Advances in chemical flooding

R. Tabary, B. Bazin

IFP, Rueil-Malmaison, 92500, France
rene.tabary@ifp.fr
brigitte.bazin@ifp.fr

Abstract

1. Introduction

New discoveries of conventional oil fields are declining while demand for oil is estimated to increase approximately 1.5% per year. Water flood is commonly used as an economic and effective method in secondary recovery after primary methods have been exhausted. Many of sandstone or carbonate reservoirs have low primary and waterflood recovery due to a poor sweep efficiency as the result of bypassed or unswept oil. In general, water flood still leaves 50-70% oil in the formation and oil cannot be further removed without the use of chemical, thermal or gas injection processes.

Chemical flooding was, up to 2000's, less common EOR method than thermal & gas but now, huge projects are initiated or revisited. Many examples of technically successful polymer and surfactant-polymer field projects are reported in the literature.

As the use of chemical flooding spreads to new reservoirs, especially oil-wet and mixed-wet reservoirs, the importance of surfactant-based wettability alteration will become important. There are also many oil-wet and mixed-wet naturally fractured reservoirs with significant amounts of remaining oil in place.

Middle East presents a significant opportunity to implement enhanced recovery methods on the fields with large remaining conventional oil resources and for future production growth.

2. Key Features

Chemical processes have been shown to be effective in recovering unswept oil by improving the mobility ratio (polymer flooding), or by reducing residual oil saturation (micellar or surfactant polymer flooding (SP), alkaline/surfactant/polymer (ASP)). Parameters such as mineralogy, permeability and viscosity ranges, temperature, salinity, have an impact on the feasibility of the process and also on the economics.

Chemical methods used in EOR are reviewed in the presentation, describing their potential, their limits and also the need of R&D to develop and to optimize recovery in low quality reservoirs. The optimization of a process consists in reducing polymer and/or alkaline-surfactant consumption, improving slug performance, and increasing reservoir contact. The presentation is mainly focused on processes applied in layered and non-fractured reservoirs.

Polymer flooding is the most important EOR process, improving the water-oil mobility ratio. The polymers act basically increasing the viscosity of the injected water and reducing the swept zone permeability, allowing an increase in the vertical and areal sweep efficiency of the water injection, and, consequently, increasing the oil recovery. The polymer is almost always hydrolyzed polyacrylamide (HPAM). Economic and technical successes are reported for polymer floods in both sandstones and carbonates. Displacement efficiency of polymer flooding is not sensitive to reservoir wettability.

Oil recovery during chemical flooding can be nevertheless heavily impacted by the petrophysical and petrochemical properties controlled by the wettability of the reservoir. Some research has been conducted to study the effects of surfactants on wettability. In several cases, it is shown that surfactants alter the wettability by reversing the chemical charges associated with the native wetting state.

Processes using surfactant are classified as SP (Surfactant-Polymer), MP (Micellar-Polymer) and ASP (Alkaline Surfactant Polymer). Basically, the method consists in injecting the surface-active agent (surfactant) to reduce the interfacial tension and mobilize the residual oil saturation The addition of an alkaline agent increases the process efficiency by decreasing the surfactant retention. Additional surface active agents may be produced in the case of acidic crude.

The ASP method can be applied as an improved waterflooding with large slug of low surfactant concentration. The alkali is sodium carbonate, sodium hydroxide or these two chemicals mixed in soft, fresh water to avoid precipitation. Some of ASP floods were commercially successful, however, the projects were generally small. Difficulties in applying large reservoir scale surfactant flooding is due to the evaluation of potential recoveries mainly because reservoir modelling is not available yet.

Fewer chemical flooding projects have been performed in carbonate reservoirs. Limestone and dolomite reservoirs can have very complex reservoir conditions and can be difficult to characterize. These reservoirs are highly heterogeneous and commonly have low porosity and permeability. In addition, carbonate reservoirs are typically oil-wet or fractured or both. The key reservoir properties affecting the SP flood are heterogeneity and high salinity.

3. Conclusions

Chemical flooding is an important technology for enhanced oil recovery. The production rates of the 100 largest oilfields in the world are all declining from plateau production. The challenge is to develop EOR methods that ensure an economical tail end production from these fields. Field practice has shown that polymer flooding can increase recovery by more than 12% OOIP, and that the production costs are comparable to that of water flooding. More than 20% OOIP incremental recoveries can be obtained with the ASP process. Better ASP systems need to be developed with more cost-effective surfactants in weak alkaline systems.

The higher quality reservoirs can utilize proven recovery technologies that could be applied with appropriate chemicals using processes economically profitable. The lower quality reservoirs (primarily tight carbonates naturally fractured) typically lead to a poor primary production. Chemical stimulation with surfactants can be used to alter the reservoir wettability toward water-wetness, oil being expelled from the rock matrix into fractures. However, at this time there is insufficient knowledge for understanding all the complex mechanisms, for improving the processes and modelling their effects.

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Speaker’s Biography

René Tabary is a senior research engineer in Reservoir Engineering Department at the Exploration and Production Business Unit of IFP. Tabary is responsible for evaluating EOR Polymer Floods processes. He has been working on Water Shutoff and Chemical EOR since 1976. His activity relates to upstream research, development of new methods and processes, field applications and on-site technical assistance. He is the Project Leader of the JIP "STARGEL" dedicated to new IFP microgel technology for Water Shutoff and Conformance Control. He holds a four-year technical degree in Chemistry, Mathematics and Physics from The University of Paris.