Laboratory study on the effect of salinity, surfactant type and concentration to recovery factor for carbonate rock

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Abstract. The needs of petroleum as energy, have increasing while the oil production has depleting. Due to that needs, the method of Enhanced Oil Recovery (EOR) or in other hands as tertiary recovery (after primary recovery and secondary recovery) is being developed. EOR has many methods; one of the methods is chemical injection that consists of surfactant, alkaline and polymer. In this experiment, the author is using surfactant injection. The using of surfactant is to decrease the interfacial tension between oil and water, with the result is surfactant can displace oil through rock pores. This study will be discussing about the effect of salinity, surfactant types and surfactant concentrations on surfactant injection for carbonate rock. The surfactant types are Alpha Olefin Sulphonate (AOS) and Tween 20. The surfactant concentration varieties are 0.1%; 0.25%; 0.5%; 0.75% and 1%. Salinity varieties are 10.000 ppm; 15.000 ppm; 20.000 ppm and 25.000 ppm. From this study, it had determined that surfactant can displace the oil from rock pores based on the influence of salinity, surfactant concentrations and surfactant types to recovery factor. The determination of recovery factor will be using these methods; Amott apparatus (imbibition process) and injection using core holder and syringe pump. From experiments that have been done, the effect of surfactant injection on carbonate rocks is more optimal in core flooding process compared with imbibition process, with the recovery factor percentage is 57%. Core flooding process uses the external thrust, therefore the oil displacement with surfactant is more evenly and optimally.

1. Introduction
The need of fossil energy is increasing time by time, as well as the depletion of the energy production. This can be a challenging issue for oil and gas industries to fulfil the increasing energy demand. Considering that fossil energy in terms of hydrocarbon (oil and gas) is still the main energy resources in Indonesia even worldwide, therefore it is necessary needed for an effort to do some methods to increase the oil production in order to fulfil the needs of energy, especially the mature oil wells in Indonesia. Basically, not all oil reserves can be produced, although in the other hand that thing can be developed by many techniques. One of those techniques is Enhanced Oil Recovery (EOR). EOR is a technique that has been used to produce the remaining oil reserves in mature wells, by increasing the percentage of recovery factor (RF). It has 4 (four) methods, miscible flooding, chemical flooding, thermal flooding, and microbial flooding. In chemical flooding, there has three injection methods sort of surfactant, polymer and alkaline injection. The chemical flooding that used for this research is surfactant injection, which used Alpha Olefin Sulfonate (AOS) and Tween 20. The result depends on salinity, surfactant concentration, rock properties, and any other parameters. Therefore, it is necessary needed to do some
experiments, in order to get the compatible parameters combination, to get the optimum percentage of RF. This case is influenced by salinity, surfactant concentration and type, also the properties of carbonate rock samples. Not all surfactant will be compatible with the certain field’s condition. Therefore, there are many parameters to determine the optimum surfactant. One of the methods to determine the optimum surfactant is by doing the phase behaviour test, where in that test, the surfactant will be divided into 3 (three) types; Winsor I (water micro emulsion), Winsor II (oil micro emulsion) and Winsor III (micro emulsion between oil and water). The compatible type is the Winsor III.

After the phase behaviour test, the test to determine RF percentage was doing by two methods; spontaneous imbibition and core flooding, where those things can be implemented to determine how optimum the percentage of RF can be reached. The optimum recovery factor has determined from the core flooding process, with the RF is 75%. The core flooding process can reach the optimum percentage of RF, rather than imbibition process. Because, the core flooding process is using mechanical energy, therefore the injection process can be faster and straight into the core.

2. Literatures

The literatures are the basic guide for authors to determine the title of this research. Authors were compiling many literatures to make a decision for choosing the parameters of this research, also many basic theories that came from the written literatures. Many literatures wrote that several times, the experiment of spontaneous imbibition and core flooding were succeeded by using the low salinity formation water and carbonate core sample. The aims of this research are to test the increase of oil production by using low salinity formation water in carbonate reservoir and to learn many factors to elevate the RF percentage. The carbonate core samples are used during this experiment in temperature 700°C. Brine with the salinity 194.450 ppm were mixed step by step with fresh water to decrease the brine concentration. From this experiment, it can be concluded that the elevation of RF percentage for core flooding is 3-5% and for spontaneous imbibition is 16-21% [1].

The following experiment is by using core flooding with low salinity in carbonate reservoir (from Bu Hasa field). Brine that had been used is seawater and injection water Um-Eradhuma (UER) with the concentration 197.584 ppm. The injection water dissolved into 5.000 ppm. The adding of surfactant (sulphate) also implemented into the optimum brine with the salinity 47 ppm, determined by interfacial tension numbers. This experiment was to determine the effect of brine salinity and surfactant composition. The result of this experiment proved that the regression of UER salinity from 197.584 ppm to 5.000 ppm and the adding of surfactant can have reached 63%-84,5% of RF. Nonetheless, the adding of concentration over the optimum concentration will be giving the negative effect to the RF [2].

In this following literature, it shows that the effect of surfactant, low salinity to the RF for carbonate rocks by using spontaneous imbibition. The variations of salinity are 9.412 ppm, 9.469 ppm and 11.000 ppm. Surfactant that had been used was anionic with the variation of concentration are 0,25%; 0,5%; 0,75%; 1%; 2%; and 4%. The core sample had 126-210 mD of permeability, and 14-16% of porosity. The optimum RF result was 80% for 0,5% of concentration; 11.000 ppm of salinity; 14,2% of porosity and 126 mD of permeability [3].

3. Methodology

This research conducted at Enhanced Oil Recovery (EOR) Laboratory, Petro physics Laboratory, Fluid Reservoir Laboratory and Chemistry Laboratory. Generally, in this chapter there will be explained about the research methodologies which were included as research design, flow charts, research procedure and research analyses.

The research design that was implemented is analytical and experimental, where both sides used to know the causal relationship between those variable in operational, differences, connections and authors’ interventions.

The authors were analysing the data sources sort of; surfactant type, surfactant concentration and brine salinity that will be used. Thus, the authors were using the relationship between three variables, and then by those differences, that can be reached for the result of the optimum RF on carbonate rock.
4. Experiment result

The compatible result after phase behaviour experiment goes to AOS for surfactant type, where AOS has three types of Winsor; Winsor I, Winsor II and Winsor III. The graphic on Figure 2 shows the solubilization ratio vs. salinity from the mixture of oil sample and AOS. It can be seen that both lines were cut on 20,000 ppm of salinity, which means that is the compatible salinity (Winsor III), and also used for spontaneous imbibition and core flooding.

Figure 1. Flow charts.

Figure 2. Solubilization ratio for AOS.
The important parameter to determine the compatible surfactant concentration is interfacial tension (IFT). The measurement of IFT for this experiment was using Du Nouy Tensiometer. The Figure 3 shows the graphic between IFT vs. AOS concentration as follow:

![Figure 3. AOS concentration vs IFT.](image)

The Figure 3 explains that from the graphic of IFT, there has the CMC (Critical Micelle Concentration) point, that marked on 0.5% concentration. The CMC point shows that the surfactant condition was stabilized on the according concentration. From CMC point, AOS with 0.5% concentration was chosen for further experiment; spontaneous imbibition and core flooding.

To prepare for the following experiment, which means to determine the percentage of RF, the core samples with compatible porosity and permeability have to be prepared. The core samples that had been used are 2 (two) carbonate core samples, with porosity and permeability data as follow:

| Core | Porosity (%) | Permeability (mD) | Note     |
|------|--------------|-------------------|----------|
| A    | 23%          | 18.24             | Good     |
| B    | 20%          | 17.67             | Good     |
| C    | 14%          | 5.50              | Average  |
| D    | 4%           | 3.79              | Bad/Average |
| E    | 6%           | 5.99              | Bad/Average |

The following graphic shows RF percentage from spontaneous imbibition and core flooding experiment. In spontaneous imbibition, core sample is drained in static way inside Amott apparatus, therefore the oil displacement by surfactant were proceed naturally without external tension. Meanwhile, for the core flooding, the injection process was only taking for 2 (two) hours, instead of spontaneous imbibition that took approximately for 1 (one) day. The core flooding process has the external tension from electricity that connected by syringe pump. The following Figure 4 shows the result of RF from spontaneous imbibition as follows:
After the result from spontaneous imbibition, the following figure 5 shows RF result from core flooding as follows:

As seen as those of both graphics, the RF result of core flooding RF result is more optimum than spontaneous imbibition, because of the external tension from the mechanical force [4].

5. Conclusion
Salinity has its effect in the forming of micro emulsion, otherwise has no effect to recovery factor. The effect of micro emulsion can be appeared by the phase of oil that has been produced. In 20.000 ppm of salinity, oil and surfactant has formed into the wanted micro emulsion, shown as the phase of Winsor III.

Concentration has its effect on CMC in the IFT test. The less of IFT number, the more RF percentage can be achieved.

AOS surfactant with 20.000 ppm salinity and 0,5% concentration is the compatible surfactant for this laboratory study.

The optimum recovery factor has determined from the core flooding process, with the RF is 75%. The core flooding process can reach the optimum percentage of RF, rather than imbibition process.
Because, the core flooding process is using mechanical energy, therefore the injection process can be faster and straight into the core.

It is wisely advised that adding more chemical materials, sort of polymer, can increase the ability and the RF percentage.

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