Impact of flood rate, salinity, and wettability on waterflood oil recovery using lab-on-a-chip methods

Abstract

Wettability, pore geometry, oil viscosity, and water salinity are among the factors with dominating effects on microscopic waterflood efficiency, and consequently on the ultimate oil recovery [1, 2, 3]. Optimal oil recovery requires a great understanding of the nature and manipulation of these factors. Most early and more recent studies on the effects of these factors on waterflood oil recovery have not reached a consensus yet [4, 5]. To gain a better understanding of the effects of these factors on the microscopic performance of a waterflood process, experimental studies were conducted using lab-on-a-chip methods. The selected conditions for displacement efficiency comparisons include: mixed-wet and water-wet conditions, high and low viscous oils, three different waterflood rates (0.05 μL/s, 0.1 μL/s, and 0.15 μL/s), and two different flood water types (sea water and distilled water). Two grain minerals were used in the experiments (calcite and quartz grains) though the effect of different grain minerals on waterflood oil recovery was not considered in this study.

Image processing technique was applied to analyse and compare the displacement efficiency in each experiment using an automated code developed with matlab. Experimental results showed that mixed-wet media, faster flood rate, low salinity flood water, and low viscous oil are favourable to waterflood oil recovery. This laboratory study illustrates that a microfluidic chip can be successfully used for enhanced oil recovery (EOR) studies.

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Chapter 1

Introduction

1.1 Introduction

The ever rising increase in the world energy demand coupled with rapid industrialization has led to the need for the production of increasing volume of crude oil while keeping the cost of doing this as low as possible [4]. Obviously, the fraction of crude oil recovered is often dependent on both the reservoir conditions and production techniques applied. Following primary depletion of reservoirs, the recovery of additional oil is only feasible by the application of external energy [5], a process referred to as enhanced oil recovery. Sequel to this, the oil industry has developed various oil recovery techniques, some targeted at reducing the interfacial tension between fluids, some at increasing the sweep efficiencies while others at reducing the viscosity of the crude oil to enhance flow. However, some of these techniques are cost ineffective due to the nature and volume of the fluids used [6] and as a result of this; optimal and economically viable techniques have been under research and development by the oil industry. The development of these viable recovery techniques have been driven mainly by the fact that over 60% of the oil in place is not recovered after primary recovery due to the impact of several factors which include: reservoir wettability states, fluid properties, pore structure and geometry of the medium. Optimal oil recovery requires a great understanding of the nature and manipulation of these factors [4, 5].

Among these identified factors, wettability seems to have the strongest impact on oil recovery and pore displacement mechanism [7, 8, 9, 10, 11]. Its significance when used as a parameter in designing linear mathematical models for predicting recovery efficiency is equal to that of viscosity and permeability [8]. For an accurate prediction of oil recovery processes, an accurate evaluation of the reservoir rock wettability is highly needed. Pore structure plays a relatively minor role in the generic behaviour though it does influence both the initial saturation for maximum recovery and magnitude of the recovery [12, 11]. To gain a fundamental understanding of two phase flow ranging from oil migration from rocks, primary and enhanced recovery processes, good information about the wetting state of the reservoir, pore geometry and fluid properties is required [4, 13, 14, 15, 16, 17, 18, 19].

This project reviews the impact of wettability on waterflood oil recovery and also investigates the effects of flood water salinity, crude oil type and more importantly waterflood flow rates on waterflood oil recovery through laboratory studies. Instead of real rock, packed beds of calcite and quartz grains created within a microfluidic chip will be used. An automated code for extracting (a) oil distribution as a function of streamwise distance and time, and (b) the fractional flow at the downstream end of the packed bed as a function of time, will be developed with matlab for the videos from the waterflood experiments.

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contact@cleanscriptgroup.com
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