CO₂-Foam EOR Field Pilots

Mohan Sharma¹,² (mohan.sharma@uio.no), PhD Candidate, Martin Fernø¹,³, Arne Graue¹,³, Svein M. Skjaervø¹,²

¹The National IOR Centre of Norway, ²University of Stavanger (UiS), Norway, ³University of Bergen (UiB), Norway

Introduction
Carbon dioxide has been successfully used in fields as EOR agent, especially in the USA due to access to CO₂ from natural sources, which is relatively inexpensive compared to other processed solvents. Because CO₂ forms a dense phase at typical reservoir conditions, it exhibits higher density and viscosity compared to other gases, thus making it favourable for gas flood. Under a specific combination of reservoir pressure, reservoir temperature and oil composition, CO₂ may become mutually soluble with the residual oil leading to miscible displacement. The residual oil saturation is then reduced nearly to zero resulting in high ultimate oil recovery. However, below some pressure called Minimum Miscibility Pressure, CO₂ and reservoir oil are no longer miscible. CO₂ may still force out additional volume of oil owing to oil swelling and viscosity reduction under immiscible displacement but considerable residual oil saturation can remain. CO₂ floods have proven successful in some re-injection fields, however, in several fields despite its high local displacement efficiency, the process suffers from poor sweep efficiency due to viscous fingering caused by unfavourable mobility ratio, and gravity segregation caused by density difference between injected and displaced phases.

Increase in global energy demand and maturing oil fields has resulted in pushing recoveries to higher levels through integrated and innovative solutions. Application of foam (generated by using surfactants) has been found to reduce gas mobility in laboratory coreflood experiments, and to establish favourable mobility conditions. The impact of various parameters like rock wettability, capillary pressure, fluid saturations, flow rates, adsorption etc. on foam flood have been studied extensively at lab scale.

Research Objectives
- Understand large scale CO₂ mobility control using foam in heterogeneous reservoirs from field pilots
- Develop a framework to scale-up the mechanisms that are observed at lab scale and are required to describe flow at reservoir scale

Ongoing Work

Lab-scale Studies
- Experiment Design: Based upon the information available about the reservoir's petrophysical properties, reservoir condition and rock-fluid/surfactant interactions, several different scenarios will be tested through 1D numerical scoping study. This would ensure lab experiments are conducted under conditions favorable to generate foam during coreflood.
- Lab Experiments: The experiments using representative core and fluid system will be carried out under in-situ conditions at UiB.
- Data Analysis: 1D numerical modelling will be used to simulate coreflood experiments. Parameters relevant to foam modelling will be tuned to get a match on pressure drop across core, breakthrough time, oil recovery trend and water-cut/GOR trends.

Field-scale Studies
- Pilot Design: A few fields have been identified onshore in Texas, USA to conduct pilot studies. This includes a sandstone reservoir, a heterogeneous carbonate reservoir and a fractured carbonate reservoir. The project involves investigating the feasibility of using the pilot area suitable for CO₂ EOR, by integrating data available from various sources and scales. Surface oil, gas and water samples are being collected for fluid characterization studies. It is planned to use historical production and injection data to calibrate the model, which would form the basis for pilot design. Numerical modelling and sensitivity studies under uncertainty will be carried out on the pilot pattern, well spacing and injection strategy.
- Pilot Execution: Appropriate data required to understand the displacement process will be acquired prior to, during and post pilot execution. This includes well logs and cores from planned infill wells; well pressure, rates and fluid samples; pressure build-up and fall-off tests; production logging; tracer studies; and base and repeat seismic surveys post feasibility study.
- Data Analysis: The data gathered during and post pilot would be analysed using appropriate tools. The interpreted results would be used for pilot model re-calibration and to understand the production mechanisms at larger scale.

Summary
The results from the pilot studies will be used to understand the flow mechanisms at larger scale, and to establish a link between relevant processes observed at lab scale and pilot scale. To date, commercial CO₂ value chain does not exist to support field-scale CO₂ EOR on the NCS. Knowledge and experience gained from pilots carried out as part of this work can be used for effective pilot design on NCS.

Acknowledgements

References:
Apparent Viscosity in Smooth Capillaries. SPE J 25 (2), 176-190. SPE-12129-PA
Martin Fernø1,3 , Arne Graue1,3 , Svein M. Skjæveland1,2
Pilot Design: A few fields have been identified onshore in Texas, USA to conduct pilot studies. This includes a sandstone reservoir, a heterogeneous carbonate reservoir and a fractured carbonate reservoir. The project involves investigating the feasibility of using the pilot area suitable for CO₂ EOR, by integrating data available from various sources and scales. Surface oil, gas and water samples are being collected for fluid characterization studies. It is planned to use historical production and injection data to calibrate the model, which would form the basis for pilot design. Numerical modelling and sensitivity studies under uncertainty will be carried out on the pilot pattern, well spacing and injection strategy.
Process Scale-up
The behaviour of foam in porous media is controlled by the behaviour of individual films between bubbles in the foam. Because foams are at best metastable, the research so far has focused to understand processes involved in dynamic break-and-reform mechanisms at small scale, and to capture them via numerical models. However, laboratory results are often used unscaled, or are only partially scaled-up, for field studies. Starting with the governing component flow equations, different scaling groups are currently being studied using Inspectional Analysis. The results from pilot will be used to validate the scale-up approach and identify any relaxation required on similarity groups under certain situations.

The National IOR Centre of Norway
University of Stavanger
University of Bergen