ENHANCED OIL RECOVERY BY SMART WATER INJECTION IN SANDSTONE RESERVOIRS (MALAYSIAN CRUDE OIL)

AHMED SAAD FARAJ AL-DULAIMI

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Faculty of Chemical and Energy Engineering

Universiti Teknologi Malaysia

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ABSTRACT

Recently, the scale of studies on smart water – one of EOR method - has increased. From decades, water flooding is one of the most used methods to increase oil recovery. However, more effective in sandstone reservoirs is injecting low salinity brine. Due to changing wettability, improved oil mobility in pores can be reached. The studies show, that the significant increase of oil recovery might be achieved.

Main objective of the project is to answer the question: Can "smart water" be used to enhance oil recovery in Malaysian sandstone reservoirs. Laboratory experiments and field tests show that it can enhance the oil recovery over conventional higher salinity water flooding. Until now, the mechanism behind low salinity water flooding is under consideration for further discussions, but it is generally accepted that low salinity water flooding improves microscopic sweep efficiency by modifying rock wettability. For low salinity condition, it has been suggested that desorption of polar oil components as result of pH increase makes the rock more water-wet.

In this project, three core flood experiments will be performed to determine the effect of different water salinities on the oil recovery. Two homogeneous reservoir cores which contain active clays with crude oil which has enough polar organic compounds will be used during the experiments. All experiments were conducted at reservoir temperature, around 100°C. Core flood effluents will be sampled regularly to investigate crude oil-brine-rock interactions by measuring pH, density, and different ions concentration of produced water. Comparison between the results of the three types of water and its effect on the recovery factor will be conducted.

ABSTRAK

Kebelakangan ini, skala kajian mengenai smart air – satu kaedah EOR - telah meningkat. Dari dekad, air banjir adalah salah satu kaedah Tempahan digunakan untuk meningkatkan pemulihan minyak. Walau bagaimanapun, lebih efektif dalam takungan batu pasir yang menyuntik rendah kemasinan air garam. Kerana perubahan wettability, minyak peningkatan mobiliti dalam liang-liang boleh dicapai. Kajian menunjukkan, bahawa peningkatan ketara minyak pemulihan mungkin boleh dicapai.

Objektif utama projek ini adalah untuk menjawab soalan: boleh "air pintar" boleh digunakan untuk meningkatkan pemulihan minyak dalam takungan batu-pasir Malaysia. Ujikaji Makmal dan medan ujian menunjukkan bahawa ia boleh meningkatkan pemulihan minyak yang lebih konvensional lebih tinggi kemasinan air banjir. Sehingga kini, mekanisme di sebalik rendah kemasinan air banjir adalah di bawah pertimbangan untuk perbincangan lanjut, tetapi ia umumnya diterima bahawa rendah kemasinan air banjir memperbaiki kecekapan mikroskopik sapu dengan mengubah suai rock wettability. Bagi keadaan kemasinan yang rendah, ia telah disarankan yang desorption minyak kutub komponen akibat membuat peningkatan pH batu lebih air basah.

Dalam projek ini, tiga teras banjir ujikaji akan dilakukan untuk menentukan kesan salinities air yang berbeza pada pemulihan minyak. Dua teras homogen takungan yang mengandungi clays aktif dengan minyak mentah yang mempunyai sebatian organik cukup kutub akan digunakan semasa eksperimen. Semua ujikaji telah dijalankan pada suhu takungan, kira-kira 100° C. Sisa banjir teras akan dirasa dengan kerap untuk menyiasat interaksi minyak mentah-air garam-rock dengan menyukat pH, kepadatan dan kepekatan iaitu ion berbeza air dihasilkan. Perbandingan antara keputusan tiga jenis air dan kesan pada faktor pemulihan yang akan dijalankan.

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LIST OF SYMBOLS

AN	**acid number**
BN	**base number**
CEC	**cation exchange capacity**
EV	**macroscopic displacement efficiency**
EDL	**electrical double layer**
EOR	**enhanced oil recovery**
FW	**formation water**
Φ	**total porosity**
HS	**high salinity**
IFT	**interfacial tension**
IOR	**improved oil recovery**
θ	**contact angle**
k	**permeability**
kro	**relative oil permeability**
krw	**relative water permeability**
μo	**dynamic oil viscosity**
μw	**dynamic water viscosity**
LS	**low salinity**
MIE	**multi-component ionic exchange**
NCS	**Norwegian Continental Shelf**
OOIP	**original oil in-place**
PLT	**production log tool**
PNC	**pulsed neutron capture log**
PV	**pore volume IX**
RF	**recovery factor**

LIST OF SYMBOLS

σ	**interfacial tension**
σos	**interfacial tension between oil and solid**
σws	**interfacial tension between water and solid**
σow	**interfacial tension between oil and water**
Siw	**immobile (interstitial) water saturation**
Soi	**initial oil saturation**
Sor	**residual oil saturation**
SWCT	**single well chemical tracer**
TDS	**total dissolved salt**
WAG	**water alternating gas injection**

CHAPTER 1

1.1 Introduction

The majority of the world oil production arises from developed fields, and therefore expanding oil recovery becomes critical. This situation agrees with the growth of world energy demand up to 37% for two decades later. Along these lines, it becomes crucial to increase recovery factor from developed fields as well as for new fields through secondary and tertiary production phase to defeat the energy needs in the future.

Water flooding as the most common secondary recovery method are usually used for pressure maintenance and physically sweep oil in the reservoir. In the conventional water flooding the injected water may be taken from the nearest sources: produced formation water or sea water. From a conventional point of view, the injection brine composition and ions were believed to have no effect on the recovery efficiency during water flooding process. Never the less, over the last decade, several laboratory studies and field tests have shown low salinity/smart water flooding improved oil recovery compare to high salinity water flooding for sandstone reservoir. This technique is applied by injecting water at significantly lower salinity compared to salinity of formation water.

till now, the mechanisms behind low salinity water flooding is under consideration for further discussions, but it is generally accepted that the purpose of low salinity water flooding is to improve microscopic sweep efficiency by modifying rock wettability. For low salinity condition, Austad et.al suggest that desorption of polar oil components by pH increase makes the rock more water-wet. Therefore, it can affect the oil recovery which depends on polar components in the crude oil, divalent cations in the formation brine, and active clays in the sandstone. It is important to conduct further research about low salinity water as an affordable EOR method. In addition, low salinity brine does not need hazardous chemical; its result is an environmentally friendly EOR. This method can be applied for current or planned water flooding projects, both offshore and onshore field location. Problems associated

with conventional water flooding, such as scale formation, souring, and filtration at the ion levels can be mitigated with low salinity water flooding method.

1.2 Problem statement:

there are many exploited oil field. these oil field are producing hydrocarbons for many years and as studies showed that these oil field will reach the abandonment situation in the next few years, as the opportunities to discover new hydrocarbon sites is decreasing, so it has been important to find new ways to exploit the existent fields to the maximum extent.

Now there are many ways to do that and one of the most effective ways is smart water injection or (water flooding). this method is used worldwide to produce as much as (oil and gas) possible from reservoirs. Smart Water injection is convenient and commercial way to enhance oil recovery. Smart water can adjusting/optimizing the ion composition of the injected fluid in such a way that the equilibrium of the initial system will modify the initial wetting conditions. Therefore, the oil is more easily displaced from the porous network. injection of "Smart Water" can be characterized as tertiary oil recovery method since extra oil was recovered after performing a secondary water flood with formation water. The physical principle for enhanced oil recovery by "Smart Water" is a change in wetting properties of the system, which has a positive effect on the capillary pressure and relative permeability of oil and water regarding oil recovery. The technique is cheap, environmentally friendly, no expensive chemicals are added, and no injection problems etc. From an economical point of view, the smart water should be injected from the start of the water flooding process. The validation of "Smart Water" as an EOR-fluid has been verified both in the laboratory and in the field by several research groups and oil companies during the last 20 years. Extensive research has been performed to understand the chemical/physical mechanism for the wetability alteration process taking place at the rock surface, and the mechanism is still under debate in the published literature. This study will focus on recovery factor that would be achieved by using smart water on sandstone rocks samples by using Malaysian crude oil cause this technique has never been tried on a Malaysian oil field environment laboratory experiments was done to investigate the effect of smart water injection on Malaysian oil field samples.

1.3 Thesis Objective

The main objectives of this thesis are:

1. To compare smart water flooding performance in a high temperature sandstone reservoir, by using modified sea water, and modified low salinity water which both have salinity lower than formation water. The low salinity water flooding process will be performed in secondary and tertiary injection mode.
2. What is the recovery factor after using smart water injection, modified sea water, and modified low salinity water.

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