Potential Materials for Enhanced Oil Production from Northern oilfield, Thailand

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Abstract. One of enhanced oil recovery techniques to produce more oil production is surfactant flooding. The surfactants are considered as the effective chemicals used in oilfield in Thailand. It is used to lower the interfacial tension (IFT) of two fluids and to increase mobility in the reservoir. For this study, various chemicals such as amine, fatty alcohol and glycerine are applied as the surfactants to reduce IFT between oil and water. Therefore, the aim of this work is to investigate the potential chemicals and measure the IFT reduction based on the conditions of subsurface at the oilfield in Thailand. These parameters such as temperature, pressure as well as the concentration of surfactant are adjusted to investigate the effects on IFT reduction. From the results, it is reported that pressure from 1,000 to 2,000 psi and temperature varied from 70 °C to 90 °C can reduce IFT insignificantly. However, types of chemicals and surfactant concentration are the main parameters that impact on the IFT reduction. Monoethanolamine at 4.0 wt. % can greatly decrease IFT up to 87 % for surfactant concentration. Finally, the results can be applied to use in the real field for enhanced oil production in Thailand.

1. Introduction
Currently, the energy demand is growing rapidly. Oil demand and production are required to serve this increasing demand. The oil production technology to satisfy this is the enhanced oil recovery (EOR) technology which is the tertiary recovery. It becomes more important because of the unpractical primary and secondary recoveries [1]. Chemical enhanced oil recovery is one of these kinds of technology. The surfactants are referred to as one of the practical flooding agents since it can remarkably lower the interfacial tension (IFT) between oil and water interfaces and enhance the performance of both displacement and sweep efficiencies. It can also lower the saturation of residual oil [2]. Nevertheless, some concerns still exist because they hinder the performance of flooding surfactants [3]. The effective in-situ surface active agent on chemical flooding is affected by several parameters such as reservoirs and operating conditions. It can cause the difficulty of how IFT changes under these conditions. However, the previous study [4] has reported some factors that influence the IFT. For this work, the research aims to study the various potential materials as surfactants used in enhanced oil production to produce more oil especially oil from the northern area in Thailand. Furthermore, it is also focusing on the evaluation of the effects of variables such as concentration of surfactant, temperature and pressure on the interaction between hydrocarbon and aqueous solution. These effects will be useful to understand the mechanism of IFT reduction.

The IFT reduction in aqueous solution has the mechanism in term of colloidal aggregates called micelles. A micelle is an aggregate of surfactant molecules dispersed in a liquid colloid. A typical micelle in aqueous solution forms an aggregate with the hydrophilic parts in contact with the hydrophobic parts.
When the surfactant concentration is higher and the surfactant concentration called critical micelle concentration (CMC) is reached, the surfactant starts aggregating into micelles [1]. The CMC is the surfactant concentration at and above which micelles are formed. It can be determined for surfactant solutions by measuring the surface tension at different concentrations. Below the CMC, the surface tension decreases with increasing surfactant concentration as the number of surfactants at the interface increases. At above CMC, the surfactants will be insignificant for IFT reduction because it cannot help in IFT reduction. The CMC values will be accomplished when significant micelles concentration is suitable proportion [5].

Based on the previous work, there are some effective chemicals applied for IFT reduction such as salt mixed with surfactant [6] and antifoam [7]. These chemicals show the high performance in IFT reduction to very low level. For this study, to overcome the IFT reduction problem, the various potential chemicals such as amine, fatty acid and glycerine are applied as the surfactants to reduce IFT between oil and water because they are cheap and available in the market. Finally, the contribution of this work is that the project life of oil production can be extended and economically viable and it is used as basic knowledge and data to cover for oil production with reservoir and operating conditions.

2. Experiment

2.1 Chemicals

Oil sample is acquired from the oilfield from the northern area in Thailand. The density of this crude oil is 0.8462 g/cm³ at 80 °C. The number of carbon atoms in oil is varied from 6 to more than 35. Monoethanolamide (MEA) and diethanolamide (DEA) are purchased from Sigma-Aldrich. Also, fatty alcohol and refined glycerine are obtained from Sigma-Aldrich Thailand. The chemical structure of all materials for IFT reduction are presented in Figure 1. From the molecular structure, it is evident that all structures have 2 main sections, a hydrophilic part (hydroxyl group) which is the polar section, the other part is called hydrophobic part (hydrocarbon chain) that is the non-polar section. Sodium chloride purchased from Ajax, Thailand is used as synthetic brine. It is obtained from distilled water mixed with sodium chloride as a main component to get the brine composition close to the original brine from the oilfield at various concentrations based on the original brine in the oilfield.

![Chemical structure of materials for IFT reduction](attachment:image)

**Figure 1.** Chemical structure of materials for IFT reduction.

2.2 Equipment

The interfacial tension apparatus from Vinci Technology Company Model 700 is applied to investigate the interfacial tension (IFT) between the interface of liquid-liquid and liquid-gas systems in the chamber with the volume of 1x10⁻⁵ m³. The maximum working conditions are 180 °C (or 350 °F) for temperature and 69 MPa (or 10,000 psi) for pressure. Moreover, a digital camera connected with a computer will take the picture and calculate the IFT. Also, the size of the drop is recorded and analyzed with Drop Analysis Software (DAS) supported by Vinci Technology.
2.3 Experimental procedure
The density of oil and the solution are measured at the beginning for software requirement by using density meter. The acetone and distilled water are used to clean the process of experiment. The solution and sample of oil are sent to the cylinders and temperature is set to the working condition. The surfactant solution and oil are fed to the chamber. The pressure gauge is applied to control to the designed pressure. The rising drop is formed and the camera linked to computer will take the pictures. The results will be recorded by the software provided by the manufacturer. The operating conditions for this work are shown in Table 1.

| Parameters                  | Conditions                                      |
|-----------------------------|-------------------------------------------------|
| Surfactant type             | MEA, DEA, Fatty alcohol, Refined glycerine      |
| Concentration of solution (wt. %) | 0.0, 0.5, 1.0, 2.0, 4.0                           |
| Temperature (°C)            | 70, 80 and 90                                   |
| Pressure (MPa)              | 3.44, 6.88 and 10.32                            |

Table 1. IFT measurement operating conditions.

3. Results and discussion

3.1 Effect of types of chemicals on IFT
Figure 2 presents the impact of the types of chemicals on IFT. It is evident that among these chemicals, MEA and DEA have the higher performance. It might be due to the size of the molecule are smaller and less complex compared to fatty alcohol and refined glycerine. Therefore, MEA and DEA can be potential candidates for IFT reduction and will be studied further in the real field in the future.

3.2 Effect of pressure on IFT
Figure 2 shows the effect of pressure on IFT. It is clear that IFT has less impact as pressure increases. This is because this system is liquid-liquid system and pressure has less effect compared to gas phase system [8]. Therefore, IFT reduction cannot be seen clearly when pressure changes.

3.3 Effect of temperature on IFT
Figure 3 shows the effect of temperature ranging from 70 °C to 90 °C covering the temperature range in the oilfield. From Figure 3, IFT reduction is oppositely proportional to the temperature because at higher temperature, the free energy between solution and oil becomes lower thus making the mobility of oil and water enhanced and lowering the IFT [9]. Another reason is that the increase in temperature
can affect solution of surfactant due to the weakness of intermolecular forces at the interface [10]. MEA is the highest performance among other chemicals. The percent change of IFT are 9.18 % at temperature from 70 °C to 80 °C and 5.57 % at temperature from 80 °C to 90 °C at 1 wt.% MEA.

![Figure 3](image-url)

**Figure 3.** Effect of temperature on the IFT at 1 wt. % and pressure at 1,500 psi.

### 3.4 Effect of concentration on IFT

The effect of surfactant concentration is presented in Figure 4 with the concentrations ranging from 0 to 4 wt. % and 1,500 psi and 80 °C. The result illustrates that the IFT reduction comes from all cases because of each chemical characteristics. Based on molecular structure, there are two parts in the structure. One part is hydrophilic part (hydroxyl group) which can dissolve in water phase, and the other part is hydrophobic part (hydrocarbon chain) that can dissolve in oil-based phase. According to Prosser and Franses [11], the surface is covered by the surfactants molecules and the surface free energy (surface tension) becomes lower. Consequently, the higher surfactant concentration can dissolve more both in oil section and water section resulting in the IFT reduction.

![Figure 4](image-url)

**Figure 4.** Effect of concentration of chemicals on the IFT at 1,500 psi and 80 °C.

In addition, MEA can reduce IFT at the lowest level and it is considered as the highest performance among this group of surfactants. Moreover, fatty alcohol cannot perform well at the concentration higher than 1 wt. % because it has the CMC effect on IFT reduction and it is not presented in this figure. The variation in concentration from 0%wt. to 4.0 wt. % can significantly decrease the IFT more than 87 % for MEA. Nevertheless, when the concentration is higher than 2.0 wt. %, the IFT value is relatively stable. This phenomena can be explained that the too much surfactant is put in a solution, thus; making the surfactant aggregating into micelles to the level above CMC and the amount of MEA is difficult to reduce IFT at the oil-water interface.
4. Conclusions
The chemical enhanced oil recovery techniques are applied to increase the oil production by using surfactant flooding. The surfactants are used as the effective chemical agents in the oilfield in Thailand. It is aimed to lower the IFT of two fluids and to make them flow easily in the reservoir. In this work, Monoethanolamide (MEA), diethanolamide (DEA), fatty alcohol and refined glycerine are commonly proposed as potential surfactants to decrease IFT between oil and brine based on the reservoir conditions from Fang oilfield. From the results, it is presented that the IFT data are measured and the effects of parameters such as surfactant concentration, temperature and pressure are also investigated at various conditions. Pressure ranging from 1,000 psi to 2,000 psi has less significant effect on IFT reduction at other constant conditions. In addition, the effect of temperature is relatively less effect and the rate of declining IFT trends to lower with the increase in temperature. However, the IFT can be decreased greatly with the types of surfactants. For this study, MEA shows the highest performance compared to other chemicals because of smaller size and less complex in the molecular structure. Furthermore, the IFT can significantly lower up to 87 % when the surfactant concentration becomes higher ranging from 0 to 4.0 wt. %. However, it will be relatively constant at the concentration higher 2.0 wt. %. The effects of each parameters will be useful to understand and used as basic knowledge to apply for oil recovery with reservoir conditions in the Fang oilfield, Thailand.

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6. References
[1] Sheng J J 2011 *Modern Chemical Enhanced Oil Recovery: Theory and Practice* (Burlington: Gulf Professional Publishing)
[2] Ahmadi M A, Arabsahebi Y, Shadizadeh S R, Behbahani S S 2014 *Fuel* 117 749
[3] Zhang Y P, Sayegh S G and Huang S 2007 *Canadian International Petroleum Conference*, Calgary, Alberta, Canada, June 12-14
[4] Buckley J and Fan T 2005 *the International Symposium of the Society of Core Analysts*, Toronto, Canada, August 21-25
[5] Bera A, Mandal A and Guha B B 2014 *J. Chem. Eng. Data* 59 89
[6] Schramm L, Stasiuk N. and Marangoni D G 2003 *Physical Chemistry* 99 10
[7] Karambeigi M S, Asl A H and Nasiri M 2014 *Journal of Petroleum Science and Technology* 4 56
[8] Green D W and Willhite G P 1998 *Enhanced Oil Recovery* (Richardson : SPE)
[9] Xu W 2005 Master Thesis, Louisiana State University and Agricultural and Mechanical College
[10] Karnanda W, Benzagouta M S, Al Quraishi A and Amro M M 2013 *Arab J. Geosci.* 6 3535
[11] Prosser A J and Franses E I 2001 *Colloids and Surfaces A: Physicochemical and Engineering Aspects* 178 1