Laboratory Studies to Increase Oil Production Using Methyl Ester Sulfonate Injection on X Field

(Kajian Laboratorium untuk Meningkatkan Produksi Minyak Menggunakan Injeksi Metil Ester Sulfonat di Lapangan X)

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Abstract
The majority of petroleum production comes from the brown field where production has decreased from year to year in Indonesia. To increase the recovery factor of petroleum from the reservoir, an advanced step of production is required, Enhanced Oil Recovery (EOR), which can optimize the depletion of old oil fields. EOR is the application of technology that requires cost, technology and high risk. Therefore, before implementing EOR, in a field, we must carefully evaluate both technically and economically to obtain an optimal additional recovery. This research was conducted to increase oil production by injection of Methyl Ester Sulfonate (MES). This study begins with a screening parameter crude oil, formation water, Berea's core, and determination of phase behavior, interfacial tension (IFT), thermal stability, imbibition, and core flooding tests. The result for concentratin optimum in 0.3% MES and had IFT 0.3267 dyne/cm. The results of core flooding tests are: Recovery factor of waterflooding is 33.95 % and recovery factor of MES injection is 4.19 %.

Keywords: Methyl Ester Sulfonate Surfactant, Enhanced Oil Recovery, Interfacial Tension

Sari
Produksi minyak bumi sebagian besar berasal dari lapangan tua (brown field) di mana produksi telah menurun dari tahun ke tahun di Indonesia. Untuk meningkatkan daya recovery minyak bumi dari reservoir diperlukan langkah produksi tahap lanjut/Enhanced Oil Recovery (EOR) yang dapat mengoptimalkan pengurasan ladang minyak tua. EOR merupakan penerapan teknologi yang memerlukan biaya, teknologi tetapi beresiko tinggi. Oleh karena itu, sebelum menerapkan EOR di suatu lapangan harus mengevaluasi dengan teliti baik secara teknik maupun ekonomi untuk mendapatkan addition recovery yang optimal. Pada penelitian ini dilakukan untuk meningkatkan produksi minyak dengan injeksi metil ester sulfonate. Penelitian ini diawali dengan sreening parameter crude oil, air formasi, Core Brea, melakukan uji kelakuan fasa, tegangan antarmuka (IFT), ketahanan panas, imbibisi, dan core flooding. Hasil untuk konsentrasi optimum pada 0,3% MES dan memiliki IFT 0,3267 dyne / cm.. Hasil uji core flooding adalah: faktor perolehan waterflooding adalah 33,95% dan MES injeksi adalah 4,19%.

Kata-kata kunci: Metil Ester Sulfonat, Peningkatan Perolehan Minyak, Tegangan Antarmuka

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I. INTRODUCTION

Until today, petroleum still plays an important role as a world energy source, estimated to need world oil or rose. Meanwhile, oil production is far slower than world oil needs. From the 2004 statistics of the Ministry of Energy and Mineral Resources (MoEMR) Indonesia, Indonesia's approved oil and condensate production amounted to 400,486 million barrels and production continued to expand and increase, until 2010 Indonesia's oil and condensate production was 344, 836 million barrels. The decline in petroleum production that occurs in Indonesia is based on large petroleum produced from old fields, where from year to year it requires a reduction of 15% of total production. In the first quarter of 2011, the average production of Indonesian oil and condensate was received at 906,941 BOPD while the total rat requirement was an average of 1.4 million BOPD. This oil demand deficit has made Indonesia to release petroleum from various countries, which proves that the oil crisis has occurred in Indonesia [1].

This petroleum crisis can be overcome by saving / reducing the use of petroleum as the main energy source, looking for alternative energy sources, alternative energy sources used, among others: biodiesel, solar energy, energy from nature (geothermal, wind, and etc.) but its use is still not optimal. Another alternative to overcome the energy crisis is an increase in oil production which can be done by means of exploration of new wells (hydrocarbon basins) and increasing the recovery of oil found in old oil fields (brown fields). Therefore, the development of enhanced oil recovery (EOR) technology is a necessity to enhance the oil production/recovery from oil fields that have now passed the primary and secondary stages [2].

II. METHOD

The procedure of the research is depicted in Figure 1. The research covered material and equipment preparation, screening tests, MES performance tests, and core flooding test.

In this study used equipment automatic permeability and porosity equipment, condensers, conductometer, core flooding test equipment, funnel, Fourier Transform Infra-Red (FTIR), Gas Chromatgraphy, beaker glass, measuring glass, heating mantle, hot plate, hydrometer, Inductively Coupled Plasma (ICP), filter paper, distillation flask, magnetic stirrer, analytic balance, oven, pH meter, pycnometer, measuring pipette, reflux, separating funel, soxhlet, DR 3200 Spectrophotometer, interfacial tension spinig drop, stabbing density meter, sunny glass, thermometer, vacuum, vial, water bath.

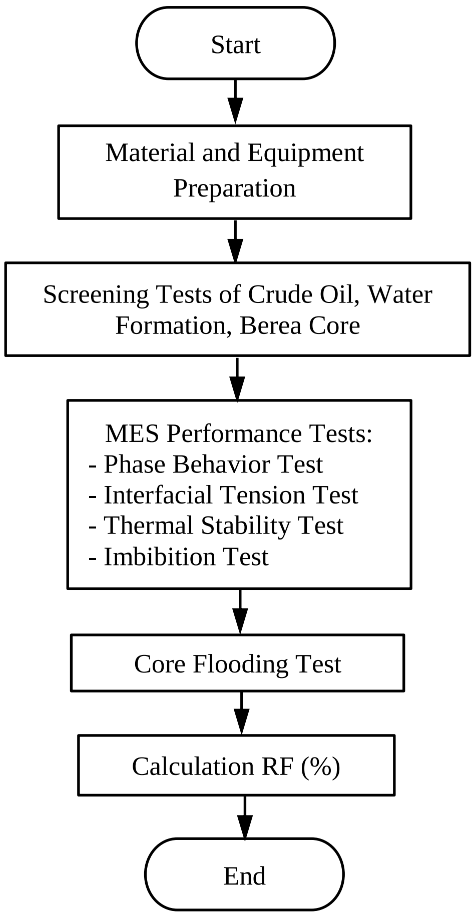

Figure 1. Research Procedure

The materials used in this study are X field formation water, distilled water, Berea Core, X field crude oil, argon gas, helium gas, nitrogen gas, carbon disulfide, methanol, and toluene.

III. RESULTS AND DISCUSSION

In the first stage of this research screening criteria was conducted for EOR on crude oil, formation water, cores. According to Nageh at 2005 screening parameters for surfactant EOR is given in Table 1.

Table 1. Screening Criteria

Screening Parameter	Unit	Specification	Result
Oil Gravity (API)	-	> 20	23,2
Depth	ft	< 8500	-
Reservoir Temprature	^{o}F	< 250	140
Initial Reservoir Pressure	Psig	n.c	-
Net pay	ft	n.c	-
Permeability	md	> 20	246,1 & 258,7
Residual Oil Saturation	%	> 25	47,6
Transmissibility	md ft/cp	n.c	-
Porosity	%	n.c	21,3 & 21,21
Salinity (TDS)	ppm	< 50000	2950
Hardness (Ca & Mg)	ppm	< 1000	104,1
Operating Pressure	Psig	n.c	-
Target Oil	bbl/acre-ft	n.c	-
Lithology	-	Sandstone	Sandstone
Well spacing	-	n.c	-

Crude Oil

From the results of testing crude oil in field X has 23.2 oAPI, and has dynamic viscosity at a temperature of 60 oC of 42.64 cp. The results of the research indicate that the X field crude oil has the characteristics of Heavy Crude Oil. That will be proven more clearly by the Composite C36 + test data and SARA testing (Saturate Hydrocarbon, Aromatics, Resins, and Asphalthenes). Obtained SARA test results are shown in Table 2.

Figure 2 shows the chromatogram of the crude oil. Obtained the largest composition is at C36+ of 33.739 mol%, which shows that this crude oil has the character of heavy oil. The X field crude oil has a very high pour point, which is 39 ^{o}C because this crude oil has a high wax content. Wax has a number of C16 atoms to C20 atoms of 13,859 mol%. Paraffin is a saturated hydrocarbon compound with an open C atomic chain (alkane group). Olefin is an unsaturated hydrocarbon compound with an open C atom (alkene group). Naphthenic is a saturated hydrocarbon compound with a closed C atomic chain (cyclo-alkane group). Aromatics are saturated hydrocarbon compounds (groups of benzene and their derivatives).

Table 2. Composition SARA Crude Oil

Name	Composition SARA (wt. %)			
	Saturate	***Aro-matic***	***Resins***	***Asphalthenes***
Crude Oil 1	74.09	18.8	1.64	5.47
Crude Oil 2	74.65	19.74	1.82	3.79

Water Formation

Mineral contents and properties of the water formation are shown in Table 3. From the results of testing water analysis 12 ions, the most important for screening parameters for surfactant EOR is salinity, Ca and Mg (hardness). The salinity of 2950 mg/l for the limit <50000 mg/l. Ca content is 104.1 mg/l and Mg <0.01 mg/l for the limit of hardness <1000 mg/l. So the X field formation water is suitable for chemical flooding EOR.

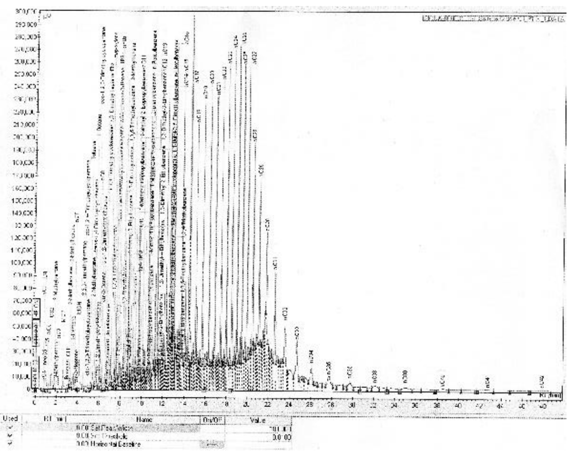

Figure 2. Chromatogram Crude Oil

Water Formation

In this core test, the determination of permeability and porosity were first used using Automatic Porosity & Permeability.

Table 4 shows the properties of Berea core. The results of the Core 1 test have a porosity of 21.3% which means it has sandstone lithology and has a permeability of 246.1 md. The test results Core 2 has a porosity of 21.21% which is sandstone rock and has a permeability 258.7 md. In the screening parameters, the core permeabilities of sandstone > 20 md, the cores 1 and 2 are suitable for EOR chemical flooding.

Table 3. Water Analyses

No	Test	Method	Unit	Result
1	TDS	Conductometer	mg/L	19560
2	Conductivity	Conductometer	µs/cm	5640
3	Sodium (Na^+)	ICP	mg/L	4716
4	Potassium (K^+)	ICP	mg/L	65.6
5	Calcium (Ca^{2+})	ICP	mg/L	104.1
6	Magnesium (Mg^{2+})	ICP	mg/L	< 0.01
7	Barium (Ba^{2+})	ICP	mg/L	< 0.01
8	Stronsium (Sr^{2+})	ICP	mg/L	23.80
9	Total Iron (Fe)	ICP	mg/L	< 0.01
10	Chloride (Cl^-)	Argentometry	mg/L	6462
11	Bicarbonate (HCO_3^-)	Titrimetry	mg/L	1465
12	Sulphate (SO_4^{2-})	Spectophotometer	mg/L	300
13	Carbonate (CO_3^{2-})	Titrimetry	mg/L	0.00
14	Hydroxide (OH^-)	Titrimetry	mg/L	0.00
15	Salinity	Conductometer	mg/L	2950
16	SG at 60°F	ASTM D 1298	-	1.0210
17	pH	pH meter	-	7.59
18	Appe-BF(Appearance Before Filtration)	Visual	-	Clear
19	Appe-AF(Appearance After Filtration)	Visual	-	Clear

Methyl Ester Sulfonate

Methyl Ester Sulfonate (MES) surfactant including anionic surfactant groups, namely negatively charged surfactants in their hydrophilic groups or surface-active parts.

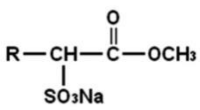

Figure 3. Molecule Structure of MES (Pratomo, 2005)

Table 4. Properties of Core Berea

Parameter	Core 1	Core 2	Unit
Diameter	2.5	2.5	cm
Length	3.53	3.6	cm
Gas Permeability	246.1	268.7	md
Gas Porosity	21.3	21.21	%
Brine Permeability	58.6	59.11	md
Brine Porosity	17.30	17.45	%
PV Gas	3.68	3.75	cm^3
PV Brine	2.99	3.08	cm^3

Figure 3 shows the molecule structure of MES. On the spectrum results by infrared spectrophotometer depicts the spectrum with absorption at ν = 1644.35 cm^{-1} indicating that the methyl ester has a carbonyl group C = O. Methyl ester sulphonates have functional groups of ester groups which are shown to be absorbed at ν = 1210.81 cm^{-1} indicating the C-O bond, and the RCOOR group at absorption ν = 1723.6 cm^{-1}. And the sulfonate group (RSO3-) is shown at absorption ν = 1348.88 cm^{-1} and absorption ν = 1044.58 cm^{-1} as an anionic surfactant as well as a hydrophilic group. At uptake ν = 3393.27 cm^{-1}, the -OH group was caused by water content because in the preparation of the sample methyl ester sulfonate was dissolved by distilled water and also affected the appearance of Si-H at uptake ν = 2126.47 cm^{-1} caused by dissolution by distilled water. Uptake of ν = 2955.80 to 2852.89 cm-1 shows the presence of vibration of the compound $–CH_1$, $-CH_2$, $-CH_3$ in methyl ester sulfonates. The intensity of the functional groups is given in Table 5.

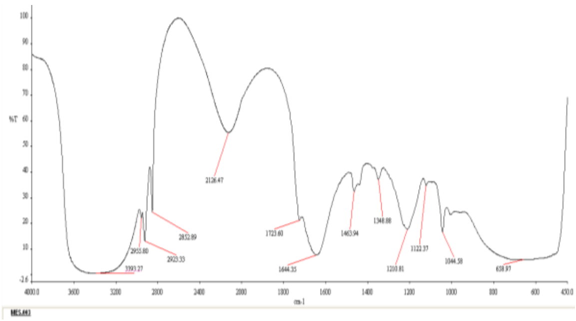

Figure 4. Spectrum of MES

Figure 5 shows the chromatogram of MES. The results of the analysis of composition by Gas Chromatography obtained the greatest MES chromatogram, namely at C19-C21 which indicates that this MES has a long chain group.

Table 5. Intensity of Functional Groups

Intensity (cm^{-1})	Functional Group
3393.27	-OH
2955.80-2852.89	-CH, $-CH_2$, $-CH_3$
2126.47	Si-H
1723.6	R-COO-R
1644.35	C=O
1463.94	-CH, $-CH_2$,
1348.88	RSO_3^-
1210.81	Bonding C-O
1044.58	RSO_3^-
658.97	Na^+

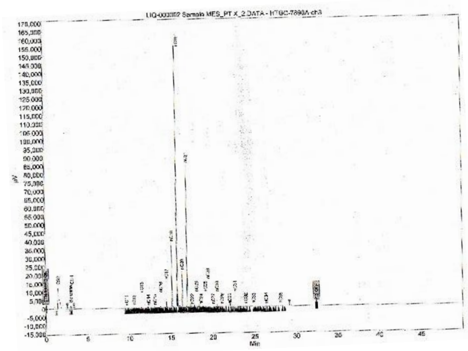

Figure 5. Chromatogram of MES

Phase Behaviour

The results of the phase behavior test showed that the optimum concentration was 0.3 and 0.5% by weight of the methyl ester sulfonate solution produced by 10% by volume of the microemulsion on the seventh day. And also for previous researchers conducted by Rivai in 2011, the optimal concentration was 0.3%.

Interfacial Tension Test

After testing the phase behavior, the interface stress test was performed using a spinning drop tensiometer, the results tested were MES solutions 0.3 and 0.5%, and the IFT results were 0.3267 dyne/cm for concentrations of 0.3% and IFT 0.5% for 0.3292 dyne/cm.

Thermal Stability Test

Figure 5 shows the results of thermal stability test. Based on the table, both density anf viscosity of MES slightly decrease and tend to be stable during the test for various concentrations of MES.

Table 6. Thermal Stability Test

Thermal Stability Test (0 day)		
Consentration MES (wt.%)	Density at 25°C (g/mL)	Kinematic Viscosity (mm^2/s)
0.1	1.0315	0.5231
0.2	1.0315	0.5187
0.3	1.0317	0.5278
0.4	1.0308	0.5239
0.5	1.0316	0.5251
0.6	1.0321	0.5301
Thermal Stability Test (7 days)		
0.1	1.0291	0.5088
0.2	1.0293	0.5059
0.3	1.0287	0.5061
0.4	1.0299	0.5056
0.5	1.0288	0.5087
0.6	1.0286	0.5075
Thermal Stability Test (14 days)		
0.1	1.0276	0.5023
0.2	1.0284	0.5090
0.3	1.0276	0.5044
0.4	1.0285	0.5038
0.5	1.0279	0.5082
0.6	1.0281	0.5065

Imbibition Test

The purpose of the imbibition test is to get the performance of surfactants before conducting core flooding tests. After having the results, calculate the Recovery Factor. Figure 6 and Table 7 show the results of the imbibition test. The figure and table indicates that recovery factor obtained from imbibition process is 24.68%. In addition the table shows that 0.58 ml of oil was displaced out during the test.

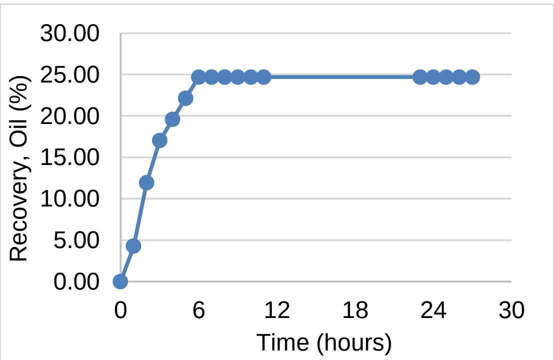

Figure 6. Imbibition Curve of 0.3 % MES

Table 7. Imbibition Test Measurement

Time (hours)	Volume of Crude Oil (ml)	*Recovery Factor* (%)
0	0	0.00
1	0.1	4.26
2	0.28	11.91
3	0.4	17.02
4	0.46	19.57
5	0.52	22.13
6	0.58	24.68
7	0.58	24.68
8	0.58	24.68
9	0.58	24.68
10	0.58	24.68
11	0.58	24.68
23	0.58	24.68
24	0.58	24.68
25	0.58	24.68
26	0.58	24.68
27	0.58	24.68

Core Flooding Test

Water injection / waterflooding in this study was carried out using x injection field water. This is because formation water is considered as water from the reservoir which is used to form a salinity gradient in synthetic cores to obtain reservoir characteristics. Waterflood is carried out at a rate of (1 ml/minute) slow flow and is expected not to exceed the actual reservoir pressure. The water injection will be stopped when the oil produced has decreased to ± 2% oil cut and has not increased.

The acquisition of oil in waterflooding using x injection field water proved to be productive by obtaining high waterflood recovery results reaching 33.95% of the initial oil amount / OOIP. The high waterflood recovery results are influenced by many factors, including porosity, good permeability and homogeneous characteristics of the synthetic cores used. The residual oil that is still inside the core and cannot be produced through water injection is determined by measuring the volume of oil that has been produced in a measuring tube.

The method is a recovery method by adding a low concentration of surfactant to injection water so that using/requiring the concept of surfactant is soaking. The thing that underlies the concept is that the fluid movement of the reservoir at the time of urging is almost the same as the fluid flow when produced (fluid flow to the wellbore), where through immersion the surfactant is expected to work optimally by providing time for the formation of a new interfacial tension (IFT) between oil and water and saturation in it so that the oil trapped in the pore will be released and will be produced with the same movement as when pressing.

Giving time soaking must also be optimal (not excessive/not less) so that the surfactant is expected to increase optimal oil recovery. The duration of the soaking period in this study is based on research conducted by Mwangi (2008) where the surfactant solution that will be injected after a long period of emulsion will occur, soaking too short can result in a decrease in IFT that is less maximal and if too long emulsion will occur which will cause plugging in rock pores. The ideal time for soaking surfactants in core flooding tests is 12 hours of soaking time at 0.1 PV; 0.2 PV; and 0.3 PV.

Injection of the methyl ester sulfonate surfactant formula carried out at 0.1, 0.2, and 0.3 PV was not able to increase the additional recovery of oil, but with continuous flooding the core pores were able to reach 4.19 % The acquisition of oil using the enhanced oil recovery chemical % OOIP.

In this case, it gets a small RF due to several factors:

1. Interfacial tension (IFT): according to Eni in 2007, the IFT value was 10-2 - 10-4 dyne/cm. In this study, IFT was 0.3267 dyne/cm for 0.3% concentration and 0.5% IFT of 0.3292 dyne/cm.

2. Alkali Addition: according to Sugihardjo in 2001 stated that the addition of alkali can reduce interface tension. In other words, surfactant injection must be added to alkali so that the optimum IFT results, in other words, the surfactant is not injected alone. And on the same problem the crude oil used is crude oil which is heavy crude oil. In Liu's research in 2006 stated that the characteristics of Heavy Crude Oil can be carried out by surfactant synthesis when alkali (Alkali-Surfactant) is added. The results obtained by IFT 10-2 - 10-3 dyne/cm, for Na_2CO_3 the optimum concentration was 0.4% and the optimum NaOH concentration was 0.3% .

3. Characteristics of crude oil (Heavy Crude Oil): this test carried out on heavy crude oil so that it can affect the RF results obtained. This crude oil has a composition of C36 + of 33.73 mol%.

IV. CONCLUSIONS

The results of methyl ester sulfonate injection can increase oil production with an optimum concentration of 0.3 weight % and produce Recovery Factor of 4.19%. The methyl ester sulfonate injection is not effective in heavy crude oils.

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