Fracture-Matrix Interaction during Polymer Flood

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ABSTRACT

Optimizing oil production from current resources is becoming the main strategy for many oil producing companies around the world. The applications of Enhanced Oil Recovery (EOR) techniques are encouraged by the current growing demand in producing from unconventional resources. Among EOR processes, polymer flooding which is an attractive option for many reservoirs. The objective of polymer flooding techniques is to control water mobility inside the reservoir to favor higher oil recovery. In this study, the polymer flood efficiency was evaluated in fractured system. The fluid flow interactions between the fractures and the matrix have a significant impact on displacement processes. This work focuses on multi-phase flow in the presence of a fracture tip. The impact of the fracture tip on polymer flow was studied. The fluid saturations and oil recovery information were evaluated to study the interaction of fracture-matrix environment with multi-phase flow. Polymer slug size, polymer concentration, and location of fracture tip were studies. They showed different impacts on polymer flooding performance. Fluid saturations around fracture tip were quantified with time. The diversion and convergence of polymer from and into the fracture were analyzed. Understanding the effect of these parameters on the stability and performance of polymer flood will help in designing the optimum scenario to maximize the oil recovery.

INTRODUCTION

Natural and artificially-induced fractures in a reservoir have a great impact on fluid flow patterns and on the ability to recover hydrocarbons. Fractures can have a negative effect on recovery process when they form bypass paths, especially in production-injection systems. For example, injected fluid may preferentially flow through the fractures leaving behind inaccessible and non-contacted hydrocarbons. It is important to understand the local and global effect of fractures on reservoir performance. In this paper, we are studying the effect of the presence of a fracture tip in a single fracture.

Hydrocarbon recovery depends on the interaction between fluids in the fractures and in the matrix. Polymer flooding is a chemical enhanced oil recovery (EOR) process which is used in many reservoirs to improve their productivity. In order to ensure favorable flood, polymers are used to reduce mobility ratio between water and oil and hence increase oil cut. The polymer increases the viscosity of the injected water and improves the mobility ratio, allowing for an increase in the vertical and areal sweep efficiency of the injected water and consequently, increases the oil recovery. Generally, there are two commonly used polymers in EOR applications which are the synthetic material, polyacrylamide in its partially hydrolyzed form (HPAM) and the biopolymer, xanthan [2]. Currently, HPAM is the favorably used polymer in the industry owing to its improved characteristics.

Polymer flooding has been used for more than 20 years with an ultimate recovery expectation of 50% and 10–15% incremental oil recovery over water flood. There are several examples for field implementations of polymer flood mentioned in the literatures. Morel et al. [3] presented a planning case study for a polymer flooding in a deep offshore oil reservoir in Angola. They illustrated the feasibility of polymer flooding in such environment given the challenging space allocation for offshore injection facilities. Furthermore, Alvarado and Thyne [4] constructed a fuzzy logic and data clustering algorithm to screen chemical enhanced oil recovery techniques in Wyoming based on results reported from field cases. They concluded that chemical flooding ranks high for some of the reservoir under investigation.

Liu et al. [5] conducted a simulation study for an oil reservoir in Daqing field in China indicating that polymer flood might reach an oil recovery factor of 61% OOIP. In another work, Fulin et al. [6] presented a case study for two pilot projects in Daqing oil field which indicates that an incremental oil recovery, over water flood, of 20-23% can be achieved for the first pilot and around 20% for the second pilot. Before implementing these pilots, the results from core flood experiments showed that an incremental recovery over water flooding of more than 20% OOIP can be achieved by early time injection of high molecular weight, high concentration polymer. Tielong et al. [7] investigated the feasibility of polymer flooding in a pilot test conducted in Shuanghe reservoir located in the southeast Henan oil field in China which is known as an elevated-temperature reservoir. At the end of the pilot, a total of 10% incremental oil recovery was achieved. They concluded that polymer with extra-high molecular weight can successfully control the mobility ratio and modify the permeability profile.

The objective of this work is to investigate the polymer flood performance in a single fractured system.

MOTIVATION

Alajmi et al. [8] studied experimentally and numerically the effect of fracture tip in a single fracture during a water flood to light oil. Figure 1 presents 24 X-ray CT images along a 2-feet Berea sandstone sample. It shows the injected fluid saturations for several stages during the flooding processes. These images present the net value of the injected fluid in the core. Each stage of injection was subtracted from the initial condition. Since the fracture had high permeability, it captured the early time, as shown by the first row of images at 0.051 pore volume injected (PVI). The fluid then was transported through the fracture to the downstream tip of the fracture. At the downstream tip, the injected fluid started to diverge out from the fracture to the matrix. When the water diverged, it formed a sharp front, which moved along the core until breakthrough.

The movement of the fluid front away from the fracture was not as fast as the movement in the fracture due to the high permeability of the fracture. These differences in velocity forced a by-passed middle regions around the fracture. At later time, as injection continued, most of the by-passed region was displaced.

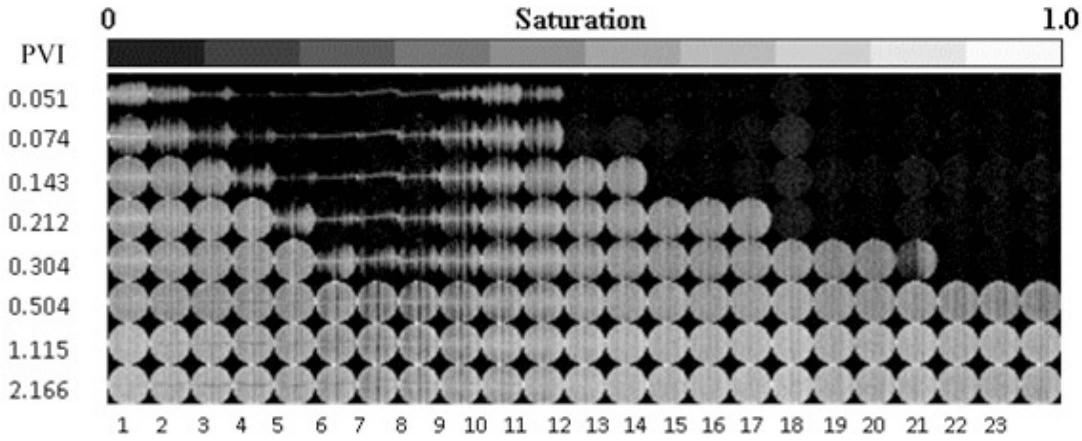

Figure 1: Injected Fluid Flow distribution.

The experimental work presented in Figure 1 was numerically simulated to understand the fracture tip effect on fluid flow. Figure 2 shows a simulated reconstruction of the net injected fluid at 0.304 pore volume injected (PVI). The injected fluid diverged from the fracture to the adjacent matrix due to the presence of the fracture tip. It shows the flow vectors direction of the fluid as the fracture is filled, the flow was then diverged to the adjacent matrix.

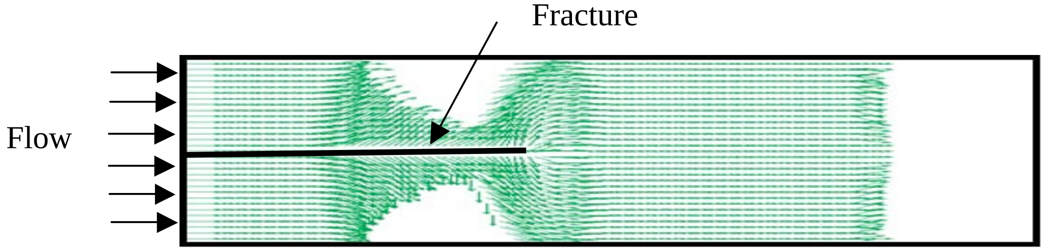

Figure 2: Flow vectors of the injected fluid.

The objectives of this paper are to investigate the efficiency of polymer flood in single fractured porous media and quantify the fracture-matrix interaction.

POLYMER FLOOD MODELLING

A numerical simulation was developed to achieve the objectives of this study. Two cases were studied, one without fracture tip (case A) and one with a fracture tip (case B).

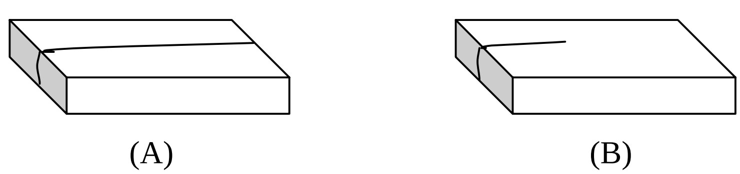

Figure 3: Schematic of the two cases.

The polymer concentration of 3000 ppm (equivalent to 10cp) was used to displace an oil with 60 cp viscosity. Water flood (1cp) was tested as a comparison to the polymer flood.

RESULTS AND DISSCUSION

Case A

In this case, the system is fully fractured with a single fracture. Two floods were preformed, water and polymer floods. Figure 4 shows the oil saturations after injecting 0.6 pore volume. The presence of the full fracture lowered the efficiencies of both floods leaving large undisplaced oil behind, which is expected. The fracture permeability is dependent of the formation stress. So average values of fracture and matrix permeabilities were selected. The fracture permeability was 10 Darcy and matrix permeability was 0.5 Darcy having a 20:1 contrast ratio.

The injected fluid moved inside the fracture much faster than in the matrix causing early breakthrough. Even though the polymer flood showed better performance and improved the mobility ratio, but still it left large oil volume behind.

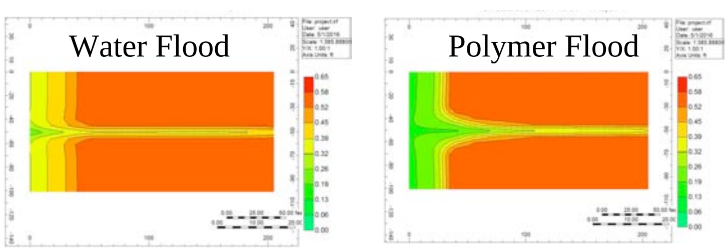

Figure 4: Oil Saturation maps for full fracture.

Case B

This case represents a system with a single fracture with a fracture tip as explained in the polymer flood modeling section.

Water Flood

Figure 5 shows the oil saturation maps during water flood. The presence of the fracture tip changed the saturation distribution compared to case A. More oil was displaced, but still the mobility ratio was not in a favorable condition. In the fracture region, the water advanced further in the matrix as the fracture was fully filled. Downstream of the fracture, since the viscosity ratio was high, the water movement was centered in the middle having difficulty to displace the oil on the sides.

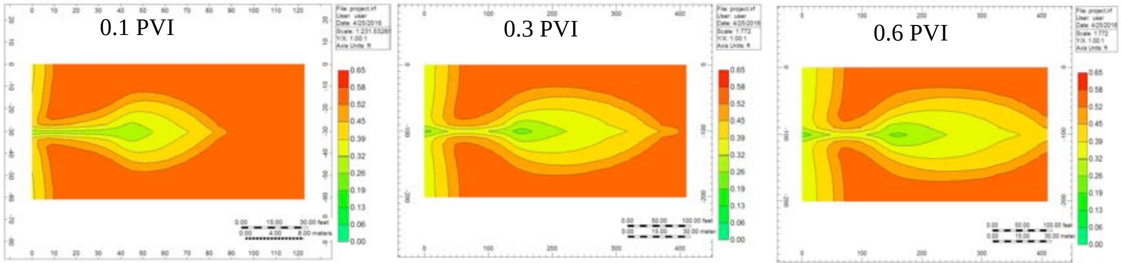

Figure 5: Oil Saturation maps during water flood.

Polymer Flood
Figure 6 shows the oil saturation maps during polymer flood. The injection of polymer improved the mobility ratio and resulted in better sweep efficiency. The same phenomena was seen as the fracture was first to be filled with the injected fluid. In the fracture region, the polymer advanced further in the matrix as the fracture was fully filled due to the improved injected fluid viscosity. Downstream of the fracture, the polymer movement was expanded across the system having a better displacing efficiency.

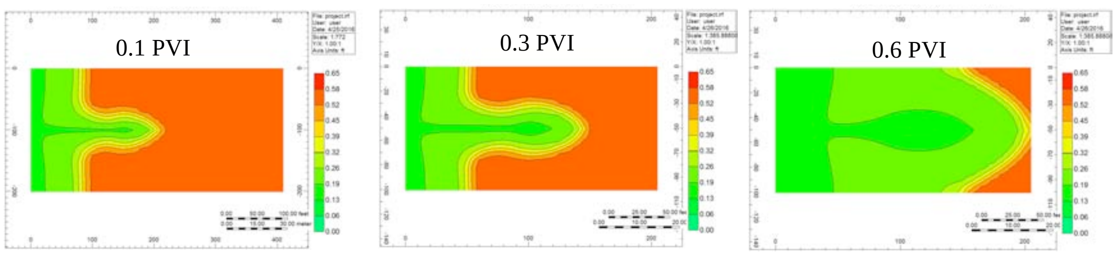

Figure 6: Oil Saturation maps during Polymer flood.

CONCLUSIONS
This study was aimed at investigating the fracture-matrix interaction assuming a permeability contrast ratio of 20:1. The performance of water and polymer floods in systems with single fracture (with and without fracture tip) were quantified. Numerical reservoir simulation was done to achieve the objectives of the study. Simulation runs were performed to determine the functional relationships between the displacement performance and fracture structure during both water flooding and polymer flooding. Results showed that the fracture structure had significant effects on the displacement performance. The displacement behavior of water flood and polymer floods can be either fracture-matrix-dominated or fracture-dominated by the presence of the fracture tip.
Results also indicated that the presence of the fracture tip allowed the polymer flood to retain it superiority and produce more oil downstream of the fracture.

ACKNOWLEDGMENT

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