Performance of Surfactant Methyl Ester Sulphonate solution for Oil Well Stimulation in reservoir sandstone TJ Field

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Abstract. Asphaltene, paraffin, wax and sludge deposition, emulsion and water blocking are kinds of process that results in a reduction of the fluid flow from the reservoir into formation which causes a decrease of oil wells productivity. Oil well Stimulation can be used as an alternative to solve oil well problems. Oil well stimulation technique requires applying of surfactant. Sodium Methyl Ester Sulphonate (SMES) of palm oil is an anionic surfactant derived from renewable natural resource that environmental friendly is one of potential surfactant types that can be used in oil well stimulation. This study was aimed at formulation SMES as well stimulation agent that can identify phase transitions to phase behavior in a brine-surfactant-oil system and altered the wettability of rock sandstone and limestone. Performance of SMES solution tested by thermal stability test, phase behavioral examination and rocks wettability test. The results showed that SMES solution (SMES 5% + xylene 5% in the diesel with addition of 1% NaCl at TJ formation water and SMES 5% + xylene 5% in methyl ester with the addition of NaCl 1% in the TJ formation water) are surfactant that can maintain thermal stability, can mostly altered the wettability toward water-wet in sandstone reservoir, TJ Field.

1. Introduction
In general, oil reservoir has different characteristics depending on its composition, temperature and pressure where the oil accumulation takes place [1], oil reservoir is different in its geological rock condition, water content in the reservoir and type of oil contained.

TJ Fields is an oil field with the main rocks is sandstones and conglomerates, with average depth is in between 800-1200 m. Number of wells operated in TJ Fields in 2006 is 79 production wells (consisting of 50 bobbing pumps and 29 ESP pump wells), and 37 injection wells [2]. TJ field showed an increasing of water production coming from the produced water and fresh water that was used as water injection, the increasing of water causing many problems in related with inorganic scale deposition in reservoirs, hole, wells, pipelines, and pumps.

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(consisting of 50 bobbing pumps and 29 ESP pump wells), and 37 injection wells [2]. TJ field showed an increasing of water production coming from the produced water and fresh water that was used as water injection, the increasing of water causing many problems in related with inorganic scale deposition in reservoirs, hole, wells, pipelines, and pumps. However the scales are not found in the surface facilities, (production flow line, separators, or storage tanks). Other than that, the unique characteristics of TJ field’s oils that containing high paraffin is also a problem. Hydrocarbons accumulation is dominated with oil, while gas only found in a small quantity in the form of associated gas and free gas. TJ oil is paraffinic 40.3. OAPI (0.8235 SG) and a wax content is 30% (pour point is approximately 95 OF) (Wibowo et al., 2008) The analysis show oil viscosity of 2.77 cp, API Density (15 °C) at 0.8340 and API Gravity (15 ° C) of 37.97.

Surfactant solution to be used in the stimulation of oil wells to a reservoir is different to other reservoir. Some test can be used in order to select the surfactants i.e. : oil solubility test, electrolyte influence, the surfactant solution density test, the viscosity test of surfactant solution, the time of solubility test, identification of surfactant co-solvent optimal formulation, and core flood [1]. To obtain the stimulation result, several laboratory researches must be conducted. I.e.: the interface tension measurements, Phase behavior examination and wettability properties of rocks by surfactants as well stimulation agent

The properties of the phase behavior and wettability properties of reservoir rocks are things that need to be understood more deeply due to the properties of rock that will affect the mechanism of fluid flowing within the rock pores. The mechanism microscopically is influenced by the wettability properties of rocks, structure and geometry of rock pores. Utilization of SMES surfactant that is injected into the oil wells is expected to prevent and or to overcome the damage occurred to the well by changing the wettability properties of rocks and also decreases the interfacial tension of oil and water.

This research aimed to examine the performance of the SMES 5 % + xylene 5% + methyl ester (TJ formation water + NaCl 1%) and SMES 5% + xylene 5% + methyl ester (TJ formation water + NaCl 1%) to the heat resistance, phase behavior and wettability properties of rocks at sandstone reservoir.

2. Materials and methods

2.1. Thermal Stability Test method

As 20 ml of surfactant solution is poured into a closed tube. The surfactant solution is made in two samples. The test is conducted by heating the SMES surfactant solution in its reservoir temperature for seven days in an oven at 60 ° C according to the reservoir sandstone temperature of TJ Field. The surfactant solution is expected to maintain the value of interfacial tension until the seventh day, or at least remain at a value of 10-2 dyne / cm. A daily observation is conducted to observe the surfactant solution and the measurement of the value of interfacial tension. The observation is conducted to observe the tendency of changes in the value of interfacial tension that occurs during the heating on the temperature of the reservoir takes place.

2.2. Phase Behavioral Examination

The stages in conducting the Phase behavioral examination is 20 ml of formation water sample and surfactant solutions which have been prepared is poured into a closed tube, with the ratio of the SMES surfactant solution sample : formation water at 80:20. Then the samples are stored in the oven with the temperature equivalent to the reservoir temperature (60 ° C) for 60 minutes. After that, the rotary mixing is turned on at a speed of 6 rpm at a reservoir temperature. The observation is conducted in the minute of 10, 60, 120, 240, 720, 1440, and 2880.
Types of emulsions that can be formed in the process of the phase behavior examination are: (1) Lower emulsion phase, where the emulsion is formed in the aqueous phase, there is oil excess phase (excess oil), in a state of two phases, and translucent colored (clear opaque); (2) micro emulsion or the middle phase emulsion, which is the emulsion consisting of three phases (water-micro emulsion-oil) and translucent colored; (3) The upper phase emulsion, where the emulsion formed is in the oil phase and is water excess phase occurred (excess water), the emulsion is consists of two phases; (4) Macro emulsion, the emulsion is viscous and milky white colored (milky).

2.3. Rocks wettability test
Test on wettability properties of rocks by using SMES solution is conducted in 4 steps. The first step is to soak the washed formation rocks in a core extraction in the formation water in the temperature equivalent to reservoir temperature for 1 week. This treatment is to put the rocks in the condition of reservoir. Then the measurement is conducted to determine the wettability by dripping oil on them. The measurement is conducted to determine the angle degree of the rocks in the early contact. The second step is the rocks are soaked in TJ field oil for 1 day. And the degree angle is measured again. The test then followed by soaking the rock in a solution of the SMES surfactant for six hours at reservoir temperature and the measurement of the contact angle is conducted as the previous step. The soaking of rocks in the surfactant solution for six hours is due to the process of minimum stimulation in the oil wells which took place is only six hours. After the rocks soaked in SMES surfactant, then the rocks angle contact are re measured. This test is a measurement of contact angle of the third step. The fourth step is the soaking of the rocks (rocks similar to the previous steps) with TJ field formation water at reservoir temperature for one day and its contact angle are re measured. It also aims to condition the rocks back to reservoir conditions after the application of SMES surfactant solution as a well stimulation agent. Oil-wet occurred if a rock has a fluid contact angle (oil) to the rock which is smaller than 90° (θ < 90°), while the water-wet is occurred if a rock has a fluid contact angle (oil) to the rocks with an angle greater than 90° (θ > 90°).

3. Results and Discussion
Surfactant solution with SMES concentration, salinity and the best concentration of aromatic solvent can be observed in its performance in solution resistance in hot temperatures, the formation of emulsions and the ability to change the wettability properties into a water-wet. The test performed is an examination on the heat resistance / thermal stability, phase behavior test/ phase behavior, and wettability properties of the rocks. The surfactant solution resulted as well stimulation agent is the methyl ester + SMES 5% + 5% of xylene (TJ Formation Water + NaCl 1%) or diesel + SMES 5% + 5% + xylene 5% (TJ Formation Water + NaCl 1%) for field reservoir sandstone of TJ field. Surfactant solution with SMES concentration, salinity and the best concentration of aromatic solvent can be observed in its performance in solution resistance in hot temperatures, the formation of emulsions and the ability to change the wettability properties into a water-wet. The test performed is an examination on the heat resistance / thermal stability, phase behavior test/ phase behavior, and wettability properties of the rocks. The surfactant solution resulted as well stimulation agent is the methyl ester + SMES 5% + 5% of xylene (TJ Formation Water + NaCl 1%) or diesel + SMES 5% + 5% + xylene 5% (TJ Formation Water + NaCl 1%) for field reservoir sandstone of TJ field.

3.1. Thermal stability
The results of the analysis on interfacial tension of the surfactant solution after the thermal stability test can be seen in Figure 1.
Surfactant solution for well oil stimulation by methyl ester carrier medium or diesel on the TJ field, until the third day still maintain the interface tension value, and after the third day there was an increase in the value of interfacial tension. Both of the surfactant solution stability tested due to the heating in each reservoir temperature was still able to maintain its interface tension value until the day of 7 as indicated by the value of the interfacial tension which is still in the range of 10^-2 dyne/cm [3] in his research the increasing of temperature which is close to the reservoir temperature is effective in lowering the value of interfacial tension.

### 3.2. Phase Behavior

The results of the analysis of the phase behavior of surfactant solution made are presented in Figure 2 and Table 1.

![Phase behavior of TJ field sandstone reservoir surfactant solutions on temperature of 60°C](image)

**Figure 2.** Phase behavior of TJ field sandstone reservoir surfactant solutions on temperature of 60°C

The behavior phase Test is intended to observe the performance of the surfactant solution with formation water fluid from each reservoir. In the process of stimulation of oil wells the surfactant solution is injected into the well, and then soaked for some time (maximum 48 hours) and after that the surfactant solution and the fluid is pumped back through the same well. Observation conducted is visual observation by observing the changes that occurred in mixture of the SMES surfactant solution with formation water fluid from each reservoir.
Table 1. The results of the phase behavior test of surfactant solutions on TJ field reservoir sandstone

| Formula                                      | Picture                                                                 |
|----------------------------------------------|--------------------------------------------------------------------------|
| Methyl ester + SMES 5% + xylene 5% (TJ Formation Water + NaCl 1%) | ![Image of surfactant solutions](image1.png)                              |
| Diesel + SMES 5% + xylene 5% (TJ Formation Water + NaCl 1%)       | ![Image of surfactant solutions](image2.png)                              |

Visual appearance on phase behavior test in TJ field reservoir sandstone on Table 1 shows that in both of the surfactant solution tested, the macro emulsion of surfactant solution formed with water formation. By observing through a microscope with 1000 times magnification, it can be seen in the middle phase (macro emulsion), the average droplet size that formed is 4.09 - 5.53 μm for Methyl ester + SMES 5% + xylene 5% (TJ Formation Water + NaCl 1%) and 11.70 - 14.61 μm. For Diesel + SMES 5% + xylene 5% (TJ Formation Water + NaCl 1%), when observed from the droplet size and visual appearance under the microscope, it can be seen that macro emulsion formed is an emulsion of oil in water (o/w). Depravity of formation due to water-in-oil emulsion causing a higher depravity than the oil in water. This is caused by the water emulsion in the oil causing a high solution viscosity. Solution with this high of viscosity will impede the flow of fluid within the pores [4]. The forming of macro emulsion showed that SMES surfactant become incompatible with the oil fluid.

3.3. Wettability properties of rocks

Rocks that are water-wet tend to be more easily wettable by water than oil, so is conversely. Rocks with oil-wet properties tend to be more easily wettable by oil than by water. The alteration of wettability properties in general is assumed due to the absorption of polar compounds onto the surface of the rock [5].

Wettability is measured by the contact angle between the liquid and the solid in this case oil with reservoir rocks. This contact angle analysis is conducted with the adjustment of the actual conditions in the reservoir. The initial reservoir condition is the soaking of the rocks with formation water and oil. Histogram of the contact angle analysis result of the surfactant solution made is presented in Figure 3.
Figure 3. The results of analysis on rock wettability properties of oil–rocks on TJ field reservoir sandstone

Figure 4. The result of analysis on rock wettability properties of oil–rocks in quartz

The alteration of the surfactant solution’s contact angle in the reservoir sandstone of TJ field shows that the surfactant solution has altered the nature of the oil-wet rocks become inclined to water-wet.

This is shown on Figure 25, where at the beginning of treatment, the contact angle formed is $33.33^\circ$ and increase to $38.24^\circ$ for the surfactant solution with methyl ester medium carrier and $33.14^\circ$ increase to $36.41^\circ$ for formula with the diesel medium carrier. The same conditions occurred in the analysis results on oil wettability properties of the oil – rocks on the quartz mineral rocks (Figure 4), where there is an increase in the contact angle after the quartz mineral treated.

The existence of paraffin and asphaltene in the TJ field’s rocks formation has become the cause of oil-wet the condition of oil wet may cause the decrease in permeability of reservoir. Therefore the properties of rocks wettability must be transformed into water wet to increase the permeability of oil.

Surfactants can cause the ion pair in the formation reacts to the alteration in the wettability properties of rocks due to electrostatic repulsion between the anionic cluster and negative content of oil components adsorbed in the surface. The surfactants may alter the rock wettability by forming a monolayer of surfactant on oil-wet rock layers. The surfactant adsorption occurred through hydrophobic interactions with the layer of hydrocarbons adsorbed in the surface of the rock, and then the hydrophilic cluster of the surfactant will move towards the solution, it would result in the formation covered by water zone and forming a weak capillary pressure during the process of imbibition. This process will occur sequentially in the surfactant-oil-rock interface zone [6]. Low salinity water is able to altered wettability of rock until the oil flow easily. Water injection with low salinity can reduce the adhesion force between the oil and the clay particles on the surface of the rock [7].

The content of the reservoir sandstone is dominated by quartz mineral (± 85%) and the rest are clay minerals and carbonates. negative charge of the quartz surfaces, and when the sandstone surface in contact with the surfactant, then the hydrophobic positive cluster of the surfactant will be adsorbed to the surface with negative charge, then the hydrophilic cluster will move away from the surface so it make the surface had the hydrophilic properties [8].

4. Conclusion

This research resulted that the solution formula from TJ field reservoir sandstone is solution of SMESoilbased with SMES 5% in + xylene + 5 % in the diesel with addition of 1% NaCl at TJ formation water and SMES 5% +xylene 5% in methyl ester with the addition of NaCl 1 % in the TJ formation water. Results of the solution formula from TJ field reservoir sandstone show that (i) formula oil based on TJ field reservoir sandstone forming macro emulsion of surfactant solution with formation water; (ii) oil based formula on TJ field reservoir sandstone is capable to alter the properties
of the rocks from oil wet into water wet; (iii) the thermal stability test of oil based formula is able to maintain the value of interfacial tension until the third day of observation.

Acknowledgements
The authors would like to thank to SBRC (Surfactant and Bioenergy Research Center) for all the support during the research.

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