy. The pictures of droplet at different time are analysed with the software of Drop Analysis System (DAS) to calculate for the IFT.

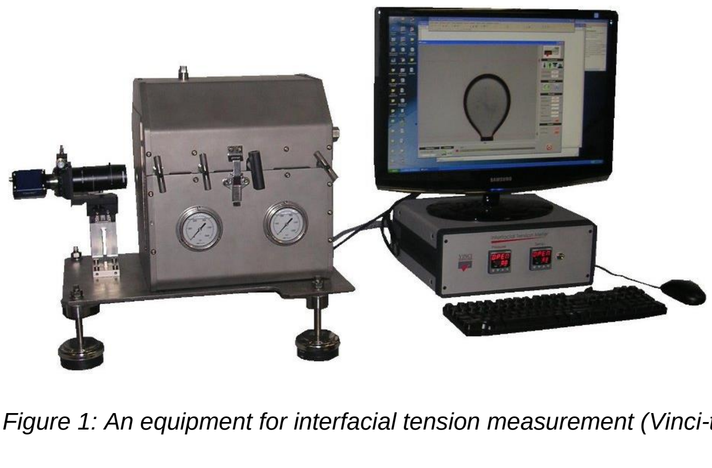

Figure 1: An equipment for interfacial tension measurement (Vinci-technologies, 2019)

Figure 2: The photograph of the rising oil from the experiment

2.3 Method

To prepare the alkaline-polymer solution, 1,000 ppm of HPAM and 0.05 wt% of sodium hydroxide will be dissolved in the simulated brine at 750 ppm. The crude oil and chemical solution are heated to 80 °C. At the certain temperature, the density meter is used to measure the density of the solution. The alkaline-polymer solution will be injected to the equipment together with the crude oil at 6.88 MPa (1,000 psi) to measure the IFT. The results are obtained from the integrated software provided by the Vinci Company. The operating conditions are varied, i.e., the polymer concentration of 500, 1,000, and 2,000 ppm, the alkali concentration of 0.025, 0.05, 0.1 wt%, the temperature from 70 to 90 °C, and the pressure of 3.44, 6.88 and 10.32 MPa (500, 1,000, and 1,500 psi). NaCl and $NaHCO_3$ would be added to the solution to make the salinity of 500, 750, and 1,000 ppm. The scope of this work is that the oil and brine sample properties are limited by the samples obtained from Fang oilfield as well as the scope of parameters to follow the conditions in the real field.

3. Results and discussion

3.1 Effects of alkali concentration

Figure 3 shows the effects of alkali concentration ranging from 0 to 0.1 wt% and salinity from 500 ppm to 1,000 ppm on IFT reduction. It presents that the alkali concentration can drastically lower the IFT for 99.49 %. It could be explained by the increasing rate of surfactant forming when the alkali concentration becomes higher which results in lowering the IFT. IFT becomes less than 1 mN/m when the alkali concentration is higher than 0.05 wt%. Beyond this point, IFT is almost stable because there is sufficient amount of in-situ surfactant at the oil/water interface.

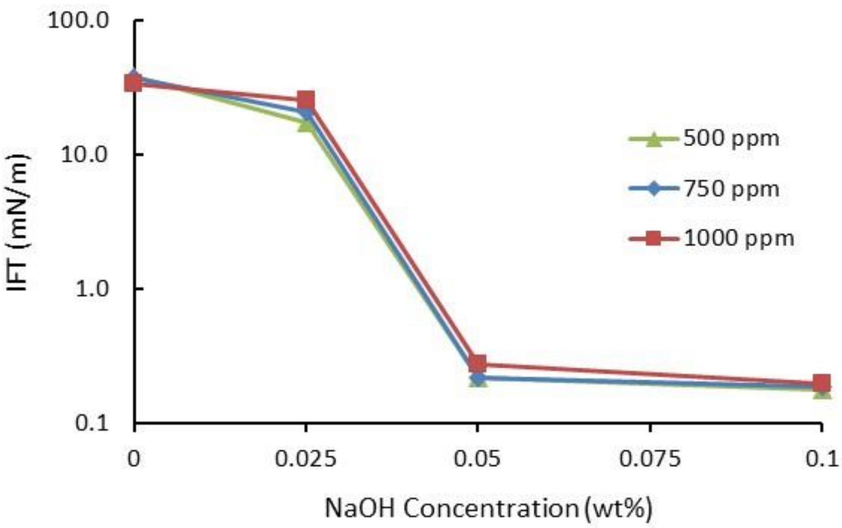

Figure 3: Effect of NaOH concentration on the IFT at various salinities (Polymer concentration = 1,000 ppm, pressure = 1,000 psi, temperature = 80 °C)

3.2 Effects of temperature

From Figure 4, the temperature has relatively less impact on the IFT compared to alkali concentration. The temperature still can reduce IFT especially at low alkali concentration because at an increasing temperature, more surfactant can be generated at the water/oil interface. Based on Wei (2005), the higher temperature can increase the solubility of water in oil, which lowers the free energy between two immiscible fluids and thus decreasing the IFT. IFT can be decreased with an increase in temperature up to 49.30 %.

3.3 Effects of polymer concentration

The concentration of polymer varied at 0, 500, 1,000 and 2,000 ppm does not engage in the IFT reduction as shown in Figure 4. An increasing HPAM concentration tends to increase the IFT. The reason is that HPAM can react with NaOH and the polymer is hydrolysed. The alkali is consumed thus, making its concentration decreased. Less amount of in-situ surfactant is formed resulting in the higher IFT. The results correspond to the study from Levitt et al. (2011) that the extensive hydrolysis of HPAM will occur under alkaline conditions and significantly enhance the polymer's viscosity. HPAM could be more beneficial in other aspects such as the mobility control process. The increasing trend could not be observed at the alkali concentration of 0.1 wt % because the amount of alkali is high enough that it can generate the excess amount of in-situ surfactant at the oil/water interface.

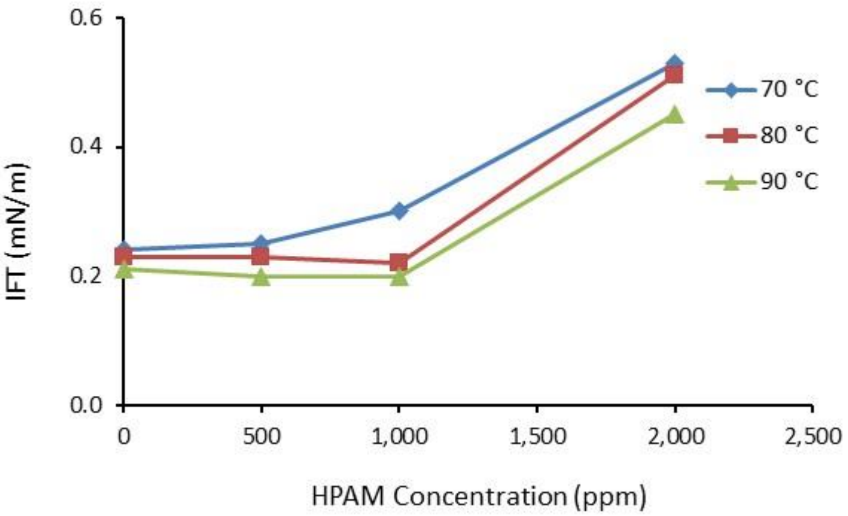

Figure 4: Effect of HPAM concentration on the IFT at various temperature (NaOH concentrations = 0.05 wt%, pressure = 1,000 psi, salinity = 750 ppm)

3.4 Effects of pressure

Pressure ranging from 3.44 to 10.32 MPa (500 to 1,500 psi) has an insignificant effect on the IFT reduction. It can be observed from Figure 5 that the IFT is relatively stable with the change of pressure. This is because the water/oil system, a liquid phase system provides the higher intermolecular force compared with the gas phase system. This makes the IFT has less effect by the change of pressure. From the previous study, Hassan et al. (1953) concluded that the IFT slightly changes with pressure at constant temperature in the range of 1 to 204 atm (0.1 to 20.4 MPa).

3.5 Effects of salinity

The salinity for this study is ranging from 500 ppm to 1,000 ppm based on the operating data of Fang Oilfield. Figure 6 shows the results of the effect of salinity on the change of IFT compared with the distilled water assuming 0 ppm salinity. The IFT is increased with the higher salinity at low alkali concentrations. According to Sheng (2011), the salt ions prevent the negative charges on polymer's backbone from repelling one another. Since the charge is neutralized, the polymer structures are compressed. These compressed and neutralized polymers can interfere with the link between the nonpolar (hydrophobic) part of the in-situ surfactant and oil. The IFT is increased instead of decreased. For the higher alkali concentration at 0.1 wt%, the IFT is slightly decreased with the increasing salinity. One mechanism can explain this phenomenon in that when the amount of alkali is high, salt ions could impact on alkali rather than polymer. The salt charges could push more in-situ surfactant to the oil/water interface, leading to the lowered IFT.

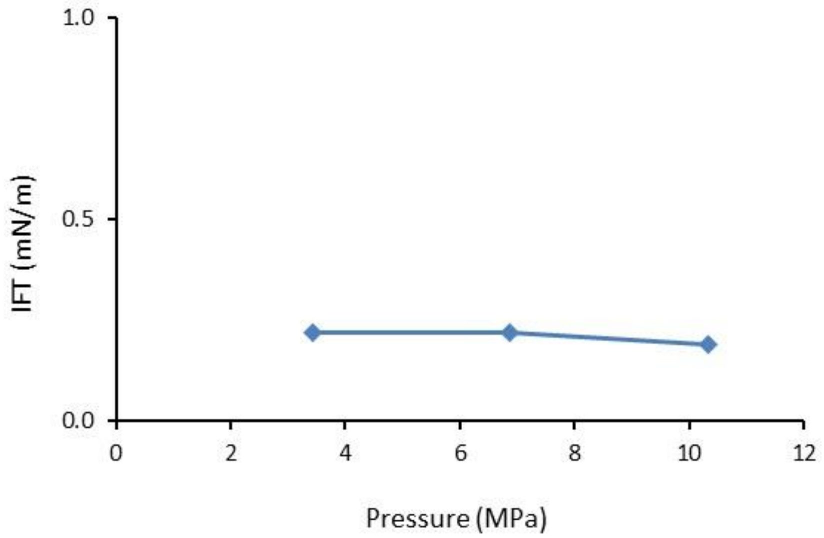

Figure 5: Effect of pressure on the IFT (NaOH concentration = 0.05 wt%, HPAM concentration = 1,000 ppm, temperature = 80 °C, salinity = 750 ppm)

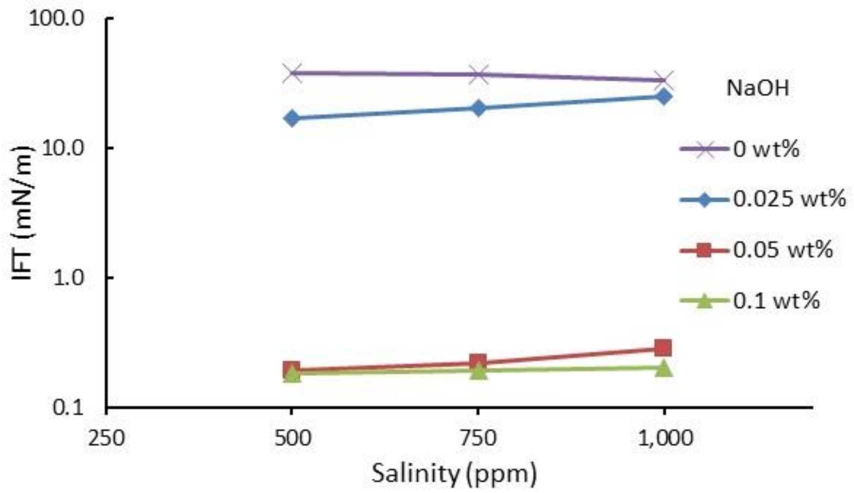

Figure 6: Effect of salinity on the IFT at various NaOH concentrations (HPAM concentration = 1,000 ppm, pressure = 1,000 psi and temperature = 80 °C)

For the future work, based on the results of this study, the chemical injection can be investigated in the rock or core samples from the real oil formation to test more on oil production with the working conditions in Fang in order to obtain the practical data of oil recovery. This future work can be used as a main data for the project of oil recovery in Fang oilfield by using chemical enhanced oil recovery method for the future.

4. Conclusions

Fang oilfield is working mainly on primary recovery and trying to use secondary one. The tertiary recovery with chemical injection will be the suitable recovery for the mature field. The required data and parameters are needed to be studied before applying the new technique. The effects of parameters such as concentrations of alkali and polymer, temperature, pressure, and salinity on IFT of petroleum fluid from Fang oilfield, Thailand are investigated in the range of reservoir conditions. The alkali concentration is the main factor for IFT reduction accounting for 99.49 %. IFT becomes lower with an increase in temperature up to 49.30 %. The polymer tends to increase IFT due to the alkaline consumption reaction. The polymer could be more beneficial in other aspects such as the mobility control process for oil and water. Pressure is relatively low effect on IFT reduction. The salinity can increase IFT at low alkali concentrations, while slightly decrease IFT for high alkali concentration. The results of this study coupled with the future of core sample testing can be applied as a fundamental data and new technology to enhance the oil production rate with the favourable conditions in Fang oilfield in the future.

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References

Chen Z., Zhao X., Wang Z., Fu M., 2015, A comparative study of inorganic alkaline/polymer flooding and organic alkaline/polymer flooding for enhanced heavy oil recovery, Colloids and Surfaces A: Physicochemical and Engineering Aspects, 469, 150-157.

Doscher T., Wise F., 1976, Enhanced crude oil recovery potential-an estimate, Journal of Petroleum Technology, 28, 575-585.

Green D.W., Willhite G.P., 1998, Enhanced Oil Recovery, Society of Petroleum Engineers, Dallas, TX, USA.

Hassan M.E., Nielsen R.F., Calhoun J.C., 1953, Effect of pressure and temperature on oil-water interfacial tensions for a series of hydrocarbons, Journal of Petroleum Technology, 5, 299-306.

Husein N., Yunan M.H., Ismail I., Sulaiman W.R.W., Boyou N.V., 2018, Enhanced oil recovery by alkaline-surfactant-polymer alternating with waterflooding, Chemical Engineering Transactions, 63, 823-828.

Johnson C.Jr., 1976, Status of caustic and emulsion methods. Journal of Petroleum Technology, 28, 85-92.

Levitt D.B., Pope G.A., Jouenne S., 2011, Chemical degradation of polyacrylamide polymers under alkaline conditions. SPE Reservoir Evaluation and Engineering, 14, 281-286.

Liang Y., Cao G., Shi G., Wang G., Li J., Zhao Y.L., 2011, Progressing cavity pump anti-scaling techniques in alkaline-surfactant-polymer flooding in the Daqing Oilfield, Petroleum Exploration and Development, 38, 483-490.

Sedaghat M.H., Ghazanfari M.H., Masihi M., Rashtchian D., 2013, Experimental and numerical investigation of polymer flooding in fractured heavy oil five-spot systems, Journal of Petroleum Science and Engineering, 108, 370-382.

Sheng J.J., 2013, Enhanced Oil Recovery: Field Case Studies, Gulf Professional Publishing, Burlington, MA, USA.

Sheng J.J., 2011, Modern chemical enhanced oil recovery: Theory and practice, Gulf Professional Publishing, Burlington, MA, USA.

Vinci-technologies, 2019, Interfacial Tension Measurements with IFT 700 <vinci-technologies.com/products-explo.aspx?IDM=536798&IDR=113223&IDR2=82565> accessed 24.10.2019.

Wang J., Liu H., 2014, A novel model and sensitivity analysis for viscoelastic polymer flooding in offshore oilfield, Journal of Industrial and Engineering Chemistry, 20, 656-667.

Wei X., 2005, Experimental investigation of dynamic interfacial interactions at reservoir conditions, Master Thesis, Louisiana State University and Agricultural and Mechanical College, Baton Rouge, Louisiana, USA.

Yang D.H., Wang J.Q., Jing L.X., Feng Q.X., Ma X.P., 2010, Case study of alkali-polymer flooding with treated produced water, SPE EOR Conference at Oil and Gas West Asia, 11th-13th April, Muscat, Oman, SPE-129554-MS

Yoosook H., Maneeintr K., 2018, CO_2 geological storage coupled with water alternating gas for enhanced oil recovery, Chemical Engineering Transactions, 63, 217-222.

Zhu Y., Hou Q., Jian G., Ma D., Wang Z., 2013, Current development and application of chemical combination flooding technique, Petroleum Exploration and Development, 40, 96-103.