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EFFECT OF ASP FLOODING ON OIL-WATER STABILIZATION AND SEPARATION

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ABSTRACT

The effectiveness of the nature of the ASP on the zeta potential, growth of mean droplet size and viscosity of emulsions have been investigated. Water in oil based emulsion was prepared and inspected the emulsion stability by analysing droplet zeta potential, growth of drop size and viscosity. An electric mechanism of dispersed phase stabilization is projected to make clear the long term stability observed for EOR implemented fields in Malaysia. Experiments results of droplet zeta potential for the different emulsions, showed that emulsions with low concentration of alkaline, polymer and high concentration of surfactant observed strong stability. By contrast, ASP stabilized emulsions of high alkaline, polymer and low surfactant, formed less stable emulsions. Cross polarized measurements were performed to analyse the drop size of water dispersed in oil stabilized at various compositions of ASP. The growth of drop sizes showed linear like behaviour with droplets zeta potential tests. Present results show that viscosity is not effected by temperature. It is also observed that increase in salinity concentration is contributing in the separation.

Keywords: emulsion stability, droplet zeta potential, droplet size, crude oil, EOR, ASP separation.

INTRODUCTION

Tertiary enhanced oil recovery (EOR) applications involving the injected combination of alkaline, surfactant and polymer are expected to affect surface facilities due to the stable emulsions that are formed in production fluids. The stable emulsions, which are often referred to as 'rag layer', reduce the effectiveness of the bulk separation process and have potential cost implications on the EOR program. Although emulsions in EOR are common, given that the working principle of ASP flooding relates to emulsion generation in the targeted reservoir, the persistence of this layer, in combination with shearing in the piping system and components introduced along the flooding pathway (i.e., Fe2+, Mg2+ ions), presents itself as a stubborn fluid-solid layer at the oil and water interface in the bulk separator. Various conventional methods for treating crude oil emulsions are available. However, the presence of ASP and its effects on the separation process is not fully understood. By modelling the emulsions, this study aims to enhance the understanding of the process requirements and to facilitate the deployment of appropriate technologies into the ASP program.

Emulsification

Crude oil produced from oilfields typically contains a complex mixture of hydrocarbons and formation water [1, 2]. These mixtures pass from the reservoir to the separator through the production system (i.e., via the casing perforations, tubing length and Christmas tree chokes). In these areas, multiple types of fluids are significantly mixed under high turbulence; the water phase subsequently starts to disperse as fine droplets in the bulk oil phase. This phenomenon generates an emulsion. The tightness and stability of these emulsions are affected by various factors, such as the water–oil ratio, chemicals present, intensity of turbulence, pH and temperature. With the passage of time, the features of the formed emulsion may also continuously change due to variations in these factors [3]. These variations include w/o and o/w emulsions. Emulsions induce a major monetary loss in the extraction process because they can block separation in primary separators when aggregating and settling seized.

Emulsion stability with different composition of ASP

Crude oil recovery can be significantly improved with the implementation of ASP via an increase in the sweeping and displacing effectiveness. Surfactant is a prospective component for dropping the interfacial tension in the oil–water phase to a level that stimulates the movement of confined droplets of oil. Alkaline is proposed to react with the acids to produce in situ surfactant to overwhelm the surfactant reduction in the liquid phases due to retention. Polymer increases the viscosity, dropping the mobility fraction and then permitting a larger volumetric swept effectiveness. Past researchers have examined the viscoelasticity of ASP solutions in EOR [3, 4], and endeavoured to identify the shared effects of ASP/oil/water on chemical properties [5]. The results indicate that the surfactants prominently incline the interfacial tension of the oil–water phase. The increase in the rag layer is subject to the rates of creaming/settling and coalescence of the dispersed droplets. The slower the rate of creaming/settling or coalescence, the quicker is the growth of the rag layer. The rate of creaming/settling depends on the phase density, droplet size and continuous phase viscosity, whereas the rate of coalescence is a function of interfacial property and droplet size [6-7]. The small size of dispersed droplets intensifies the problematic phase separation [1].

Separation optimization was recently conducted in Daging oilfield and Malaysian oilfield where ASP flooding is practiced [8, 9]. They found that coalescence was reduced with the increase of polymer concentration. There is a need to analyse the factors responsible for stabilizing emulsion where ASP is being implemented, which are believed to significantly affect the growth of rag layers. This paper focuses on these factors by employing experimental measurements on the effect of ASP in terms of the composition, separation process temperature, and separation time. This study also supports the separation and treatment process in oilfields where EOR is being implemented [10-12].

METHODOLOGY

Materials

Crude oil and brine water for this study were obtained from an identified field in Malaysia, where water flooding was performed. Crude oil has high wax, and density is 42 API with a live oil viscosity of 0.4 cP. Reservoir temperature ranges from 110 ºC to 119 ºC. The chemical used in this study was provided by PETRONAS, which is being utilized for the EOR purpose. The amount used in the experiment was based on the chemical amount that emerged in the primary separator. The amounts of alkaline, surfactant and polymer were 5%–15%, 20–40% and 60–70%, respectively, of the total ASP injections in the separator.

Emulsion preparation

The emulsion was produced in the lab by mixing reservoir brine solution containing alkaline, surfactant and polymer with oil by shearing at 15000 RPM for 3 min. Emulsion was prepared with 60% oil and 40% brine containing ASP. The amount of ASP was calculated from the chemical breakthrough in the primary separator. ASP used in the experiment included alkaline, Na_2Co_3, 5%–15%, surfactant, AOS, 20%–40% and polymer, GLP 100, 60%–70%. Table-1 shows the parameters used in this study.

Table-1. Parameters.

Sample code	Temperature, °C	Brine, %	Alkali, ppm	Surfactant, ppm	Polymer, ppm
A-i	60	40	Without ASP		
B-i			500	200	700
B-ii			1000		
B-iii			1500		
B-iv			500	400	600
B-v			1000		
B-vi			1500		

RESULTS AND DISCUSSION

Effect of ASP on droplet zeta potential

As shown in Figure-1, Droplet zeta potential measurements clearly show that the ASP produced liquid has increasing emulsification trend and stability, and emulsifies easily after shearing. The droplet zeta potential are among -21~-31.5mV at 60ºC, the absolute value of it increased with the surfactant-containing concentration rising up and is the highest at the 400ppm. A clear micro-emulsion layer was produced, and this hypo-stable state aggregate of oil droplets can directly result in an increase of the emulsification stability and corresponding increase in interfacial tension, perhaps due to the formation of a viscous and elastic film caused by the lots of surfactant in the ASP produced liquid. The results indicate that the excessive negative charge density on the surface of oil droplets ASP produced liquid is high and the electrostatic attraction force between oil droplets is strong. We can conclude that extending dehydration time to improve the demulsification effect of ASP produced liquid is not an effective method.

Zeta potential of ASP stabilized emulsions carried out at low polymer-high surfactant concentration and high polymer-low surfactant concentration at various alkaline concentrations is shown in Figure-1. As identified, the behavior of the emulsions is dissimilar and depends strongly on the concentration used. Emulsions containing high polymer 700ppm, attained much larger negative zeta potential values even in the presence of surfactant which is the major component of stabilization. There is decrease in the negative charge as the polymer concentration decrease to 600ppm when the surfactant concentration increase to 400ppm. These differences may suggest a very specific interaction between components of polymer and surfactant. Surfactant present in crude oil emulsion playing significant a role in the stabilization. Zeta potential results shows that increase in polymer concentration affects to increase the attraction force of droplets resulting in separation enhancement.

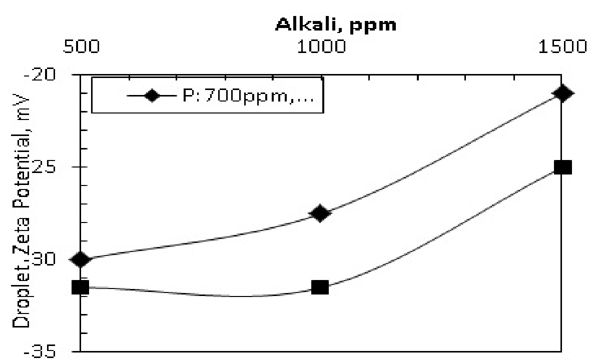


Figure-1. Droplets zeta potential at various ASP concentrations & 40% water.

Zeta potential of emulsions of water in oil, were also measured to observe the separation in the absence of the ASP in the oil as shown in Table-2. Zeta potential increase significantly in magnitude when there is no ASP (-13.66 mV). There is an extreme decline of the magnitude of the zeta potential in the presence of the ASP at the oil-water interface.

Table-2. Droplets zeta potential with and without ASP at 60 °C.

Sample code	Zeta Potential, mV	Sample code	Zeta Potential, mV	Zeta Potential, mV(No ASP)
B-I	-30	B-IV	-31.5	-13.66
B-II	-27.5	B-V	-31.5	
B-III	-21	B-VI	-25	

a) Effect of ASP on growth of droplet size

In the present study, the droplet diameter from different emulsions prepared with varying ASP concentrations. Emulsions were produced with IKA disperser at 15000 rpm for 3 min. It was observed that the mean diameter of droplets of emulsion with surfactant and polymer concentration of 200ppm and 700ppm after preparation was in the range of 6–8.5 µm. For the surfactant and polymer concentration of 400ppm and 600ppm respectively, we found an average mean diameter ranging from 3.5 to 5.5 µm.

The emulsified oil droplet size distribution of ASP produced liquid obeys normal distribution, as shown in Figure-1 & Figure-4. Results reflect that the tendency of the oil droplets coalesced into bigger drops is weak. This result is in agreement with a strong stability of the emulsions and indicates that the oil-water separation of produced mixture is difficult.

The droplet size growth of different emulsions were measured with the CPM method as described in the experimental part. The results are shown in Figure-2 and Figure-4, where the variation of drop size is shown for different ASP concentrations. In Figure-4, there is shown the behaviour for drop size for water in oil emulsion without ASP. There is flocculence of droplets resulting in the coalescence of drop with mean drop size of 22 µm.

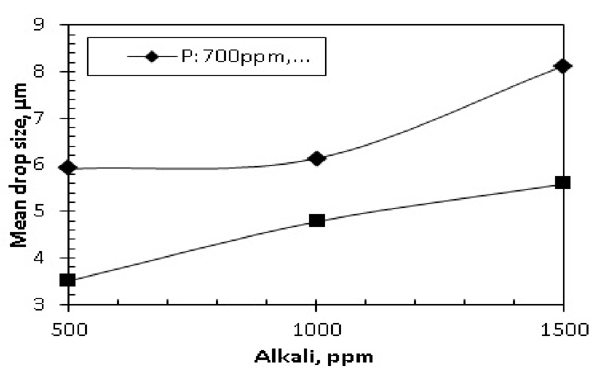


Figure-2. Mean drop size with CPM at various ASP concentrations.

It is interesting to notice that the average diameter obtained resulted smaller for emulsion with ASP as the ones shown in Table-3. There is more reduction in the drop size for the emulsions prepared at higher concentration of surfactant and lower concentrations of polymer and alkaline.

Table-3. Mean drop size of emulsion with and without ASP using CPM.

Sample code	Mean Drop Size, µm	Sample code	Mean Drop Size, µm	Mean Drop Size, µm (No ASP)
B-I	5.92	B-IV	3.51	22.19
B-II	6.14	B-V	4.78	
B-III	8.13	B-VI	5.59	

Figure-3 shows that without ASP droplets are coalescing resulting fast separation.

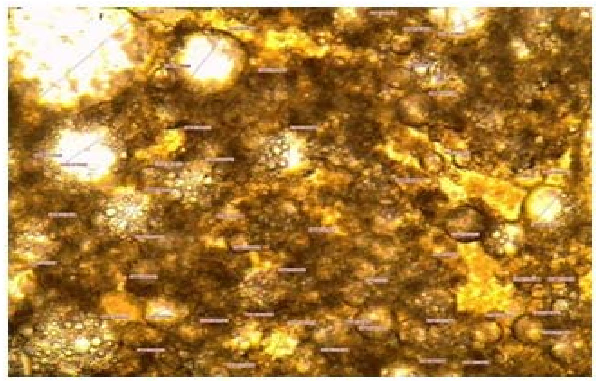
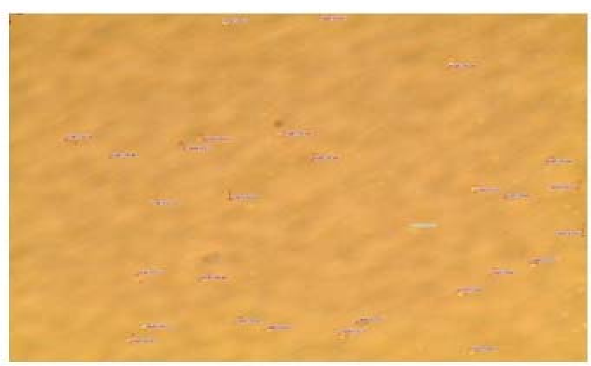


Figure-3. CPM image of emulsion without ASP at 60 °C.

In Figure-4, the behavior of the droplet size for water in oil emulsions stabilized with ASP showed a higher rate of decrease in drop size as compared with the emulsion without ASP. Notice however, that water droplets remain very small as observed for emulsions at lower concentration of polymer at high polymer concentration for constant alkaline concentration.



(a) Alkali: 500; Surfactant: 200ppm; Polymer: 700ppm

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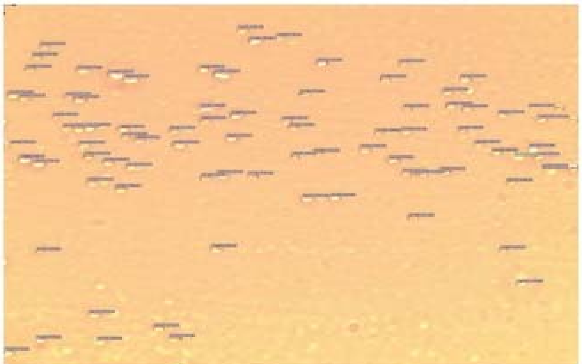
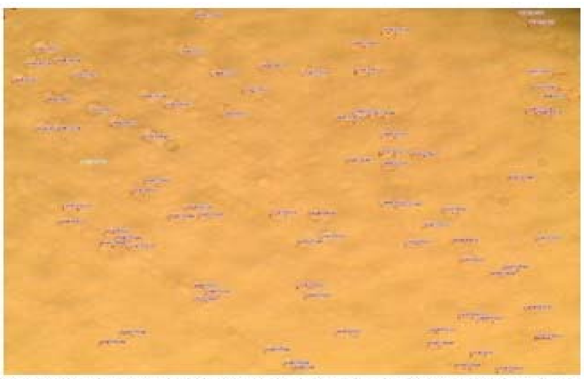
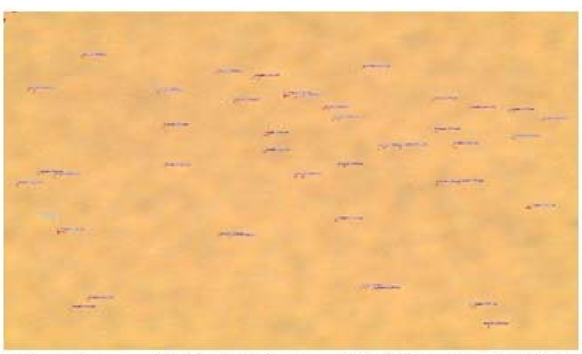


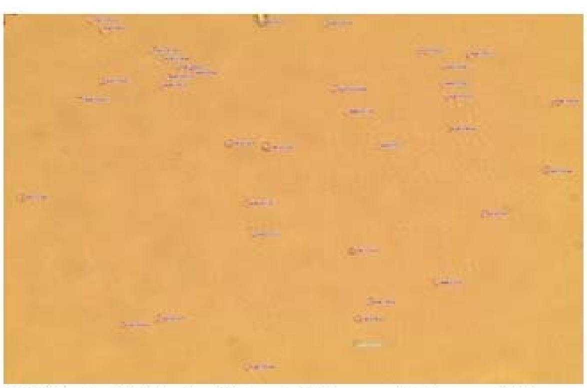
(b) Alkali: 1000; Surfactant: 200ppm; Polymer: 700ppm,



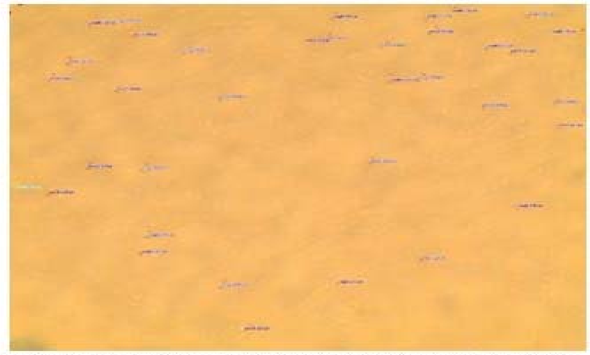
(c) Alkali: 1500; Surfactant: 200ppm; Polymer: 700ppm



(d) Alkali: 500; Surfactant: 400ppm; Polymer: 600ppm,



(e) Alkali: 1000; Surfactant: 400ppm; Polymer: 600ppm

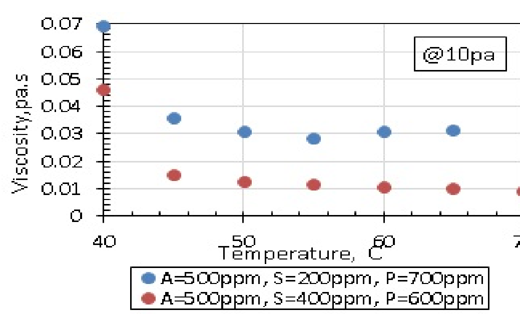


(f) Alkali: 1500; Surfactant: 400ppm; Polymer: 600ppm

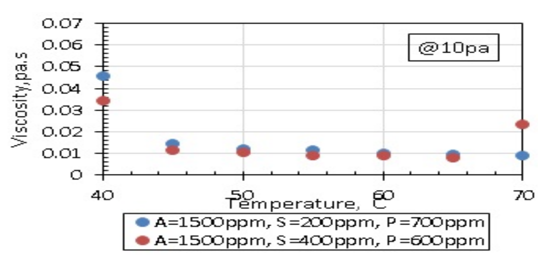
Figure-4. CPM image of emulsion in the presence of ASP at 60 °C (a) Alkali: 500; Surfactant: 200ppm; Polymer: 700ppm, (b) Alkali: 1000; Surfactant: 200ppm; Polymer: 700ppm, (c) Alkali: 1500; Surfactant: 200ppm; Polymer: 700ppm, (d) Alkali: 500; Surfactant: 400ppm; Polymer: 600ppm, (e) Alkali: 1000; Surfactant: 400ppm; Polymer: 600ppm, (f) Alkali: 1500; Surfactant: 400ppm; Polymer: 600ppm.

Effect of temperature and ASP on the viscosity of EMULSION

Figure-5 show the viscosity of ASP produced emulsion at various temperature and salinity. There is high viscosities of emulsion in the presence of less alkali. It is observed that increase in salinity concentration is contributing in the separation. As there is no significant effect of temperature on the viscosity so it is conclude that increase in temperature is not favourable solution to achieve separation.



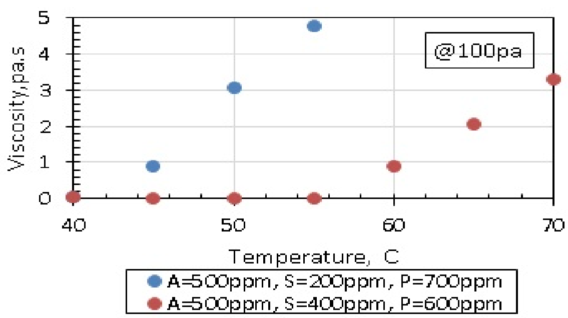
(a) Viscosities at low shear rate in the presence of low salinity



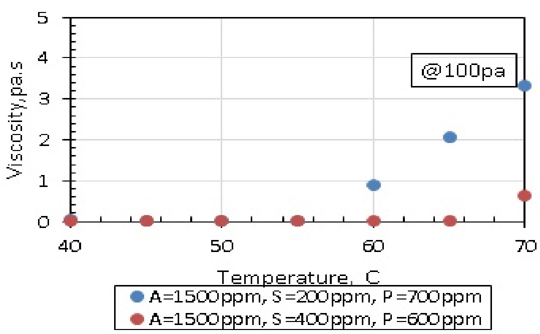
(b) Viscosities at low shear rate in the presence of high salinity

Figure-5. Comparison of different composition of ASP on the viscosities at low shear rate.

It is observed that at high shear rate emulsion viscosity increased significantly as shown in Figure-6. There is also high viscosities of emulsion in the presence of less alkali. Present results show that separation process is not effected by temperature. It is also observed that increase in salinity concentration is contributing in the separation.



(a) Viscosities at low shear rate in the presence of low salinity



(b) Viscosities at high shear rate in the presence of high salinity

Figure-6. Comparison of different composition of ASP on the viscosities at high shear rate.

CONCLUSIONS

Past research shows that higher polymer and low surfactant concentration results in the reduction of separation as compared to low polymer and high surfactant [9]. As the bottom layer of emulsion with high polymer and low surfactant was examined it is found that water drops size is around 500 µm which shows that layer is unstable. The bottom layer developed with low polymer and high surfactant concentration contained water droplets around 30 µm which shows that layer is stable. This is concluded that a small agitation/mechanical force/chemical force can easily separate the water drops in that bottom layer which contained more polymer and low surfactant concentration.

The reduction in the attraction force between droplets with the decrease in polymer and alkaline shows that injection of high polymer and high sanity is required to separate the dispersed phase. ASP flooding produced liquid is more stabilized due the presence of surfactant. The droplet size become very small with very small increase of surfactant concentration in ASP resulting low separation of dispersed phase. It is found that increase in salinity concentration is contributing in the separation. As there is no significant effect of temperature on the viscosity so it is conclude that increase in temperature is not favourable solution to achieve separation.

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