DETERMINATION OF PG12S SURFACTANT PHASE BEHAVIOUR IN THE MIXTURE OF OIL - SURFACTANT - COSURFACTANT - WATER

By
Tjuwati Makmur and **Nuraini**

ABSTRACT

Surfactant is surface active agent chemical, while isopropyl alcohol (IPA) and also isobutyl alcohol (IBA) are known as cosurfactant and include types of alcohols used in enhanced oil recovery (surfactant flooding) method. Factors of surfactant, cosurfactant, and NaCl concentrations play important role in determination of phase behavior. Based on the results of phase behavior tests that the mixture of oil – PG12 surfactant – cosurfactant (IPA & IBA) – WIP water showed macroemulsion phase for all analyzed samples at different experimental conditions. PG12 surfactant is unable to be used for enhanced oil recovery by chemical injection, because it is very difficult to flow in porous media and to displace oil, because the occurrence of plugging which is caused by opaque and milky macroemulsion.

Key words : Iso propyl alcohol (IPA), iso butyl alcohol (IBA), PG12 S surfactant, phase behavior, mixture of oil - surfactant - cosurfactant - water

I. INTRODUCTION

One of enhanced oil recovery (EOR) methods that is used to improve oil recovery factor, is surfactant flooding. Surfactant is surface active agent chemical that has two types of properties: soluble in oil and water. Oil and water are two separated phases and have high interfacial tension value (around 30 – 40 dyne/cm). According to theory and practice of microemulsions by Prince, L.M, that the mixture of oil – surfactant – cosurfactant (such as iso buthyl alcohol) - formation water will form the phase behavior. In this case, four types possibilities of emulsion formed, these are:

- Upper phase
- Middle phase (microemulsion).
- Lower phase.
- Macroemulsion.

The main focus of this research is to determine phase behavior of PG12S surfactant in the oil – surfactant – cosurfactant - formation water mixture at different experimental conditions. namely surfactant concentration in a range of 0.20 – 1.0 % and cosurfactant (IPA and IBA) in a range of 0.30 – 0.90 % concentrations conditions.

II. SCOPE OF RESEARCH

Scope of research is focused on the determination of PG12S surfactant phase behavior in the mixture of oil – surfactant – cosurfactant – formation water at different experimental conditions, namely :

a. Different NaCL concentration water samples (5000 – 25000 ppm).
b. Surfactant concentrations in a range of 0.2 % – 1.0 %.
c. Cosurfactant concentrations (0.3 % - 0.9 %).
d. Type of cosurfactant (IPA and IBA).

III. PHASE BEHAVIOR

The form of surfactant in surfactant/water are lamellar (see in Figure 3.1), spherical (see in Figure 3.2), and vesichel (see in Figure 3.3).

Mixture oil – surfactant – cosurfactant (IPA/IBA) – formation water can result in emulsion, which consists of four main phases; these are as follows:

LEMIGAS SCIENTIFIC CONTRIBUTIONS
VOL. 31. NO. 3, DECEMBER 2008 : 26 - 33

- Upper phase.

  Oil – surfactant – cosurfactant – formation water are mixed, then upper phase is formed which is emulsion in oil phase.
- Middle phase

  Mixture of oil – surfactant – cosurfactant – formation water forms middle phase, which means emulsion in middle phase, called microemulsion.
- Lower phase.

  Lower phase occurs in the system of oil - surfactant – cosurfactant – formation water mixture, which is emulsion in water phase.
- Macroemulsion

  The form of macroemulsion in the system of oil – surfactant – IPA – formation water.

Factors that influence phase transition from lower phase to middle phase or to upper phase or macroemulsion in system of oil - surfactant – IPA – formation water mixture are as follows :

a. Increasing salinity.
b. Decreasing alkane carbon number (oil).
c. Increasing alcohol concentration (C4, C5, C6).
d. Decreasing temperature.
e. Increasing surfactant concentration.
f. Increasing brine/oil ratio.
g. Increasing surfactant/oil ratio
h. Increasing molecular weight of surfactant.

IV. MATERIAL STRUCTURES SIZE

The appearance of scattered light is used to identify emulsions and to roughly measure size of material structure droplets. The results of measurements test is presented in Table 4.1 below.

This table above indicates that diameter of macroemulsions is much higher than micellar solutions diameter.

V. RESULTS OF TEST AND DISCUSSION

The phase behavior laboratory tests of oil – surfactant – cosurfactant – WIP water mixtures for enhanced oil recovery need were carried out at different experimental conditions:

a. NaCL concentration (5000 – 25000 ppm) in WIP water samples.

Figure 3.1
Lamellar structure

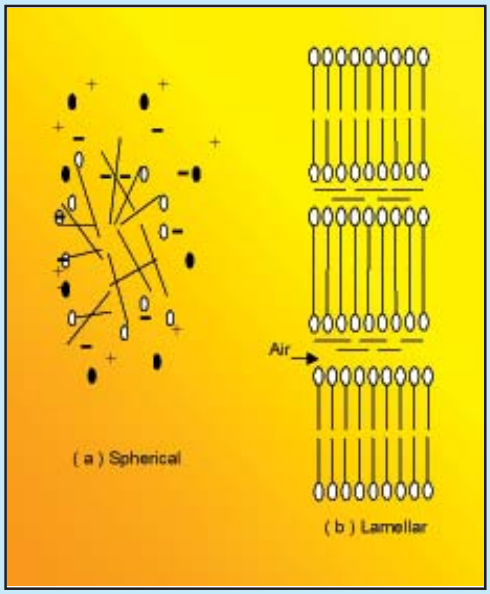

Figure 3.2
Spherical structure

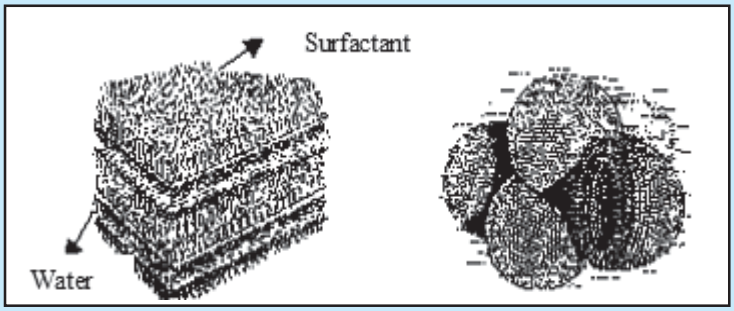

Figure 3.3
Lamellar and vesichel structures

LEMIGAS SCIENTIFIC CONTRIBUTIONS
VOL. 31. NO. 3, DECEMBER 2008 : 26 - 33

b. PG12S surfactant concentrations in a range of 0.2 % – 1.0 %.

c. Concentations of Iso propyl alcohol/IPA and iso butyl alcohol/IBA Cosurfactant (0.3 % - 0.9 %).

Based on results of PG12S surfactant phase behavior tests for all the analyzed samples at different experimental conditions as mentioned above can be summarized generally, namely : the occurrence of macroemulsion phase for the following mixtures :

1. Oil – PG12S Surfactant (0.2 – 1.0 %) – 0.3 % IPA Cosurfactant – WIP (NaCl 5000 ppm (see in Table 5.1).
2. Oil – PG12S Surfactant (0.2 – 1.0 %) – 0.9 % IPA Cosurfactant – WIP (NaCl 5000 ppm (see in Table 5.2).

Table 4.1
Visual Guide For Estimating Aggregate Size

Material structures	Diameter (A)	Appearance to naked eye
Water molecules	2.7	Transparent
Soap micelles	35 - 75	Transparent
Micellar solutions	50 - 150	Transparent and translucent
Resolvable units (microscopically)	1000 - 2000	Translucent when dispersed
Macroemulsions	2000 - 100,000	Opaque, milky
Resolvable units (visually)	500,000	Discrete anggregates

Table 5.1
Results of phase behaviour tests determinations
Oil-PG12S surfactant (0.2 - 1.0%) - IPA consurfactant (0.3%) - WIP (5000 ppm NaCL)

Water sample	PG12S surf. conc.	IPA (%) cosurfactant	Water volume cc	Emulsion volume cc	Oil volume cc	Remarks
WIP-5000	0,2000	0,30000	5,9733	0,2881	4,8974	Macroemulsion
WIP-5000	0,4000	0,30000	5,9733	0,2881	4,8974	Macroemulsion
WIP-5000	0,6000	0,30000	6,1173	0,1440	4,8974	Macroemulsion
WIP-5000	0,8000	0,30000	6,1173	0,1440	4,8974	Macroemulsion
WIP-5000	1,0000	0,30000	6,1173	0,1440	4,8974	Macroemulsion

Table 5.2
Results of phase behaviour tests determinations
Oil - PG12S surfactant (0.2 - 1.0%) - IPA cosurfactant (0.9%) - WIP (5000 ppm NaCL)

Water sample	PG12S surf. conc.	IPA (%) cosurfactant	Water volume cc	Emulsion volume cc	Oil volume cc	Remarks
WIP-5000	0,2000	0,90000	6,2613	0,0000	4,8974	Macroemulsion
WIP-5000	0,4000	0,90000	6,1173	0,0000	5,0414	Macroemulsion
WIP-5000	0,6000	0,90000	5,9733	0,2881	4,7533	Macroemulsion
WIP-5000	0,8000	0,90000	5,9733	0,2881	4,7533	Macroemulsion
WIP-5000	1,0000	0,90000	6,1173	0,1440	4,7533	Macroemulsion

LEMIGAS SCIENTIFIC CONTRIBUTIONS
VOL. 31. NO. 3, DECEMBER 2008 : 26 - 33

3. Oil – PG12S Surfactant (0.2 – 1.0 %) – 0.3 % IPA Cosurfactant – WIP (NaCl 15000 ppm (see in Table 5.3).
4. Oil – PG12S Surfactant (0.2 – 1.0 %) – 0.9 % IPA Cosurfactant – WIP (NaCl 15000 ppm (see in Table 5.4).
5. Oil – PG12S Surfactant (0.2 – 1.0 %) – 0.3 %

Table 5.3
Results of phase behaviour tests determinations
Oil - PG12S surfactant (0.2 - 1.0%) - IPA cosurfactant (0.3%) - WIP (15000 ppm NaCL)

Water sample	PG12S surf. conc.	IPA (%) cosurfactant	Water volume cc	Emulsion volume cc	Oil volume cc	Remarks
WIP-15000	0,2000	0,30000	6,1173	0,0000	5,0414	Macroemulsion
WIP-15000	0,4000	0,30000	6,0453	0,2161	4,8974	Macroemulsion
WIP-15000	0,6000	0,30000	6,1173	0,0000	5,0414	Macroemulsion
WIP-15000	0,8000	0,30000	6,1173	0,1440	4,8974	Macroemulsion
WIP-15000	1,0000	0,30000	6,0453	0,3601	4,7533	Macroemulsion

Table 5.4
Results of phase behaviour tests determinations
Oil - PG12S surfactant (0.2 - 1.0%) - IPA cosurfactant (0.9%) - WIP (15000 ppm NaCL)

Water sample	PG12S surf. conc.	IPA (%) cosurfactant	Water volume cc	Emulsion volume cc	Oil volume cc	Remarks
WIP-15000	0,2000	0,90000	6,1173	0,1440	4,8974	Macroemulsion
WIP-15000	0,4000	0,90000	6,1173	0,1440	4,8974	Macroemulsion
WIP-15000	0,6000	0,90000	6,1173	0,1440	4,8974	Macroemulsion
WIP-15000	0,8000	0,90000	6,1173	0,1440	4,8974	Macroemulsion
WIP-15000	1,0000	0,90000	6,1173	0,1440	4,8974	Macroemulsion

Table 5.5
Results of phase behaviour tests determinations
Oil - PG12S surfactant (0.2 - 1.0%) - IPA cosurfactant (0.3%) - WIP (25000 ppm NaCL)

Water sample	PG12S surf. conc.	IPA (%) cosurfactant	Water volume cc	Emulsion volume cc	Oil volume cc	Remarks
WIP-25000	0,2000	0,30000	6,0453	0,0720	4,7533	Macroemulsion
WIP-25000	0,4000	0,30000	5,9733	0,1440	4,7533	Macroemulsion
WIP-25000	0,6000	0,30000	5,9733	0,1440	4,7533	Macroemulsion
WIP-25000	0,8000	0,30000	5,9733	0,1440	4,7533	Macroemulsion
WIP-25000	1,0000	0,30000	5,9733	0,1440	4,7533	Macroemulsion

LEMIGAS SCIENTIFIC CONTRIBUTIONS
VOL. 31. NO. 3, DECEMBER 2008 : 26 - 33

IPA Cosurfactant – WIP (NaCl 25000 ppm (see in Table 5.5).

6. Oil – PG12S Surfactant (0.2 – 1.0 %) – 0.9 % IPA Cosurfactant – WIP (NaCl 25000 ppm (see in Table 5.6).
7. Oil – PG12S Surfactant (0.2 – 1.0 %) – 0.3 % IBA Cosurfactant – WIP (NaCl 5000 ppm (see in Table 5.7).

Table 5.6
Results of phase behaviour tests determinations
Oil - PG12S surfactant (0.2 - 1.0%) - IPA cosurfactant (0.9%) - WIP (25000 ppm NaCL)

Water sample	PG12S surf. conc.	IPA (%) cosurfactant	Water volume cc	Emulsion volume cc	Oil volume cc	Remarks
WIP-25000	0,2000	0,90000	5,9733	0,1440	4,7533	Macroemulsion
WIP-25000	0,4000	0,90000	5,9733	0,1440	4,7533	Macroemulsion
WIP-25000	0,6000	0,90000	5,9733	0,1440	4,7533	Macroemulsion
WIP-25000	0,8000	0,90000	5,9733	0,1440	4,7533	Macroemulsion
WIP-25000	1,0000	0,90000	5,9733	0,1440	4,7533	Macroemulsion

Table 5.7
Results of phase behaviour tests determinations
Oil - PG12S surfactant (0.2 - 1.0%) - IBA cosurfactant (0.3%) - WIP (5000 ppm NaCL)

Water sample	PG12S surf. conc.	IBA (%) cosurfactant	Water volume cc	Emulsion volume cc	Oil volume cc	Remarks
WIP-5000	0,2000	0,30000	6,1173	0,1881	4,7533	Macroemulsion
WIP-5000	0,4000	0,30000	6,1173	0,1440	4,8974	Macroemulsion
WIP-5000	0,6000	0,30000	6,1173	0,1440	4,8974	Macroemulsion
WIP-5000	0,8000	0,30000	6,1173	0,1440	4,8974	Macroemulsion
WIP-5000	1,0000	0,30000	6,1173	0,1440	4,8974	Macroemulsion

Table 5.8
Results of phase behaviour tests determinations
Oil - PG12S surfactant (0.2 - 1.0%) - IBA cosurfactant (0.9%) - WIP (5000 ppm NaCL)

Water sample	PG12S surf. conc.	IBA (%) cosurfactant	Water volume cc	Emulsion volume cc	Oil volume cc	Remarks
WIP-5000	0,2000	0,90000	6,2613	0,2775	4,8974	Macroemulsion
WIP-5000	0,4000	0,90000	6,1173	0,2853	5,0414	Macroemulsion
WIP-5000	0,6000	0,90000	5,9733	0,2881	4,7533	Macroemulsion
WIP-5000	0,8000	0,90000	5,9733	0,2881	4,7533	Macroemulsion
WIP-5000	1,0000	0,90000	6,1173	0,2440	4,7533	Macroemulsion

LEMIGAS SCIENTIFIC CONTRIBUTIONS
VOL. 31. NO. 3, DECEMBER 2008 : 26 - 33

8. Oil – PG12S Surfactant (0.2 – 1.0 %) – 0.9 % IBA Cosurfactant – WIP (NaCl 5000 ppm (see in Table 5.8).
9. Oil – PG12S Surfactant (0.2 – 1.0 %) – 0.3 % IBA Cosurfactant – WIP (NaCl 15000 ppm (see in Table 5.9).
10. Oil – PG12S Surfactant (0.2 – 1.0 %) – 0.9 % IBA Cosurfactant – WIP (NaCl 15000 ppm (see in Table – 5.10).

Table 5.9
Results of phase behaviour tests determinations
Oil - PG12S surfactant (0.2 - 1.0%) - IBA cosurfactant (0.3%) - WIP (15000 ppm NaCL)

Water sample	PG12S surf. conc.	IBA (%) cosurfactant	Water volume cc	Emulsion volume cc	Oil volume cc	Remarks
WIP-15000	0,2000	0,30000	6,1173	0,1440	4,8974	Macroemulsion
WIP-15000	0,4000	0,30000	6,1173	0,1440	4,8974	Macroemulsion
WIP-15000	0,6000	0,30000	6,1173	0,1440	4,8974	Macroemulsion
WIP-15000	0,8000	0,30000	6,1173	0,1440	4,8974	Macroemulsion
WIP-15000	1,0000	0,30000	6,1173	0,1440	4,8974	Macroemulsion

Table 5.10
Results of phase behaviour tests determinations
Oil - PG12S surfactant (0.2 - 1.0 %) - IBA cosurfactant (0.9 %) - WIP (15000 ppm NaCL)

Water sample	PG12S surf. conc.	IBA (%) cosurfactant	Water volume cc	Emulsion volume cc	Oil volume cc	Remarks
WIP-15000	0,2000	0,90000	6,1173	0,1440	4,8974	Macroemulsion
WIP-15000	0,4000	0,90000	6,1173	0,1440	4,8974	Macroemulsion
WIP-15000	0,6000	0,90000	6,1173	0,1440	4,8974	Macroemulsion
WIP-15000	0,8000	0,90000	6,1173	0,1440	4,8974	Macroemulsion
WIP-15000	1,0000	0,90000	6,1173	0,1440	4,8974	Macroemulsion

Table 5.11
Results of phase behaviour tests determinations
Oil - PG12S surfactant (0.2 - 1.0 %) - IBA cosurfactant (0.3 %) - WIP (25000 ppm NaCL)

Water sample	PG12S surf. conc.	IBA (%) cosurfactant	Water volume cc	Emulsion volume cc	Oil volume cc	Remarks
WIP-25000	0,2000	0,30000	6,0453	0,0720	4,7533	Macroemulsion
WIP-25000	0,4000	0,30000	5,9733	0,1440	4,7533	Macroemulsion
WIP-25000	0,6000	0,30000	5,9733	0,1440	4,7533	Macroemulsion
WIP-25000	0,8000	0,30000	5,9733	0,1440	4,7533	Macroemulsion
WIP-25000	1,0000	0,30000	5,9733	0,1440	4,7533	Macroemulsion

LEMIGAS SCIENTIFIC CONTRIBUTIONS
VOL. 31. NO. 3, DECEMBER 2008 : 26 - 33

11. Oil – PG12S Surfactant (0.2 – 1.0 %) – 0.3 % IBA Cosurfactant – WIP (NaCl 25000 ppm (see in Table 5.11).
12. Oil – PG12S Surfactant (0.2 – 1.0 %) – 0.9 % IBA Cosurfactant – WIP (NaCl 25000 ppm (see in Table 5.12).

Tables 5.1 - 5.12 show that PG12S surfactant results in macroemulsion phase for all the analyzed samples and experimental conditions. Material structure diameter of PG12S surfactant is 2000 – 100000 A^o and larger than micellar solution (50 – 150 A^o). If, the PG12S surfactant solution is used in enhanced oil recovery (chemical injection), the PG12S surfactant solution will contact with oil and will result in macroemulsion phase. Appearance of the PG12S surfactant to naked eyes is opaque and milky. In the chemical injection system, capability of the PG12S surfactant solution to flow through porous media and displaces oil, is very difficult because plugging occurrence which is caused by opaque and milky macroemulsion phase. This explanation is illustrated in Figure 5.1.

VI. CONCLUSIONS

As a result of work undertaken, the following conclusions can be made.

1. The results of phase behavior test in the mixture of oil – PG12S surfactant (0.2 – 1.0 %) – isopropyl alcohol (0.3 – 0.9 %) – WIP (5000 – 25000 ppm NaCl) are macroemulsion phase.
2. The results of phase behavior test in the mixture of oil – PG12S surfactant (0.2 – 1.0 %) – isobutyl alcohol (0.3 – 0.9 %) – WIP (5000 – 25000 ppm NaCl) are macroemulsion phase.
3. Macroemulsion phase is formed, has larger material structure size (2000 – 100000 A^o, which it looks opaque and milky.
4. PG12 surfactant is unable used for enhanced oil recovery (chemical injection) because it is very difficult to flow in pore media and to displace oil,

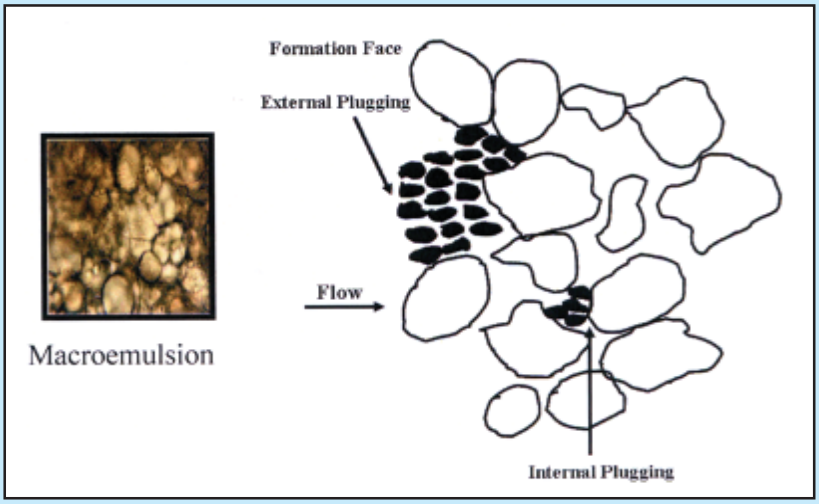

Figure 5.1
Illustration of the occurrence of plugging caused by macroemulsion

Table 5.12
Results of phase behaviour tests determinations
Oil - PG12S surfactant (0.2 - 1.0 %) - IBA cosurfactant (0.9 %) - WIP (25000 ppm NaCL)

Water sample	PG12S surf. conc.	IBA (%) cosurfactant	Water volume cc	Emulsion volume cc	Oil volume cc	Remarks
WIP-25000	0,2000	0,60000	6,0453	0,0720	4,7533	Macroemulsion
WIP-25000	0,4000	0,60000	5,9733	0,1440	4,7533	Macroemulsion
WIP-25000	0,6000	0,60000	5,9733	0,1440	4,7533	Macroemulsion
WIP-25000	0,8000	0,60000	5,9733	0,1440	4,7533	Macroemulsion
WIP-25000	1,0000	0,60000	5,9733	0,1440	4,7533	Macroemulsion

because the occurrence of plugging, which is caused by opaque and milky macroemulsion.

REFERENCES

1. Noronha, J.C. and Shah D.O : "Ultra Low IFT, Phase Behaviour and Micro - structure in Oil / Brine / Surfactant/Alcohol Systems", Aiche Symposium Series, Vol. 78, No. 212, 1982.
2. Salter, S.J. " The influence of Type and Amount of Alcohol on Surfactant - Oil - Brine Phase Behavior and Properties., SPE 6843, 1977.
3. Fayer F.J.: " Enhanced Oil Recovery", Elsevier Scientific Publishing Company, Amsterdam, Oxford, New York, 1981.
4. Adamson, A.W.: "Physical Chemis- try Of Surface", Interscience Publisher, Inc. New York, 1960.
5. Prince, L.M.: "Microemulsion - Theory and Practice", Academic Press, INC. New York, 1977.˘