Improved Oil Recovery Using Supercritical Carbon Dioxide/Oil Microemulsions

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Abstract
Microemulsions created by surfactants in supercritical carbon dioxide (scCO₂) have greatly increased oil recovered in enhanced oil recovery (EOR) wells. Currently, the average surfactants used in EOR are very expensive fluorinated surfactants which are also very harmful to the environment. They may be able to extract a much larger amount of the original oil in place (OOIP), but are not reusable and must operate above the minimum miscible pressure (MMP) of the CO₂ at the well’s temperature. The wells also can have various salinities of the brine, changing the efficiency of each surfactant, so choosing a surfactant requires knowing the temperature of the well, the salinity of the brine, and the API gravity of the oil. Overall, the use of surfactants can greatly increase the sweep efficiency compared to no surfactant, but it requires very specific knowledge of the oil well and the effective range for various variables for each surfactant.

Background information
In recent years, oil prices have gone up very rapidly in response to our limited supply of oil around the world. Cost of oil has risen to $100/bbl for crude oil at various points, creating a large interest in the idea of getting more oil out of used oil wells. Most oil wells previously only went through two stages of oil recovery, the first being digging a hole and letting the oil shoot up. The secondary state is where water is pushed into one well end to push the oil out of another, although this still leaves approximately 55-88% of the oil is still in place. The third stage is referred to as EOR, where techniques such as using supercritical carbon dioxide can capture an estimated 8-20% of the OOIP from wells. Supercritical carbon dioxide has been used for the past 30 years and works by becoming miscible with the oil, giving the oil a lower viscosity as well as a lowering the interfacial tension (IFT) between the rocks and the oil. Once no more oil can be removed from the wells, the wells can even be used as a source for carbon dioxide sequestration, with a possibility for pumping more CO₂ into the ground than the oil pumped out might produce.

Factors of Surfactants
• Chain length
• Longer chain for larger API
• Bulkier head
• % active/weight
• Limits of operation
• Salinity
• Temperature
• Pressure

Conclusion
I believe that although TC₁₄, the most recently discovered type of surfactant, showed promising values for the sweep efficiency, environmental impact, and cost, it didn’t operate at sufficient pressures to become a viable candidate for use in EOR. The IOS surfactants seem to be the most heavily used currently in industry, with many more different types developed, based upon the well depth, temperature, salinity, and rock formation, creating the ability for the oil companies to choose precisely which surfactant would benefit their well the most. If a surfactant similar to the NaTC₁₄ could be produced that operated at a higher pressure, I would choose that surfactant in most situations, based upon it’s low cost, viscosity, and lowering the oil’s IFT. APS also seem like an effective type of surfactant, but mostly based upon it’s use as a cosurfactant, not as a surfactant on it’s own.

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How CO₂ EOR works
To be able to use CO₂ to extract more oil, you must have two wells, one injection well to pump the CO₂ and water into, and a production well to extract the oil. An average well used for CO₂ must be able to operate at very high pressures to get the CO₂ to the supercritical state; a regular well might operate at 31ºC and 70 bar of pressure. The most efficient way of getting the CO₂ to the wells is via pipelines to a nearby source; although they cost a lot to put in place, the pipelines are a way to transport the gas at high pressures, quantity, and quality, while also offering a way for the power plants to sell the CO₂. The injection wells are pumped with alternating slugs of CO₂ and water. The gas mixes partially with the oil to increase the viscosity and reduce the interfacial tension between the oil and rocks, thereby freeing the oil from the rock pores, to be pushed by the water into the production well. One major downside to this method is the formation of fingers of water as a result of the low viscosity of the sCO₂. To decrease fingering as well as improving the efficiency and sweep ratio of this method of EOR, other substances are added to the carbon dioxide and water, such as surfactants, polymers, and alkaline.