

Experimental studying of pore morphology and wettability effects on microscopic and macroscopic displacement efficiency of polymer flooding

Hamid Emami Meybodi ^{a,b,*}, Riyaz Kharrat ^a, Majid Nasehi Araghi ^c

^a Petroleum University of Technology Research Center, Petroleum University of Technology, Shahid Ghasemzadian St., Sattarkhan Ave., Tehran, 1453953111, Iran

^b Department of Chemical and Petroleum Engineering, Schulich School of Engineering, University of Calgary, 2500 University Drive NW, Calgary, AB, Canada T2N 1N4

^c International Performance Assessment Centre for Geologic Storage of CO₂ (IPAC-CO₂), 120-2 Research Drive, Regina, Saskatchewan, Canada S4S 7H9

ARTICLE INFO

Article history:

Received 20 January 2010

Accepted 20 July 2011

Available online 29 July 2011

Keywords:

polymer flooding

wettability

pore morphology

microscopic and macroscopic displacement

ABSTRACT

Pore morphology and wettability of a porous medium have dominating effects on microscopic displacement efficiency, and consequently on the ultimate oil recovery. To provide a better understanding of the effects of these parameters on microscopic displacement mechanisms and macroscopic performance of a polymer flood process, a comprehensive experimental study was conducted using five two-dimensional glass micromodels. A combination of three wettability conditions and five different pore structures was used in this study. The selected scenarios include four homogeneous synthetic pore networks at water-, mixed- and oil-wet conditions. A random network that represents the pore space in Berea sandstone was also used for further investigation.

Image processing technique was applied to analyze and compare displacement mechanisms and displacement process efficiency in each experiment. Microscopic mechanisms, such as oil and polymer solution trapping, configuration of wetting and non-wetting phases, flow of continuous and discontinuous strings of polymer solution, polymer solution snap-off, distorted flow of polymer solution, emulsion formation, and microscopic pore-to-pore sweep of oil phase were observed and monitored in conducted experiments. Experimental results showed that water- and mixed-wet media generally have comparable and higher recoveries in contrast with oil-wet media. Moreover, the results confirmed a significant dependency on the pore structure and wettability of the media on both displacement mechanisms as well as oil recoveries. This experimental study illustrates the successful application of glass micromodel techniques for studying enhanced oil recovery (EOR) processes in a five-spot pattern, and also provides a useful reference for understanding the displacement mechanisms involved in a polymer flood process at different pore morphologies and wettabilities of porous media.

Crown Copyright © 2011 Published by Elsevier B.V. All rights reserved.

1. Introduction

Polymer flooding has been found to be an excellent candidate for enhancing oil recovery in heterogeneous oil reservoirs with high water cuts. However, a complete analysis need be conducted prior to implementing the polymer flooding. Studies by different researchers (Chauveteau and Kohler, 1974; Castagno et al., 1987; Sorbie et al., 1987; Shiya et al., 1998; Tong et al., 1998; Abou-kassem, 1999) have resulted in developing a set of criteria either for screening of oil reservoirs, or perceiving appropriate operational conditions for a successful polymer flood operation. Evaluating performance of a polymer flooding requires an understanding not only of the rheological behavior of a polymer solution, but also of its interaction

with porous medium. Reservoir wettability, as one of the factors, strongly affects the fractional flow and displacement efficiency of this EOR method. Another important factor that affects microscopic mechanisms of the displacement process is pore structure and geometry of the medium. Therefore, it is necessary to study the physical relationship between fluids and porous media for each displacement process separately. In addition, a fully developed understanding of the role of pore structure and geometry on the microscopic mechanisms of a desired displacement process, such as polymer flooding, would certainly pave the way for an efficient network modeling.

Prior to the 1950s, oil reservoirs were thought to be all water-wet. Later it was discovered that oil reservoirs can have wide range of wettabilities, i.e., water-, intermediate-, and oil-wet. However, most oil reservoirs have a non-uniform wettability named mixed-wet (Treiber et al., 1972). The evaluation of reservoir wettability and its effects on oil recovery have been investigated extensively since 1950s (Anderson, 1987; Cuiec and Anderson, 1990). During the late 1980s and early 1990s, numerous experimental studies examined the role

* Corresponding author at: Department of Chemical and Petroleum Engineering, Schulich School of Engineering, University of Calgary, 2500 University Drive NW, Calgary, AB, Canada T2N 1N4. Tel.: +1 403 869 6893.

E-mail address: [hemamime@ucalgary.ca](mailto:hmemamime@ucalgary.ca) (H. Emami Meybodi).

Nomenclature

E_A	areal sweep efficiency (%)
EOR	enhanced oil recovery
MW	mixed-wet
OOIP	original oil in place
OW	oil-wet
PV	pore volume (cm^3)
S_{oi}	initial oil saturation
S_{or}	remaining oil saturation
WW	water-wet

of wettability in various aspects of oil recovery in waterflooding (Anderson, 1986; Anderson, 1987; Yadav et al., 1987; Buckley and Morrow, 1990; Morrow, 1990; Yunan and Idris, 1990; Jia et al., 1991; Jadhunandan et al., 1995).

Numerous authors have identified the pore morphology as an important parameter affecting microscopic displacement and eventually oil recovery in an immiscible displacement process (Templeton and Rushing, 1956; Handy and Datta, 1966; Wardlaw, 1980; Wardlaw, 1982; Yadav et al., 1987; Dullien, 1992; Dixit et al., 1999; Blunt, 2001).

Broseta et al. (1995) conducted a series of polymer flood experiments in glass micromodels under various wettabilities and saturation conditions with the purpose of characterizing polymer adsorption on hydrophobic surfaces, and understanding the effects of residual oil upon polymer adsorption during the polymer EOR process. They showed that the presence of residual oil reduces the polymer adsorption/retention in an oil-wet porous medium, whereas the inverse trend was observed in a water-wet porous medium. Zaitoun and Chauveteau (1998) conducted a series of polymer flood experiments using granular packs and Berea sandstone cores with different permeabilities, and reported that heterogeneity in pore structure is unfavorable to the bridging adsorption process of macromolecules. Elmkies et al. (2001) performed several core flood experiments to investigate the effect of wettability on polymer adsorption and oil/water relative permeabilities. Their results indicated that polymer (polyacrylamide) adsorbs on the rock surface regardless of the rock's wetting condition. However, the adsorption of hydrophilic polymer in partially oil-wet cores seems to indicate that the polymer restores part of the initial rock water wettability. Liu et al. (2002) conducted several experiments on glass micromodel to compare oil displacement mechanisms of three EOR methods of polymer, alkali/surfactant/polymer, and foam of alkali/surfactant/polymer in micropores and dead-ends. They proposed that the foam of alkali/surfactant/polymer has a higher efficiency in displacing oil from pores and dead-ends compared to the polymer and the alkali/surfactant/polymer. In another experimental study, Dong et al. (2006) proposed that the polymer flooding is not sensitive to reservoir wettability. They used three core samples (Berea sandstone) with different wettabilities, i.e., water-, oil-, and neutral-wet. In their study, the core samples were water flooded first until 98% water cut was reached, then a slug of polymer (0.5 PV) followed by water was injected. Recently, Yadali Jamaloei and Kharrat (2009, 2010) investigated the wettability and morphology effects of porous media on microscopic and macroscopic behavior of polymer assisted dilute surfactant flooding using glass micromodels. Their results showed that the wettability and pore geometric properties in a porous medium greatly affect the instability of displacement front and the displacement mechanisms of microscopic two-phase flow. In the most recent research, Romero-Zerón et al. (2010) applied MRI technique to visualize the performance of polymer flooding and to quantify the in-situ fluid saturation distribution in rocks with different wettabilities. They showed that polymer flooding is significantly more efficient in the strongly water-wet conditions than preferentially oil-wet conditions.

In this paper, effect of pore morphology and wettability in polymer flooding has been examined by using five two-dimensional glass micromodels (one-quarter five-spot). Glass micromodels used in this work made it possible to study the effects of pore morphology and wettability on microscopic mechanisms as well as macroscopic behavior of the polymer flooding. The micromodel is a transparent artificial model of porous medium that can be used to simulate transport processes at the pore scale and also is a powerful tool to efficiently restore different wettability states for a porous medium. According to the literature, most of the micromodel studies have been focused on qualitative investigations of phase displacements behavior, and only a few works used micromodels for both qualitative observations and quantitative measurements (Wardlaw, 1980; Dawe and Zhang, 1994; Larsen et al., 2000).

2. Experimental section

2.1. Apparatus

The micromodel setup was composed of four parts including cleaning system, fluid injection section, optical system, and micromodel holder. Fig. 1 shows a schematic diagram of the experimental setup. Cleaning was accomplished by flushing solvent through micromodel using an Eldex pump. This pump was connected to four containers that contained cleaning fluids (i.e., distilled water, methylene chloride, acetone, and toluene). A precise pressure transducer and a high-accuracy low-flow-rate Quizix pump were used to control the injection flowrate of fluids. The Quizix pump was able to inject at rates varying from 10^{-5} to $10 \text{ cm}^3 \text{ min}^{-1}$.

In this study, the visual data acquisition was achieved by using high-resolution optical equipment for image capturing and analysis. A computer-controlled linear drive system was used which allowed a magnifying video camera to be positioned automatically at any part of the micromodel and sequentially or continuously record the phase displacements occurring within the micromodel. The camera was capable of working at a magnification up to 200 times. While running the experiments, in addition to continuous video recording, pictures of micromodel were digitally captured and recorded by a computer. The pictures were later used for image analysis and saturation measurement purposes. To analyze the experiments' results, it was necessary to measure fluid saturation variations within a micromodel. Sigma Scan® Pro 5.0 image analysis software and statistical analyses were used to obtain detailed characterization of porous medium and measurement of the fluid saturations from the micromodel microshots. Sigma Scan is capable of counting the number of pixels

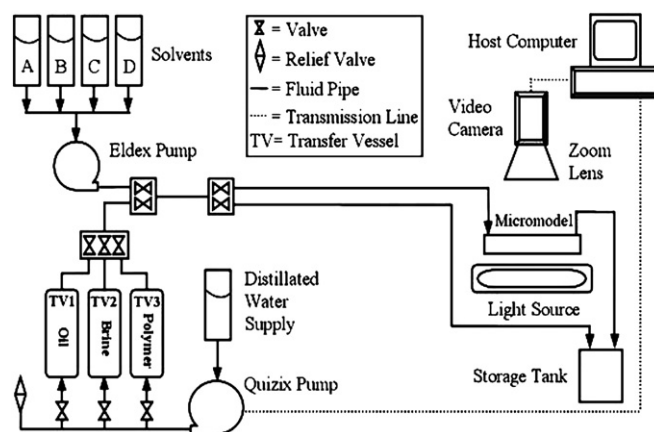


Fig. 1. Schematic of micromodel set-up (Emami Meybodi et al., 2008).

Download English Version:

<https://daneshyari.com/en/article/1755636>

Download Persian Version:

<https://daneshyari.com/article/1755636>

[Daneshyari.com](https://daneshyari.com)