Experimental and Numerical Investigation of Tertiary-CO2 Flooding in a Fractured Chalk Reservoir

Mohammad Ghasemi
Petrostreamz AS

Sayed Ahmad Alavian
PERA AS

Lykourgos Sigalas
GEUS

Vural Sander Suicmez
Maersk Oil & Gas A/S

Wynda Astutik
Petrostreamz AS

Curtis Hays Whitson
PERA AS / NTNU

Dan Olsen
GEUS
Abstract

This paper describes tertiary CO2 recovery mechanisms observed in two distinct core flooding experiments. In both experiments, water flooding followed by CO2 injection into an outcrop chalk with matrix-fracture system at reservoir conditions. The objective of this paper is to study the main mechanisms that control the rate of oil recovery during tertiary-CO2 flooding. A series of experiments as well as compositional numerical simulations have been carried out to evaluate the efficiency of the process.

The core sample is a vertically-oriented 26 cm long outcrop chalk with 12 cm diameter. A centralized hole with a diameter of 2 cm along the core represents the “fracture” that results in a pore-to-fracture volume ratio of 14. In the first experiment (Exp-1), the fractured core is initially saturated with North Sea Chalk Field (NSCF) stock tank oil (STO) and the connate water. Whereas in the second experiment (Exp-2), the core is saturated with NSCF live-oil and the connate water. Once the reservoir condition is established (258 bara, 110 °C), sea water (with considerable sulfate content) is injected from the bottom of the fracture and the oil is recovered from the top. Once no more oil recovery is observed, the water flooding (WF) is stopped. A “shut-in” period follows which allows preparing the rig for the CO2 flooding (CF). Right after the “shut-in”, CO2 is injected from the top of the fracture and the oil is produced from the bottom.

A three-phase acoustic separator is employed for measuring the complex mixtures of oil, gas and water. The separator is initialized at specific water-oil and gas-oil interface prior to the core flooding. The strong effect of vaporization on the measured separator oil volume during Exp-2 is considerably addressed in this work.

A compositional reservoir simulator with a tuned equation-of-state (EOS) is utilized to model the experimental work. An automated history matching algorithm is developed to fit the experimental data of WF and CF periods.

Compositional simulations are conducted to match the experimental data together with the water-breakthrough time during water injection. This is performed by tuning the imbibition capillary pressure and relative permeability curves. In addition, the experimental data during the CF are also matched by tuning the oil and gas diffusion coefficients which are constant input parameters for the numerical model. Good agreement between the model and experimental data is obtained. We observe a strong impact of hysteresis on fitting the fluid production during CO2 flooding in Exp-2. The sensitivity analysis shows that tertiary CO2 recovery is affected by the water saturation in the core after the secondary WF. Moreover, the fracture-matrix transport function during tertiary-CO2 flooding is dominated by the diffusion rather than the convective flux or viscous forces.

The outcome of this work is an important step towards modeling the tertiary-CO2 flooding in an actual fracture-chalk system. Proper modeling of imbibition and diffusion dominated processes in a chalk system at reservoir conditions has been accomplished.