



Rate-dependent polymer adsorption in porous media



P.E.G. Idahosa*, G.F. Oluyemi, M.B. Oyenehin, R. Prabhu

School of Engineering, Robert Gordon University, Riverside East, Garthdee Road, Aberdeen AB10 7GJ, United Kingdom

ARTICLE INFO

Article history:

Received 14 July 2015

Received in revised form

28 January 2016

Accepted 22 February 2016

Available online 23 February 2016

Keywords:

Polymer adsorption

Core flooding

Enhanced oil recovery

Porous media

Flow rate

ABSTRACT

Laboratory core flood experiments were conducted at different flow rates with partially hydrolysed polyacrylamide (HPAM) oilfield Enhanced Oil Recovery (EOR) polymer and silica sand to investigate the polymer retention in porous media due to flow rate variation. Specifically, the double-polymer bank method was used in a new way to quantify and understand total incremental retention (both reversible and irreversible) induced by flow rate variation for HPAM polymers. Experimental results indicate that adsorption was the dominant retention mechanism. Further, the results obtained show that polymer adsorption was rate-dependent (i.e., as flow rate increased, adsorption increased), and that the adsorption was largely reversible with minimal incremental irreversible adsorption. It was also observed that flow rate impacted polymer inaccessible pore volume (IAPV) decreasing from 32% to 15% as flow rate increased from 0.8 ml/min to 6.0 ml/min. Finally, results from the study also give better insight into understanding HPAM flow-induced adsorption and their effect on permeability reduction processes.

© 2016 Elsevier B.V. All rights reserved.

1. Introduction

Polymer flooding has been widely used as an attractive alternative to conventional water flooding in Enhanced oil Recovery (EOR) and in oilfield water and gas shut-off. The main objectives being to increase the oil recovery factor by decreasing the mobility between the displacement (water) and displaced (oil) fluids (Lake et al., 2014). However, Polymer retention and inaccessible pore volume (IAPV) are the two components that govern polymer propagation through porous media in the dynamic mode. It is also widely recognised that when polymer solutions interact with a solid surface, the polymer molecules may be retained on the solid surface by both the physical forces of van der Waal's and hydrogen bonding forces (Dang et al., 2014). Retention refers to all mechanisms that remove polymer from the transported aqueous phase. These include: adsorption, mechanical entrapment (Yerramilli et al., 2013) and hydrodynamic (or rate) retentions (Chauveteau et al., 2002). However, a survey of the literature reveals that only a few studies have investigated the variation of polymer retention with flow rates (Maerker, 1973; Dominguez and Willhite, 1977; Huh et al., 1990; Aubert and Tirrell, 1980; Chauveteau et al., 2002). For example, using 100 to 300 mD Berea cores at residual oil saturation, Huh et al. (1990) showed that xanthan retention was only about 6% greater at 1 ft/d than at 0.333 ft/d. Using different xanthan solution in similar cores in a

separate experiment, the same authors observed that the retained polymer was 40% more at 5 ft/d than at 1 ft/d. In a similar manner, Maerker (1973) showed some evidence of xanthan retention in a 121 md Berea core as the fluid velocity was increased and proposed that the higher pressure gradient resulting from the increased fluid velocity caused the deformation of the xanthan molecules which got trapped within the core in relatively smaller pores. Maerker further argued that as flow reduced, the molecules relaxed to a random coil and then diffused to larger pore channels, causing temporary increase in polymer concentration until the excess polymer was flushed from the core. Using Pusher 700 and 86-mD core made of compacted Teflon powders, Dominguez and Willhite (1977) showed that flow rate affects polymer retention and that nearly all retention could be attributed to mechanical entrapment because of the low polymer adsorption on the Teflon surface. These reversible occurrences have been described as hydrodynamic retention. However, most of these previous works used xanthan gum in their studies. The permeability reduction factor is not significant for many polymers such as xanthan gum or when the formation permeability is very high (Lake et al., 2014). The above literature survey shows that these previous works have not generally explored the correlation between the magnitude of polymer retention and flow rate; and specifically therefore, the effect of flow rate on HPAM polymer retention have not been fully quantified. In this paper, the focus is on single phase linear polymer core displacement experiments using HPAM polymers with natural sand pack; and the data generated were analysed by a special method to quantify the effect of flow rate on HPAM

* Corresponding author.

E-mail address: p.e.g.idahosa@rgu.ac.uk (P.E.G. Idahosa).

polymer adsorption and their impact on permeability reduction. The method also enables the differentiation of total incremental polymer retention in terms of “reversible” and “irreversible” adsorption induced by flow rate variation.

2. Experimental implementation

2.1. Materials and methods

Fig. 1 shows a simplified schematic of the core flood experimental rig setup in which the important and required key equipment are indicated. In the dynamic flow system, lines and valves are set up to minimise dead volumes in which fluids can be lost. The coreflood rig setup for the polymer flooding experiments consisted of a stainless steel radial core or sandpack holder designed in-house to simulate reservoir radial flow. However, the sandpack core holder was operated as a linear flow model during the core flooding with inlet from top and outlet from bottom. In Fig. 1, a high performance syringe pump (model HPLC 1500) was used to deliver a varying, pre-defined fluid volume at constant injection or flow rate across the core sample. The pump (which has a maximum pressure of 6000 psi and can deliver to 12.00 ml/min) was used to provide a non-pulsating flow during the experiment. All in-place pressure monitoring and measurements were electronic and digitised with the aid of a high-speed National Instruments data acquisition system (NIDAQ) through Validyne pressure transducers of varying capacities mounted across the core and a personal computer. Low (0–12.5 psi) and high (0–320 psi) capacity transducers were chosen according to the pressure range and the requirements of the measurement resolution. A Validyne carrier demodulator model CD223 (manufactured by Validyne Engineering, USA) was used to provide the correct sensor excitation and demodulate the returned Alternating Current (AC) signal from the sensors into a ± 10 Vdc signal appropriate for

the data acquisition input. The CD223 accepts two transducer inputs but the display and signal follow a front panel switch so that the readings from only one sensor at a time are displayed. As the analog output follows the display, it was not possible to record both transducer readings simultaneously. Furthermore, an absolute pressure gauge (0–360 psi) was mounted at the pump outlet in order to monitor inlet pressure and avoid over-pressuring the flow system.

2.1.1. Porous media description

Commercial grade silica sand (20/40 mesh size) was used to make the sand pack in the experiments. Their interactions with polymer molecules in solutions as well as with salts are quite comparable to those of natural sands (Zitha et al., 1995). Also, the possibility of hydrogen bond formation with silica has been proposed to explain the high affinity of polymers for many reservoir rocks (Pefferkorn et al., 1985). Fig. 2 and Table 1 show the results of the analysis of the grain size distributions of the sand done by direct sieving of the sample. Optical microscopy (using Leica DFC420 Digital Microsystems) was used to capture high-resolution images of the silica sands for shape identification. The sand was observed to be spherical in shape as shown in Fig. 3. The geometry of this type of shape enables its porosity to be calculated.

The sand was dry-packed in radial core holder with length of 2.28 cm, internal diameter of 4.40 cm, cross-sectional area of 15.21 cm², and internal volume of 34.67 cm³. The sand material loaded into the holder was weighed and recorded. The volume of the sand material was determined accurately from knowledge of the grain density. The pore volume of the porous media was then calculated using the direct method (i.e. by subtracting the volume of the sand material in the holder from the bulk volume). The porosity was thereafter determined from the pore volume and bulk volume data. After the sample's pore volume and porosity measurements, the brine absolute permeability was experimentally determined for the porous media. In computing absolute

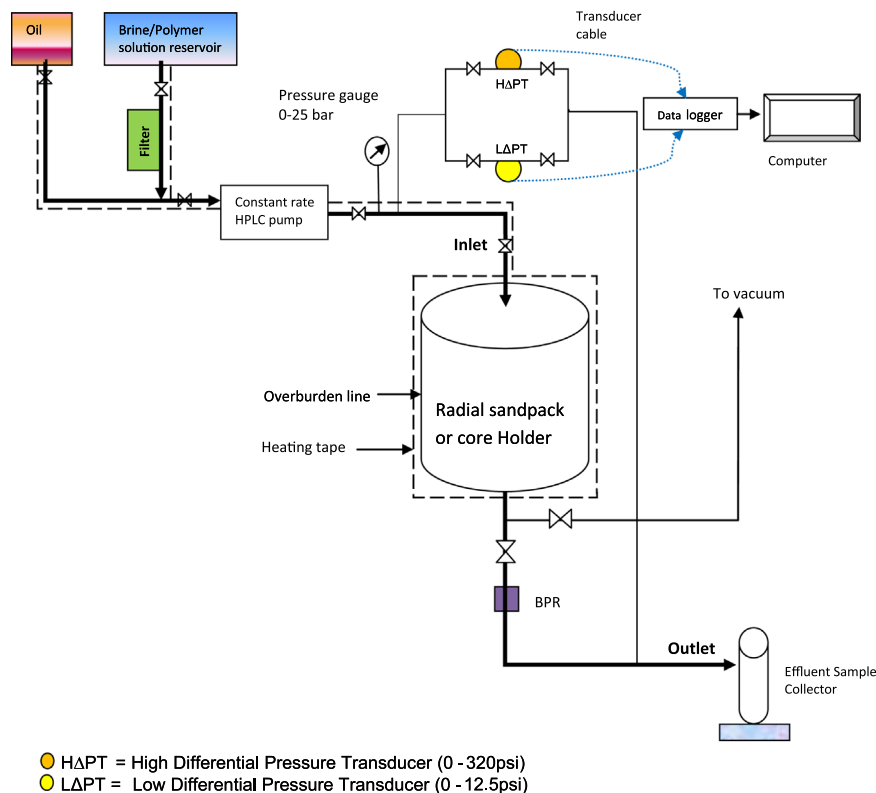


Fig. 1. Schematic of experimental setup for the implementation of the dynamic polymer coreflood.

Download English Version:

<https://daneshyari.com/en/article/1754569>

Download Persian Version:

<https://daneshyari.com/article/1754569>

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