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Matrix-Fracture Interaction in Sandstone Rocks During Carbon Dioxide Injection

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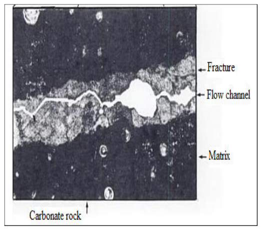
INTRODUCTION

Naturally fractured reservoirs, which consist of a high porous, low permeable matrix and a low porous, high permeable fracture network, contribute to the hydrocarbon reservoir in the world in a great extent. In order to recover oil remaining in the matrix system, gas injection is a favorable method since it activates gas oil gravity drainage (GOGD) mechanism. Molecular diffusion also plays an important role in oil recovery in fractured reservoirs.



Matrix - Fracture Network System with Flow Channels (Reiss, 1980)

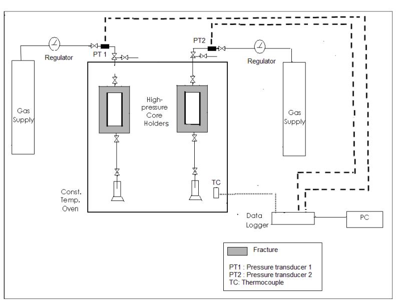
AIM OF THE STUDY

The aim of the study carried out is to investigate matrix-fracture interaction mechanisms in a fractured sandstone core system during gas injection. In the study, an experimental work is carried out to understand the recovery mechanisms including gas-oil gravity drainage (GOGD) and diffusion by keeping the pressure of the fractured system at 250 psi with the injection of CO_2 at 70 ºC reservoir temperature. A modeling study is also carried out, in which CMG (Computer Modeling Group Ltd.) WinProp (Microsoft Windows™ based Phase-Behavior and Fluid Property Program) and GEM (Generalized Equation-of-State Model Compositional Reservoir Simulator) are used to model experimental results.

EXPERIMENTAL STUDY

Consolidated core samples with fracture are used in experiments. The space around the core sample between the wall of the core holder and the core is considered as a surrounding fracture. Fracture width at the top is 1.9 cm and at the bottom is 1.2 cm. In the annulus space around the core a width of 0.445 cm is created for the fracture space.

After core sample is saturated with brine (5 wt % KCl aqueous solution)& n-decane, it is weighted & placed into high-pressure core holder.

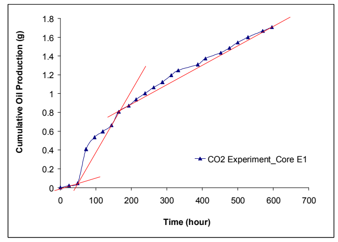


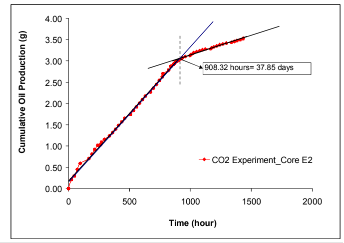
The system is kept at 250 psi and at 70 ˚C for a 24 hour-period by CO_2 injection from the top. After the 1 day period, the valve at the bottom of the core holder is opened to collect recovered oil. Recovered oil is weighted. The valve at the bottom of the core holder is closed and pressure is adjusted to 250 psi, again by injecting CO_2 into the holder.

EXPERIMENTS

Test	Core	Dry Weight (g)	Weight After Saturated with Brine (g)	Weight After Saturated with Brine+ n-decane(g)	S_{oil} (frac)	S_{brine} (frac)	S_{CO2} (frac)	OOIP (cc)	Duration (days)
1	E1	273.22	299.78	294.96	0.797	0.203	0	21.96	25
2	E2	269.78	296.37	286.43	0.552	0.203	0.244	15.06	60

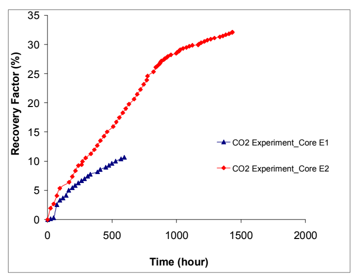
EXPERIMENTAL RESULTS AND DISCUSSION





In Experiment-1, core is fully saturated with brine and n-decane only, leaving no pore space for gas initially. The only available contact area for gas and reservoir fluids is the fracture surface. In that respect, the diffusion should be the effective recovery process at the initial stage of production. This is why the cumulative production of the first few days is very limited.

Experiment-2 is conducted with an initial gas saturation promoting the entrance of high pressure gas into pore space. Entrance of gas into pore space will increase the effective contact area of gas and reservoir fluids resulting with more efficient recovery mechanism.

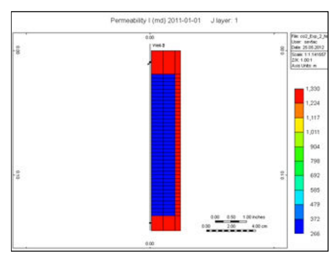


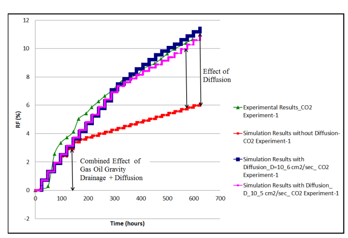
Comparison of recovery of two tests indicate that the availability of initial gas saturation in the matrix increased the recovery for all times. This is attributed to the fact that the readily available space for CO_2 makes the penetration of CO_2 into the matrix easier.

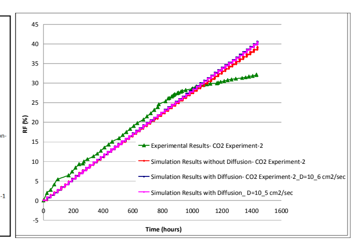
As oil becomes more saturated with CO_2, oil density increases (Holm & Josendal, 1974), which may cause more efficient gas oil gravity drainage mechanism due to higher density difference between oil and gas phases. In addition, decrease in the viscosity of oil causes also higher recovery.

SIMULATION RESULTS AND DISCUSSION

For the simulation of the CO_2 experiment without initial CO_2 saturation, a radial grid system is created with 3 divisions along r and 3 layers along k- direction in CMG Builder. For the 2nd CO_2 Experiment, 3 divisions along r and 40 layers along k- direction is used.







Experiment-1 results follow a similar trend with model results of CMG GEM with diffusion, indicating that the dominant recovery mechanism is diffusion from the initial stages to the end of the production.

In Experiment-2, existence of free gas space promotes the entrance of gas from the fracture into the matrix. As a result, recovery from gas oil gravity drainage mechanisms become significant along with diffusion processes.

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