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Novel Chemical Flooding Technology – Applicability to Canadian Oil Fields

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Summary

In the last 20 years polymer flooding has become a widespread, and effective chemical EOR recovery technology. There are large scale commercial floods operating in China, Canada, the Middle East, India, etc. and it has been reported from results of a large scale flood in China that the oil recovery is 8-10% of the original oil in place (OOIP) (1).

It is well known in the industry that oil recovery from a polymer flood can be significantly increased as the interfacial tension (IFT) between oil and water is reduced. (2) This is due to the increase in the relative permeability to oil with lower IFT. Typically reduction in IFT is accomplished by the addition of surfactant (SP) or a combination of alkali and surfactant (ASP) along with polymer. At the Daqing Oil Field in China for 12 ASP pilots recovery ranged from 18-30% of OOIP (1). Even with this higher recovery SP and ASP have not been as widely applied as polymer flooding due to increased complexity and higher UTC (Unit Technical Cost = Total Cost of Project/BBL of oil recovered). In this period of lower oil prices only low UTC projects are typically implemented.

Recent research (3,4) has led to two developments that can lower the cost of chemical flooding relative to SP or traditional ASP projects. These developments are not applicable to all oil types, but attractive candidates exist in Canada, and elsewhere. The discoveries are that for some oils a “cosolvent” can replace the surfactant in ASP, and that a novel organic amine alkali (monoethanolamine) can improve project economics compared to sodium carbonate.

Results, Observations, Conclusions

The reason surfactant enhanced flooding is often not economically attractive is because significant quantities of surfactant tend to adsorb on reservoir rock. Adding alkali to injection brine has been shown to improve economics as this reduces surfactant adsorption, and can also generate petroleum soaps with high acid number oils (5). This development (ASP) often has improved economics but not to the extent that implementation has been to the level of polymer flooding. This paper describes two new approaches that can improve the economics of ASP flooding, and the combination of these approaches is especially attractive.

Alkali-Cosolvent-Polymer Flooding (ACP)

As mentioned earlier surface active components can be formed at the oil-brine interface by increasing the pH of injection brine which converts petroleum acids into soaps. This is a low cost process (AP), but it has never been successful without surfactant. Even if the right conditions occur to generate low IFT the emulsions that form at the brine-oil interface tend to be viscous, and this is especially true with more viscous oils. Co-solvents can be used to break these viscous macroemulsions and promote formation of low-viscosity microemulsions. We have discovered a class of inexpensive co-solvents (IBA-xEO) that are particularly effective with some viscous crude oils and this is part of the basis for the process we are calling ACP flooding. These same co-solvents also work well with ASP flooding. Co-solvents are needed to reduce both the bulk viscosity and interfacial viscosity of emulsions. (3)

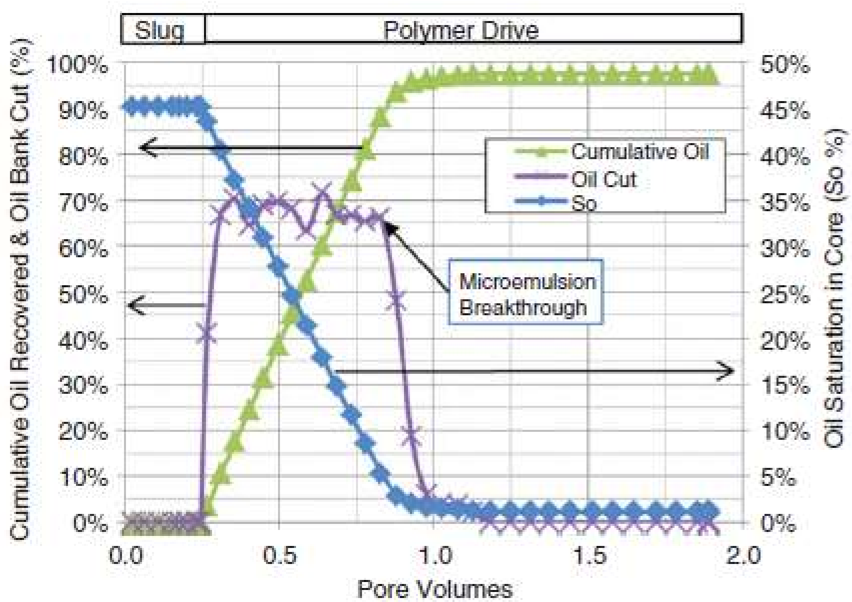
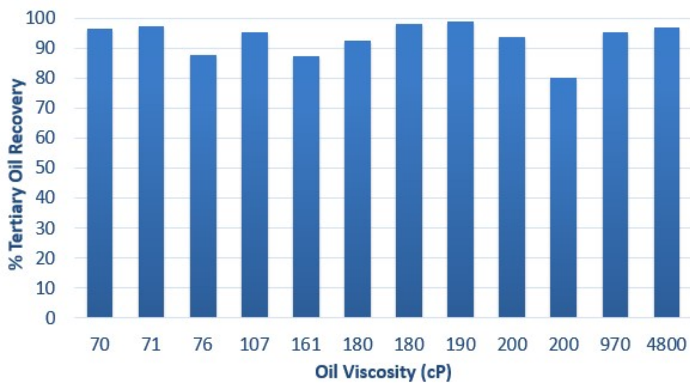


Fig. 14—ACP-2.1 oil recovery.

Shown above is a plot for a core flood in Berea outcrop sandstone with the ACP process (3). The formulation comprised 1% sodium carbonate, 0.3% cosolvent (IBA-5EO), and 0.4% hydrolyzed polyacrylamide polymer. Sor after waterflood was ~45%, and within one pore volume injection of ACP nearly all the residual oil was produced as a clean oil bank. This result is impressive, and further fine tuning with reservoir rock may potentially show that even less cosolvent can be used.

The below figure shows that high oil recoveries obtained with ACP formulations are not limited to only a few specific oils. High oil recoveries were obtained with 12 different crude oils with a range of viscosities from 70 to 4800 cp. These results are for laboratory core floods in outcrop sandstone.(3)

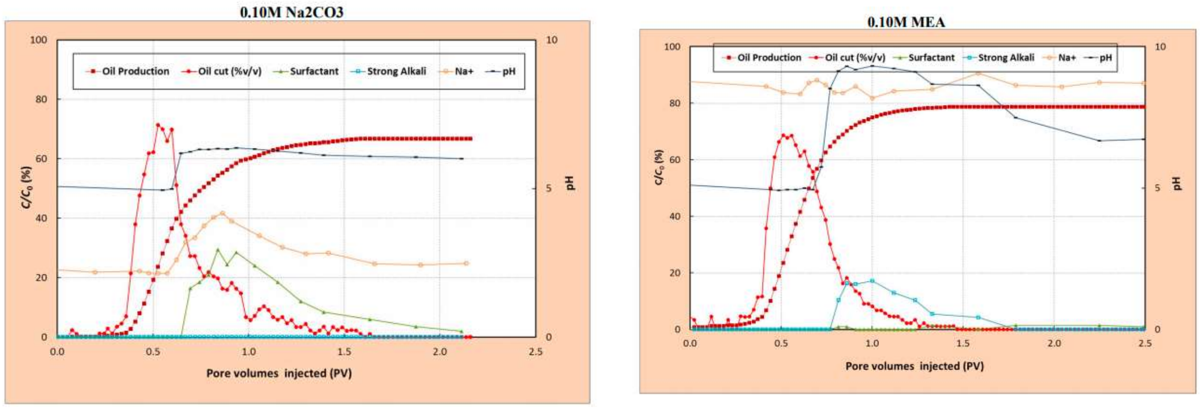
ACP Coreflood Recoveries – Effective with Multiple Oils



Monoethanolamine (MEA) as Alkali for ASP or ACP Flooding

Successful ASP pilots (6,7) have led to the consideration and design of large scale commercial projects. Alkali (sodium carbonate) is the lowest cost component of an ASP formulation but is by far the largest bulk component (74% of (6), and 84% of (7)). This leads to significant logistical issues of transport, sometimes threatening project viability. For this reason liquid ammonia (NH_3) was investigated as alkali for ASP (8,9). Laboratory experiments showed that ammonia is an attractive alkali as six times less mass is needed per mole of alkali compared to sodium carbonate, but field implementation was not pursued due to HSSE concerns of handling ammonia in the oilfield.

The next most attractive alkali amine in terms of mass/mole of alkali is MEA (4); and there are no significant HSSE concerns. Also MEA is a low viscosity liquid at atmospheric pressure (unlike ammonia), with a melting point of 10^{o}C (50^{o}F). Laboratory experiments showed equal performance to sodium carbonate in oil recovery and also the unexpected result that fewer moles of alkali are consumed by reservoir rock for MEA (4). This is due to the fact that addition of MEA to produced brine does not raise the salinity, and therefore when injected does not disturb the sodium-hydrogen exchange which is in equilibrium between brine and clay minerals.

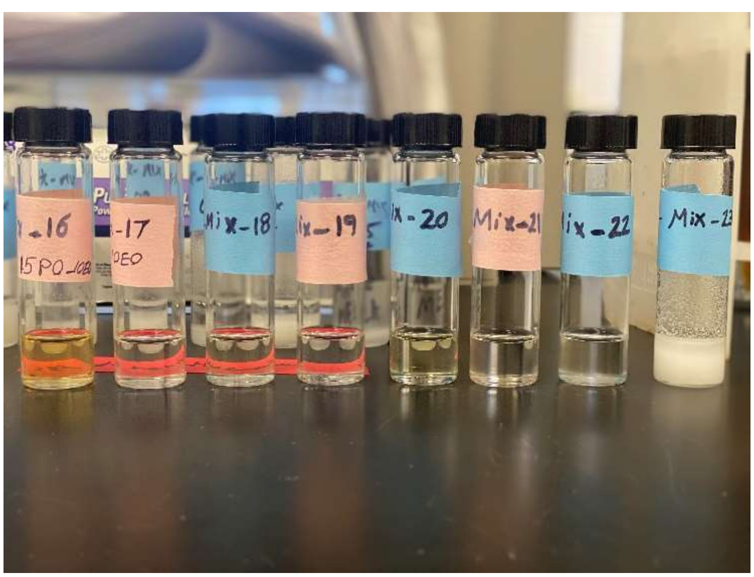


Fig, 4 from (4). Production plots for Boise core floods with 0.10M Na2CO3 (left) and MEA (right).

A further advantage of MEA as alkali is that low viscosity blends can be formed by mixing MEA with specific surfactants. This raises the possibility that a formulated alkali-surfactant liquid blend can be delivered to the oil field and directly mixed with a softened polymer injection stream. This will require substantially less facilities than the traditional application of ASP which handles powders (sodium carbonate) and high viscosity surfactant concentrates.

Monethanolamine (MEA) Cosolvent Blends

An especially attractive implementation of chemical flooding would be to combine the two concepts discussed. Potentially a low viscosity blend with a variety of cosolvents tailored to oil and reservoir conditions could be formed with MEA. Particular attention to freezing point, phase separation, and viscosity will be essential. Initial experiments prepared in the laboratories of Ultimate EOR Services are shown below showing the potential for stable, low viscosity blends.



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