BIOBASED POLYMER AND SURFACTANT FOR ENHANCED RECOVERY OF HEAVY OIL

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ABSTRACT

Rising energy demand, coupled with a decline in conventional oil reserves, has led to increase interest in heavy oil recovery in recent years. Chemical enhanced oil recovery methods have become an efficient and economical option for heavy oil reservoirs where thermal methods cannot be applied like in thin deep reservoirs. The purpose of this study is laboratory scale investigation of new environmentally friendly biopolymer and biosurfactant for heavy oil recovery application. The biopolymer and biosurfactant were Guar gum and Coco glycoside, respectively. To determine the optimum concentration of biopolymer and surfactant system for tertiary flooding application, rheological characterization study was conducted using Brookfield RST Rheometer and interfacial tension studies was carried out by using Kruse force Tensiometer at room temperature (25°C). The performance of these optimum formulations was determined by conducting four different injection schemes heavy oil displacement tests in artificial glass bead (125 µm to 850 µm) flooding models saturated with engine as the heavy oil phase and brine (30,000 ppm) representation formation water. The injection schemes for flooding tests were single polymer, single surfactant, sequential polymer - surfactant and polymer surfactant combine slug at optimum formulation concentration. Findings of the characterization tests shown that that the optimum concentration of biopolymer and biosurfactant were 6000 ppm concentration and minimum 1.7mN/M interfacial tension at 920 ppm concentration, respectively. Experimental Results also shown that salinity has no impact upon biopolymer shear viscosity while it improves interfacial activity of biosurfactant. Oil displacement tests shown that combine polymer –surfactant slug give high incremental oil recovery (27.8 % IOIP) compared to polymer injection scheme (21.5% IOIP), polymer -surfactant sequential injection scheme (18.4% IOIP) and surfactant injection scheme (9.2% IOIP) that indicated their good synergy in compound flooding after water flooding. Based upon flooding experiments findings it was revealed that main mechanism for increasing incremental oil recovery factor is mobility ratio improvement of displacing fluid compared to IFT reduction. The polymer and surfactant used in this study are natural plant derived materials and show great potential for use in future heavy oil enhanced oil recovery operations.

ABSTRAK

Permintaan tenaga yang meningkat, ditambah dengan penurunan cadangan minyak konvensional, telah mendorong peningkatan minat dalam pemulihan minyak berat dalam beberapa tahun terakhir. Kaedah pemulihan minyak yang ditingkatkan secara kimia telah menjadi pilihan yang cekap dan ekonomik untuk takungan minyak berat di mana kaedah termal tidak dapat diterapkan seperti di takungan dalam yang tipis. Tujuan kajian ini adalah penyiasatan skala makmal mengenai biopolimer dan biosurfaktan baru yang mesra alam untuk aplikasi pemulihan minyak berat. Biopolimer dan biosurfaktan masing-masing adalah Guar gum dan Coco glycoside. Untuk menentukan kepekatan optimum sistem biopolimer dan surfaktan untuk aplikasi banjir tersier, kajian pencirian reologi dilakukan menggunakan Brookfield RST Rheometer dan kajian ketegangan antara muka dilakukan dengan menggunakan Kruse force Tensiometer pada suhu bilik (25°C). Prestasi formulasi optimum ini ditentukan dengan melakukan empat skema suntikan yang berbeza ujian anjakan minyak berat dalam manik kaca buatan (125 µm hingga 850 µm) model tepu dengan mesin sebagai fasa minyak berat dan air garam perwakilan (30,000 ppm). Skema suntikan untuk ujian banjir adalah polimer tunggal, surfaktan tunggal, polimer berurutan - surfaktan dan surfaktan polimer menggabungkan slug pada kepekatan formulasi optimum. Hasil ujian pencirian menunjukkan bahawa kepekatan optimum biopolimer dan biosurfaktan adalah kepekatan 6000 ppm dan ketegangan antara muka minimum 1.7mN / M pada kepekatan 920 ppm. Hasil Eksperimen juga menunjukkan bahawa kemasinan tidak mempengaruhi kelikatan ricih biopolimer sementara meningkatkan aktiviti antara biosurfaktan. Ujian anjakan minyak menunjukkan bahawa penggabungan polimer-surfaktan memberikan pemulihan minyak yang tinggi (27.8% IOIP) berbanding dengan skim suntikan polimer (21.5% IOIP), skema suntikan berurutan polimer-surffaktan (18.4% IOIP) dan skema suntikan surfaktan (9.2% IOIP)) yang menunjukkan sinergi mereka yang baik dalam banjir kompaun setelah banjir. Berdasarkan penemuan eksperimen banjir, terungkap bahawa mekanisme utama untuk meningkatkan faktor pemulihan minyak tambahan adalah peningkatan nisbah mobiliti pengalihan cecair dibandingkan dengan pengurangan IFT. Polimer dan surfaktan yang digunakan dalam kajian ini adalah bahan yang berasal dari tumbuhan semula jadi dan menunjukkan potensi besar untuk digunakan dalam operasi pemulihan minyak yang ditingkatkan dengan minyak masa depan

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LIST OF ABBREVIATIONS

APG	-	Alkyl poly glucoside
API	-	American petroleum institute
CMC	-	Critical Micelle Concentration
CHOPS	-	Cold Production of Heavy Oil Using Sand
CSS	-	Cyclic Steam Stimulation
EOR	-	Enhanced Oil Recovery
OOIP	-	Original Oil in Place
GG	-	Guar gum
HPAM	-	Hydrolysed polyacrylamide
PHPA	-	Hydrolysed polyacrylamides
PHPC	-	Partially hydrolysed polysaccharides
ISC	-	In-Situ Combustion
IFT	-	Interfacial Tension
MMP	-	Minimum Miscible Pressure
NaCl	-	Sodium Chloride
SAGD	-	Steam Assisted Gravity Drainage
WAG	-	Water alternating gas
WOR	-	Water oil ratio
VAPEX	-	Vapor Extraction

LIST OF SYMBOLS

Nc	-	Capillary Number
K_{rw}	-	Relative permeability to water
K_{ro}	-	Relative permeability to oil
μo	-	Oil viscosity
μw	-	Water viscosity
λo	-	Oil mobility
λw	-	Water mobility
μ	-	Fluid viscosity
V	-	Fluid Velocity
M	-	Mobility ratio

CHAPTER 1

Introduction

1.1 Background study

Rising energy demands, coupled with a decline in conventional oil reserves, has led to increased interest in heavy oil recovery in recent years. The size of these heavy oil deposits is immense, and these are likely one of the main future energy sources in the years to come. The world's proven reserves for non-conventional oil are approximately 8 trillion barrels, approximately 3 times larger than the world's reserves of conventional oil (Dusseault, 2006). As techniques in heavy oil recovery improve over time, the world's proven reserves for non-conventional oil are expected to increase as well Unfortunately, the oil in these reservoirs is highly viscous, and cannot easily flow to production wells under normal reservoir conditions. Understanding the mechanisms by which heavy oil can be displaced in reservoirs is crucial to the successful recovery of this resource base.

Heavy oil can be defined as a class of oils with viscosity ranging from 50 mPa·s (cP) up to around 50,000 mPa·s. The viscosity of heavy oils highly depends on temperature, a slight increase in temperature results in a sharp decrease in oil viscosity. popular thermal recovery methods for the development of heavy oil reservoirs are shown in Figure 1. The main mechanisms behind these heavy oil recovery methods are decreasing oil viscosity and increasing oil mobility. This oil has limited mobility under reservoir temperature and pressure, and Darcy's Law predicts that the oil can flow slowly under high-applied pressure gradients. However, it has been observed that in these reservoirs, solution gas drive leads to significantly higher rates and recoveries than what was expected by conventional understanding of gas-oil relative permeability.(Tackie-Otoo et al., 2020)

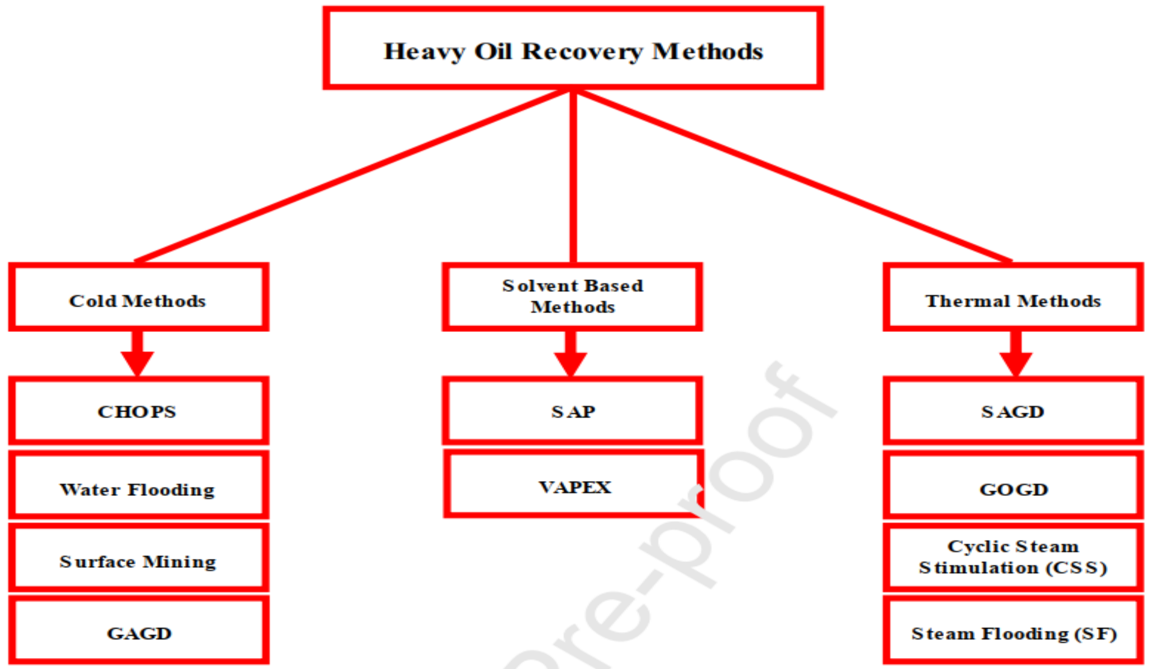

Figure 1.1 Heavy oil recovery methods

There exist several criteria for classifying a crude oil (Miller, 1994), which are mainly based on its density or viscosity under reservoir conditions. In general, a crude oil with viscosity in the range of 100 to 10,000 mPa·s under the actual reservoir condition is considered as heavy oil, whereas a crude oil with a viscosity of higher than 10,000 mPa·s under the actual reservoir conditions is regarded as extra heavy oil (Miller, 1994; Strausz, 1989; Clark, 2007). Bitumen is more solid-like in nature and has a viscosity of higher than 10,000 mPa·s and up to 10,000,000 mPa·s (Mehrotra and Svrcek, 1984; Clark, 2007).

The world's original-oil-in-place (OOIP) of heavy oil and bitumen was estimated to be 6.0 trillion barrels (Jiang, 1997), most of which are located in Venezuela and Canada (Tam, 2007). The estimated OOIP of heavy oil and bitumen in Canada is 2.5 trillion barrels, which is twice of the total conventional reserves in the Middle East (Jiang, 2007; Dusseault, 2001; Farouq Ali, 2003; Sadler and Davis, 2005). The Canadian heavy oil deposits are mainly located in east-central Alberta and extended into western

Saskatchewan (Petroleum Communication Foundation, 2000). Effective and economical recovery of such heavy oil deposits has gained considerable attention due to an increase in demand for hydrocarbon fuels and a decline in production from the conventional light and medium oil resources. world conventional and unconventional heavy oil distribution by region is depicted in bar chart as:

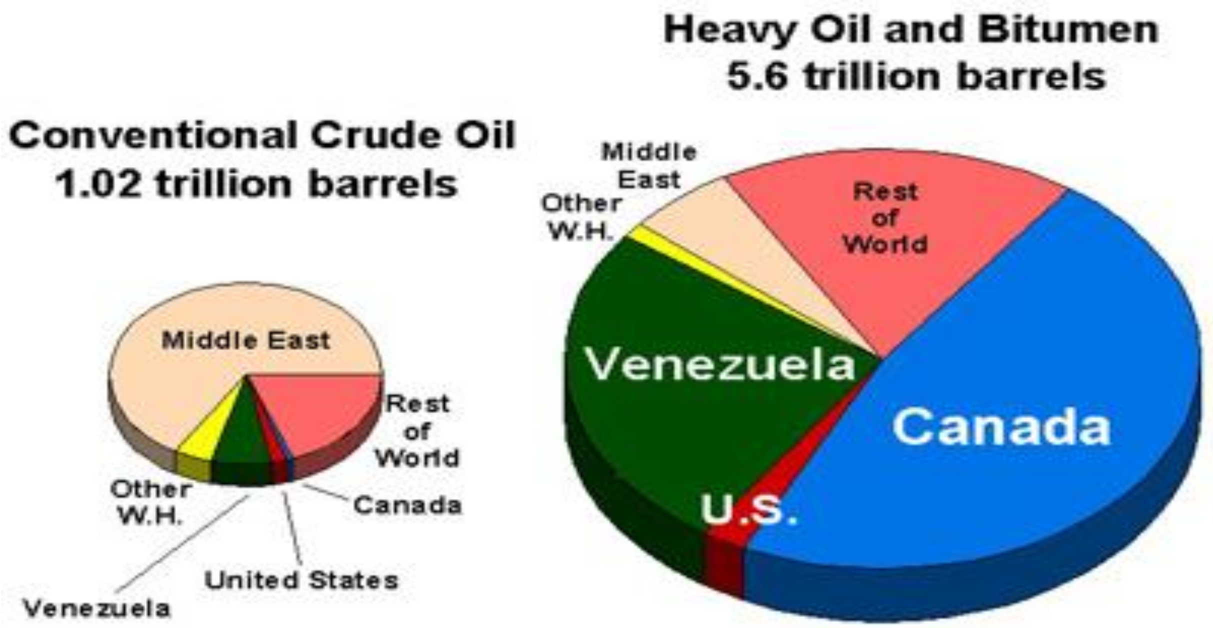

Figure 1.2 World heavy oil distribution

1.2 Problem statement

Conventional oil reservoirs are often developed (or depleted) through waterflooding the reservoir. The recoveries obtained are about 30-40% at the field scale and can be as high 60-70% at the laboratory scale. Waterflood application for the heavy oil, albeit possible is expected to suffer from lower oil recoveries both at the laboratory scale and the field scale (Jennings 1996, Kumar et.al. 2005, Miller 2006, Bryan et.al. 2008) due to a large contrast in viscosities between water (1 cp) and the heavy oil (100cp $<\mu o<$10,000 cp) leading to poor sweep efficiency. Comparatively, low primary and secondary recovery (10-20%) than conventional oil (45-55%) make heavy oil reservoir a more suitable candidate for EOR.

In order to effectively recover these denser and high viscous resources, reducing their viscosity (μo) and improving their mobility (k/μo) are the top priority for effective production. According to research and field experience, widely used thermal EOR techniques are less efficient and economical for moderately viscous oil (50-200cp),thin formation (<30 ft) , less permeability (< 1md) and depths greater than 3000 ft.An alternative is to employ suitable non-thermal oil recovery methods, which encompass waterflooding, certain improved waterfloods, and other fluid injection schemes involving the use of a chemicals, gas, an emulsion, or a solvent(Druetta & Picchioni, 2020). Various non thermal chemical EOR method as shown in figure 1.3 are employed to deal with these problematic low productive reservoirs.

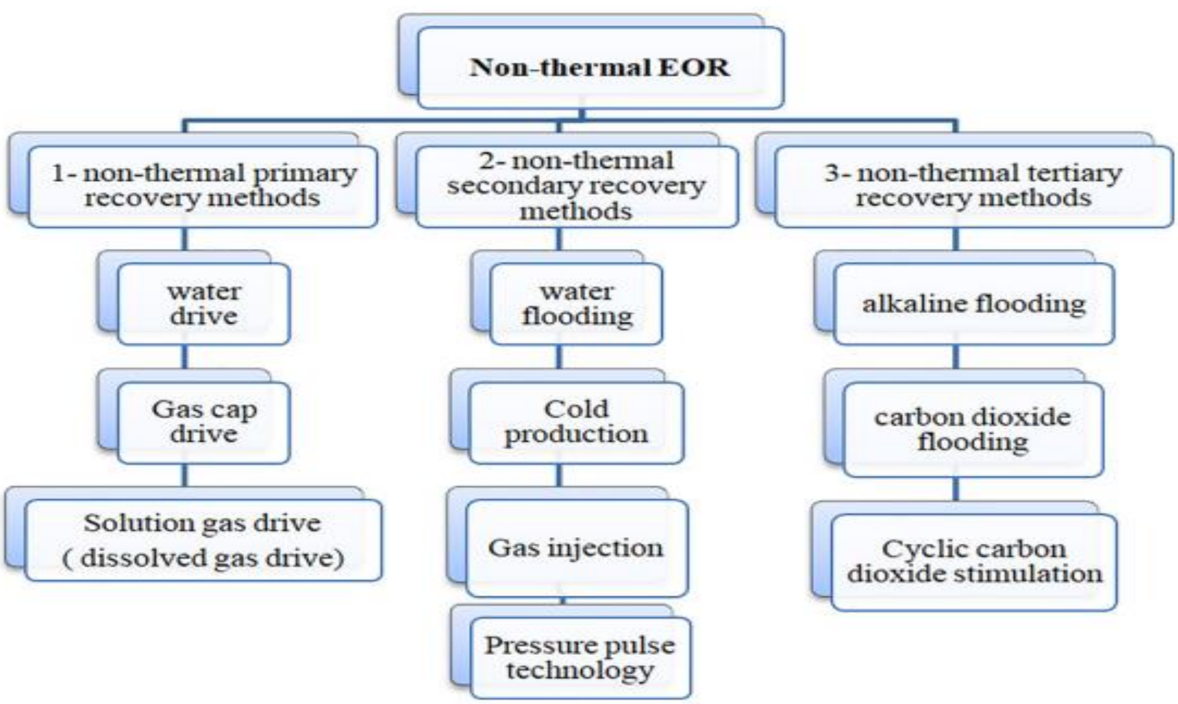

Figure 1.3 Non thermal EOR methods

Laboratory tests have shown that the chemicals have the potential to increase its economic productivity. The contribution of chemical EOR among all methods for heavy oil recovery is depicted in figure 1.4. Chemical additives, including surfactants, polymers, nanofluids, and foam, are a potential solution for improving the performance of steam-based heavy oil recovery methods.

However, many factors must be addressed to make it successful. For instance, the availability and cost of chemicals are one of those factors. The main mechanism of oil production during the alkali injection process is ultra-low IFT (interfacial tension), which is obtained by generating an in-situ surfactant. The reaction between the reservoir oil and alkali results in generating an in-situ surfactant and this surfactant is capable of emulsifying oil and improving oil production (Mai et al., 2009). There are numerous mechanisms counted for the use of nanoparticles for improving an oil recovery factor, and based on reservoir characterizations, one, two or hybrid of several mechanisms would contribute to oil production. These mechanisms are increasing the viscosity of an injected fluid ,reducing viscosity of heavy oil , and altering wettability , emulsification and catalytic capability .The primary mechanisms behind surfactant-assisted heavy oil recovery principally are (1) an IFT reduction between heavy oil and an injected fluid, (2) the spontaneous emulsification or micro-emulsification of heavy oil, and (3) wettability alteration of a rock surface toward a water-wet condition (Santa et al., 2011)

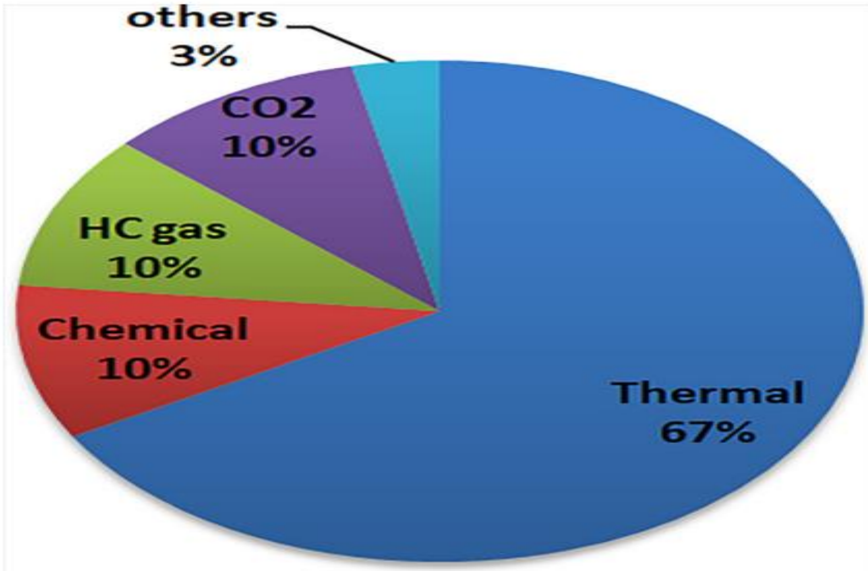

Figure 1.4 Chemical EOR for heavy oil recovery (Soliman, 2019)

Based upon previous study conducted by many researchers, surfactant-polymer (SP) formulations ware based on synthetic chemicals whose properties dependent upon polymer viscosity and surfactant IFT when different concentration of polymer and surfactant used.(Tmáková et al., 2015)

In recent years, much attention has been directed toward biobased chemicals owing to their advantage such as lower toxicity, better environment capability, biodegradability, high selectivity, specific activity at extreme temperature, PH and salinity and the ability to be synthesized from renewable feed stocks.

Biobased surfactant has been proposed based on various research activities as an environmentally friendly and economical alternative to synthetic surfactant. They could act as a cosurfactant to reduce the cost of expensive synthetic surfactant or used to reduce environmental issues. Plant based surfactant, proved to outperform synthetic surfactant in addition to being environmentally friendly. (Kamal, 2016)

On the other hand, biopolymers have also been recommended as a stable alternative to synthetic polymer in harsh temperature and salinity reservoirs. Combination of biobased polymer and surfactant would reduce the incompatibility issue which is detrimental to the efficiency of oil recovery process. In compatibility with polymer will result high surfactant adsorption on rock surfaces, phase separation and trapping in porous media that leads to increase amount of surfactant required for optimum oil displacement efficiency.(Tackie-Otoo et al., 2020)

This research will be conducted using a biobased formulation comprises guar gum biopolymer and coco glycoside biosurfactant for the enhanced recovery of heavy oil. New database regarding to the formulation, phase behaviour observation, polymer viscosity and surfactant IFT will be developed that can be applied to field which have the same condition and parameters.

1.3 Objective

` Objectives of the study is limited to:

i. To investigate the rheological behaviour of polymer solution at different shear rate and salinity.

ii. To characterize surfactant based upon its surface and interfacial tension activity.

iii. To investigate surfactant compatibility with formation saline water and polymer solution at ambient condition.

iv. To investigate influence of different injection schemes of polymer surfactant flooding for heavy oil recovery in artificial glass bead flooding model at ambient conditions.

1.4 Scope

Scope of the project is laboratory-based study to fulfil all the defined objectives. these are:

i. Preparation of Guar gum polymer solution with the use of mixer at different concentration (0-2000 ppm) and salinity (0-10 wt.%).

ii. Measurement of shear viscosity of Guar gum polymer solution and investigating its chemical stability using sodium chloride (0-10 wt.%) at different shear rate (1-1000^{s-1}) at ambient condition (1 atm,25^{0}C) using RST Brookfield Rheometer.

iii. Determination of Critical micelle concentration of Coco glycoside surfactant and impact of salinity (10,000-100,000ppm) at ambient condition using kruss force tensiometer.

iv. Analysing different Guar gum polymer concentration (1000-8000 ppm) on Interfacial tension of Optimum surfactant formulation at ambient condition using kruss force tensiometer

v. Conducting flooding displacement test using Artificial Glass beads pack (125 µm-850 µm) at different injection schemes (P, P/S, P+S, S) using optimum concentration at ambient conditions (1 atm,25^{0}C)

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