EXPERIMENTAL STUDY : Chemical Synergism in Concocting Surfactant Formulation for Low Salinity Reservoir

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Abstract

Chemical EOR by using surfactant needs to notice about optimum salinity. The optimum salinity is when the volume of water in microemulsion is equal to volume of oil in microemulsion (James J. Sheng,2010). This type of microemulsion is named Type III by Winsor. The type of microemulsion will become a representative of the microemulsion was formed in the reservoir as we designed in the surfactant injection.

Chemical formulation was conducted to get the proper chemical recipe for a certain reservoir. This experiment was conducted to observe each chemical effect to optimum salinity. This experiment was implemented by using tube test which was filled by the sample of dead oil of a target layer, artificial brine with desired salinity, and surfactant solution with a certain ratio. Surfactant were used are LAS and DOSS. Both of them are anionic surfactant. Comparing salinity scan of LAS and DOSS only, reducing surfactant concentration and using different concentration of alkali are steps to achieved the experiment's goal. That is giving the guidance to reach the desired optimum salinity for EOR design.

As the result, DOSS has lower HLB than LAS that gave lower optimum salinity. Reducing optimum salinity could be achieved by using or mixing with low HLB surfactant, adding alkali, and reducing surfactant concentration.

Keyword : surfactant, optimum salinity, chemical injection, EOR.

PRELIMINARY

This oilfield target for chemical EOR has light oil and low salinity reservoir. Therefore, concocting a proper surfactant solution formulation with this condition is needed. Concocting chemical formulation must look carefully at salinity/type of microemulsion, compatibility each component in the solution such as cloudiness, precipitation and phase separation. In the laboratorium, some surfactants are available, which then LAS dan DOSS were selected in this experiment. Both of them are anionic surfactant. Because of surfactant type gives different optimum salinity, so that each surfactant was tested to obtained the data for concocting surfactant formulation. This formulation will be used for coreflooding experiment.

Phase behavior in this experiment aims to observe the effect of adding specific chemical component to optimum salinity. Because of the low salinity reservoir target, so the investigation was directed to formulate the solution for desired low salinity injection design.

These results can be a guidance in formulating surfactant solution for chemical EOR, so it gives more efficient time and facilitates in reaching the optimum salinity target.

METHOD

The phase behavior is conducted to find the most suitable surfactant formulation for reservoir target condition. Optimum salinity is the most considerable matter in surfactant injection for creating gradient type of microemulsion in chemical EOR design. Doing experiment with dirrefent type of surfactant, adding alkali, reducing surfactant concentration were applicated to observe the effect of each chemical component to optimum salinity. Beside optimum salinity, the clearness of solution was given attention too as one of screening criteria of a proper injected solution.

LAS and DOSS are anionic surfactant were selected. Alkali and cosolvent were used are Na_2CO_3 and TEGBE. Stock solutions of each component were made for salinity scan. Salinity scan was conducted by using artificial brine with only NaCl content.

The first salinity scan experiment was used formulation ; 0,5% of Na_2CO_3, 1% of LAS, 1% of TEGBE. Second experiment was used formulation ; 0,5% of Na_2CO_3, 1% of DOSS, and 1% of TEGBE. Third experiment was used formulation ; 0,5% of Na_2CO_3, 0.5% of LAS, 0.5% of DOSS, and 1% of TEGBE. The forth experiment was used formulation ; 0,1% of LAS, 0.325% of DOSS, and 0.3% of TEGBE. The fifth experiment was used formulation ; 4% of Na_2CO_3, 1% of LAS, 2% of TEGBE. The optimum salinity changes can be seen directly both at the tube test and the graph (plot salinity vs oil/water solubility). Oil or water solubility (σ) in the microemulsion was attained by calculating :

$$\sigma_{(o/w)}=(\text{volume of oil or water in microemulsion})/(\text{volume of microemulsion}) \quad (1)$$

The compatibility of solution was checked by seeing phase separation, cloudiness and precipitation.

RESULT AND DISCUSSION

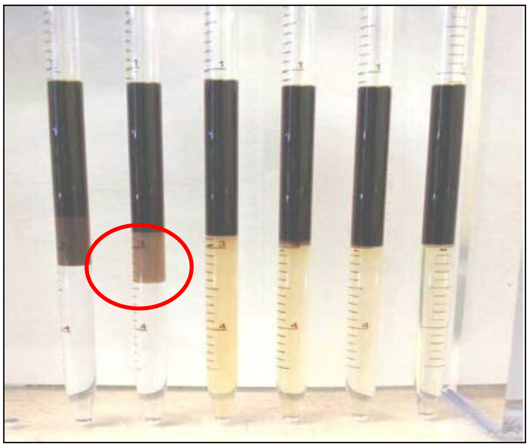
This investigation is benefit as a guidance to concocting chemical formulation by knowing the effect each component to its optimum salinity. When the reservoir's salinity target is low, the attempting technique to lower optimum salinity must be taken.

The first experiment took only LAS in the solution. The phase behavior result is figured in **Fig.1**. The optimum salinity resulted is 4%. The second experiment took only DOSS in the solution. The phase behavior result is figured in **Fig.2**. The optimum salinity resulted is 1%.

The third experiment took LAS and DOSS. The salinity observed each tube test, total surfactant concentration and other chemical components concentration are the same with experiment 1. From this experiment, the concentration ratio between LAS and DOSS is 1:1. The phase behavior's result is figured in **Fig.3**. It can be seen that the optimum salinity change to 2%.

The forth experiment investigated the effect of reducing surfactant concentration (LAS and DOSS) to optimum salinity. The composition of chemical component is the same with the formulation in the experiment 3. The result is figured in **Fig.4**. The optimum salinity was changed to 0,8%. The difference between the first experiment and fifth experiment is the concentration of alkali. In the first experiment used 0,5% of Na_2CO_3 while the third used 4% of Na_2CO_3. This experiment investigated the effect of adding alkali to optimum salinity changes. The result showed that the optimum salinity change to 2% (**Fig.5**).

Beside observing optimum salinity changes by tube test profile, the correlation graph was plotted between oil/water solubilization in microemulsion versus optimum salinity can be used to ensure the optimum salinity position. The graphs were plotted for experiment 1 and 3 (**Figure 6** and **Figure 7**). It showed the changes of optimum salinity from 4,2% to 2% by reducing LAS concentration and adding DOSS. While the adding alkali gives optimum salinity reduction from 4,2% to 2%. Surfactant concentration reduction in experiment 4 gave optimum salinity reduction to 0.8%.



5% 4% 3% 2% 1% 0.5%

Figure 1. Experiment I (Only LAS)

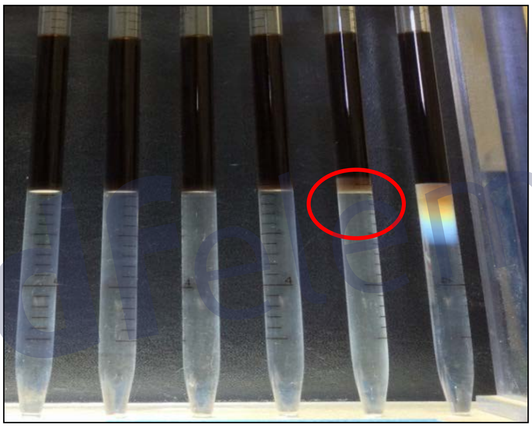


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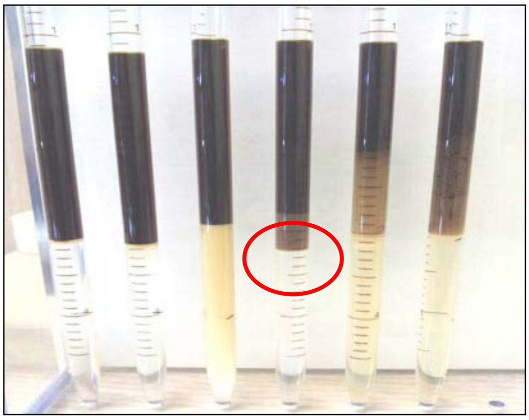
Figure 2. Experiment II (Only DOSS)

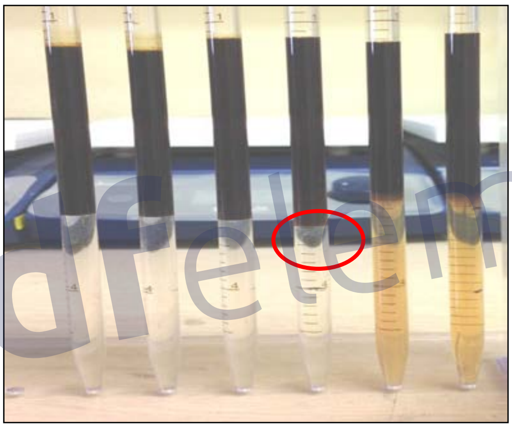


5% 4% 3% 2% 1% 0.5%

Figure 3. Experiment III (LAS:DOSS=1:1)

1.6% 1.4% 1.2% 1% 0.8% 0.6%

Figure 4. Experiment IV (Reducing Surfactant Concentration)



5% 4% 3% 2% 1% 0.5%

Figure 5. Experiment V (Adding Alkali)

Surfactant has 2 main part ; "head and tail", where the head is water-like and tail is oil-like. The longer tail means stronger lipophilic. The head strength is neutralized (charge) by salinity in brine. The head of LAS in solution for experiment 1, can be neutralized with 4,2% of salt. Whereas the DOSS is lipophilic surfactant if it's compared to LAS because it (experiment 2) gave optimum salinity at 1%. In HLB (Hydrophilic Lipophilic Balance) concept, it categorized surfactant to more hydrophilic or more lipophilic. So, by seeing the salinity scan result of expeiment 1 and 2, showed that LAS HLB is higher than DOSS qualitatively. This characteristic makes solubility of DOSS in water is less than LAS. So that, less salt needed to neutralize DOSS (lower optimum salinity). This matter that caused lower optimum salinity in experiment 2.

Lower concentration of surfactant means small amount salt needed to neutralize the surfactant (head charge). That is the reason of reducing surfactant concentration will lower optimum salinity. It is described in experiment 4 (Figure 4).

Alkali is also called as electrolyte modifier in surfactant solution. The usage of Na_2CO_3 which is hydrolyzed in the water becomes $2Na^+$ and CO_3^{2-}, increases Na^+ content in the brine solution.

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Because the anionic surfactants were used in this experiment, so the ion Na^{+} from alkali also neutralize the negative charge of surfactant. This matter lowers optimum salinity. It is explained in experiment V (**Figure 5**).

From experiment result, LAS gave higher optimum salinity than DOSS. Refer to HLB concept, so LAS has higher HLB than DOSS. It means LAS is more hydrophilic (more soluble in water) and DOSS is more lipophilic (more soluble in oil). By seeing from solubilization ratio, the solution in the experiment 3 gave higher than the experiment 1. Solubilization ratio is closely related to IFT (Huh, 1979). While higher solubilization ratio is lower IFT.

Besides observing the effect of adding each component, the phenomenon of precipitation, cloudiness and phase separation also was founded (**Figure 8** and **Figure 9**). One of criteria that the solution is feasible to inject is a clear solution. The phase separation is founded when there is incompatible component to other. The precipitation could be happened because of solubility reduction of some component such as in experiment V.

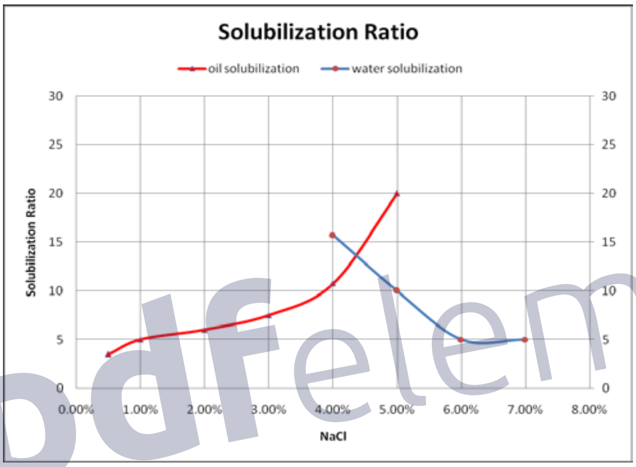

Figure 6. Solubilization Plot of Experiment 1 Result

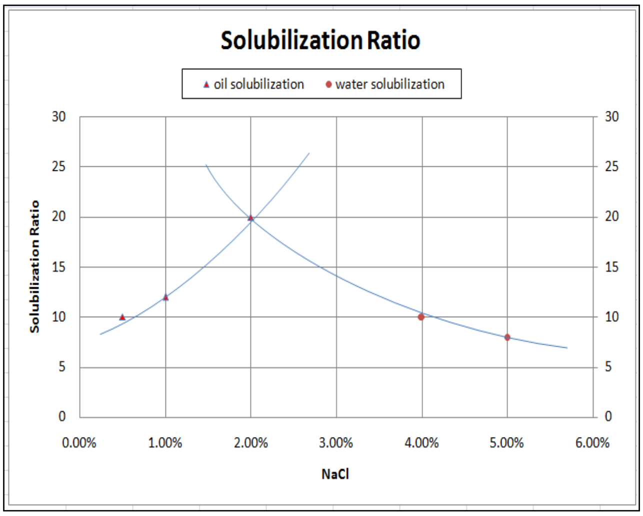

Figure 7. Solubilization Plot of Experiment 2 Result

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Figure 8. Precipitation and Cloudiness

Figure 9. Phase Separation

Conclusion

1. LAS's characteristic is more soluble in water surfactant. It gives higher optimum salinity than DOSS. It means LAS's HLB is higher than DOSS (more liphophilic surfactant).
2. In solubilization ratio concept which related to IFT, the experiment 2 gave lower IFT than experiment 1.
3. Reducing optimum salinity coul be ahieved by using or mixing with los HLB surfactant, adding alkali and reducing surfactant concentration.
4. In concocting surfactant formulation, some parameters should be given attention are optimum salinity, solubilization ratio (correlate to IFT) and clearness/stability of injected solution.

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