SYNERGIZATION OF SILICA OXIDE NANOPARTICLES AND SODIUM DODECYL SULFATE FOR CHEMICAL FLOODING IN ENHANCE OIL RECOVERY

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SYNERGIZATION OF SILICA OXIDE NANOPARTICLES
AND SODIUM DODECYL SULFATE FOR CHEMICAL

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ABSTRACT

Nowadays, enhanced oil recovery is vital in improving the oil recovery. Oil has been known as highly demand source around the world. However, the oil productions keep depleting due to production problem such as high surface tension and interfacial tension reservoirs. Therefore, chemical flooding is one of the methods used in enhanced oil recovery. The synergy between Silica Oxide nanoparticle and Sodium Dodecyl Sulfate has been proposed as a compound for chemical flooding in enhanced oil recovery in this project. The major aim of this study was to measure the effectiveness of synergization between Silica Oxide (SiO_2) nanoparticles and Sodium Dodecyl Sulfate (SDS) with different injection ratio by measuring the oil recovery using chemical flooding. After the synergization of surfactant with nanosilica solution take place, the surface tension and interfacial tension test have been conducted to identify the optimum concentration when various concentrations have been used. The results showed that the optimum concentration for SDS is 2000 ppm with surface tension (ST) and interfacial tension (IFT) are 33.5 and 36.0 mN/m respectively. When the SiO_2 nanoparticles were added, it showed that 6000 ppm was the optimum concentration with reduction in surface tension and IFT to 31.0 and 34.5 mN/m respectively. The 20,000 ppm brine and paraffin oil have been injected into the sandpack followed by waterflooding and chemical flooding to measure the oil recovery. The results from the experiment presented that the oil recovery for waterflooding were in between 23% to 28% therefore, more oil left in the sandpack. Then, surfactant with nanosilica solution was injected with 20,000 ppm of brine as a slug with injection ratio in between 0.1 to 0.5 as tertiary recovery. It showed that the oil recovery increase up to 48% for 0.1 of injection ratio and 64% for 0.5 injection ratio. As a conclusion, it is proved that the synergization of SiO_2 nanoparticle and SDS is applicable for chemical flooding as tertiary recovery because in can recover up to 70% of oil production.

ABSTRAK

Pada masa kini, mempertingkatkan pemulihan minyak adalah penting dalam meningkatkan perolehan minyak. Minyak telah diketahui sebagai satu sumber yang mempunyai permintaan yng sangat tinggi di seluruh dunia. Walau bagaimanapun, pengeluaran minyak semakin berkurangan kerana masalah pengeluaran seperti ketegangan permukaan yang tinggi dan takungan tegangan antara muka. Oleh itu, banjir kimia adalah salah satu kaedah yang digunakan dalam pemulihan minyak dipertingkatkan. Sinergi antara nanopartikel *Silica Oxide* dan *Sodium Dodecyl Sulfat*e telah dicadangkan sebagai sebatian untuk banjir kimia dalam pemulihan minyak dipertingkatkan dalam projek ini. Tujuan utama kajian ini adalah untuk mengukur keberkesanan penggabungan antara *Silica Oxide* (SiO_2) nanopartikel dan *Sodium Dodecyl Sulfate* (SDS) dengan nisbah suntikan berbeza dengan mengukur perolehan minyak menggunakan banjir kimia. Selepas penggabungan peluntur dengan *nanosilica* mengambil tempat, ketegangan permukaan dan ujian ketegangan antara muka telah dijalankan untuk mengenalpasti kepekatan optima apabila pelbagai kepekatan telah digunakan. Hasil kajian menunjukkan bahawa kepekatan optima untuk SDS ialah 2000 ppm dengan ketegangan permukaan (ST) dan ketegangan antara muka (IFT) adalah 33.5 dan 36.0 mN/m masing-masing. Apabila nanopartikel SiO_2 ditambah, ia menunjukkan bahawa 6000 ppm adalah kepekatan optimum dengan pengurangan ketegangan permukaan dan IFT kepada 31.0 dan 34.5 mN/m masing-masing. Air garam 20,000 ppm dan minyak kuat telah disuntik ke dalam *sandpack* yang sejajar dengan *waterflooding* dan banjir kimia untuk mengukur perolehan minyak. Keputusan daripada eksperimen yang dikemukakan bahawa pemulihan minyak untuk *waterflooding* berada di antara 23% hingga 28% oleh itu, lebih banyak minyak yang tinggal dalam *sandpack* itu. Kemudian, peluntur dengan penyelesaian *nanosilica* telah disuntik dengan 20,000 ppm air garam sebagai *slug* dengan nisbah suntikan di antara 0.1 hingga 0.5 pemulihan pengajian tinggi. Ia menunjukkan bahawa pemulihan minyak meningkat sehingga 48% bagi 0.1 nisbah suntikan dan 64% bagi nisbah 0.5 suntikan. Kesimpulannya, ia membuktikan bahawa penggabungan antara SiO_2 nanopartikel dan SDS adalah untuk banjir kimia pemulihan tinggi kerana dalam boleh mendapatkan sehingga 70% daripada pengeluaran minyak

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LIST OF ABBREVIATIONS

EOR	Enhance oil recovery
CO_2	Carbon Dioxide
Nm	Nanometer
CMC	Critical micelle concentration
Ppm	Pound per million
CAPEX	Capital expenditure
OPEX	Operation Expenditure
US/USA	United State/United State of America
Wt	Weight
Bbls/day	Barrels per day
DOE	Department of Energy
IFT	Interfacial tension
SDS	Sodium Dodecyl Sulfate
PAM	Polyacrylamide
Mol/l	Mol per liter
SLS	Sodium Laurylsulphate (SLS)
mN/m	mili-Newton per meter
cP	Centipoise
SiO_2	Silica Oxide
CTAB	Cetyl Trimethyl Ammonium Bromide

SDBS	Sodium Dodecyl Benzene Sulfate
CPC	Cetylpyridinium Chloride
NaOH	Sodium Hydroxide
HCl	Hydrochloric acid
Rpm	Revolution per minute
NSP	Nano-surfactants polymer
NP	Nano-polymer
Cc/min	Centimeter cubic per minute

LIST OF SYMBOLS

θ	Contact angle
°C	Degree Celcius
μ	Viscosity
ΔP	Pressure difference

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Fuel energy is one of the major energy sources in the world such as oil, coal and natural gas. Currently, oil supply 80% of the world's energy needs and its demand projected to be higher for about 40% in 2035 than in 2010 even if current policy commitments and pledges by governments to tackle the climate change are all implemented (Vaughan, 2018). The primary demand of the fuel source is shown in the Figure 1.1 below.

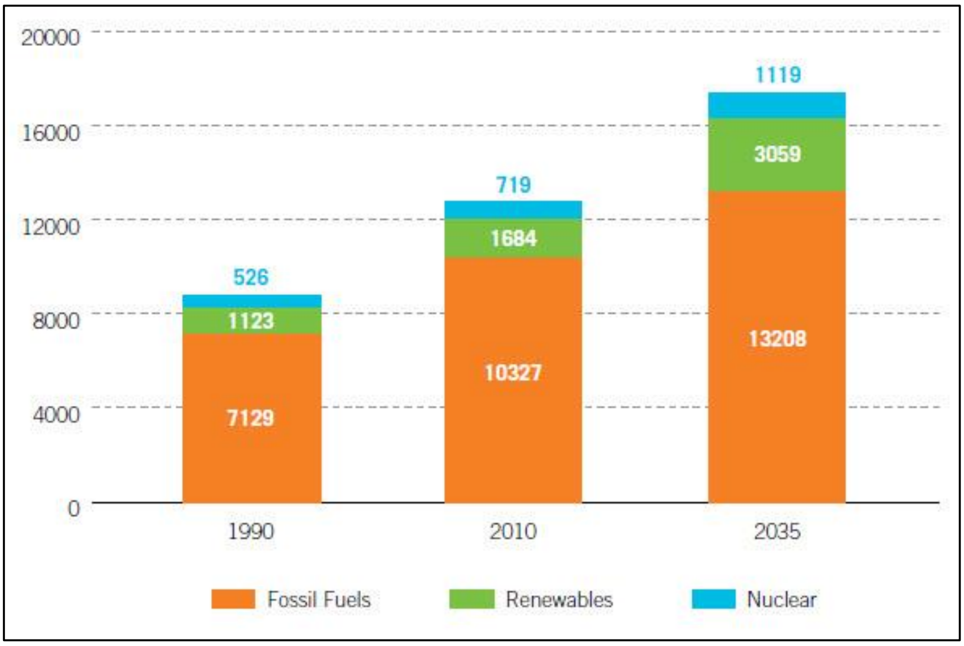

Figure 1.1 The primary demand of the fuel source, million tonnes of oil equivalent (Vaughan, 2018)

Vaughan A. (2018) reported that the influential thinkers have predicted that global oil demand as fuel energy will peak in 2023. The demand for the oil energy increased 1.5% per year due to the civilizing life styles and population growth. The primary sectors that required highly demand to the oil energy are transportation and power generation.

Anyway there is no sufficient energy source that broadly integrated to replace the crude oil energy. The demands of the oil energy keep growing from day to day. We need 97 million barrels per day of new oil to meet the oil demand (Investopedia S., 2018). However, the remaining resources of the oil energy getting decline throughout the years.

Technology improvements are required in order to increase the oil production. The oil production can be categorized to three categories; primary recovery, secondary recovery and tertiary recovery. Primary oil recovery refers to the process of extracting hydrocarbons that naturally rise to the surface or via artificial lift equipment like pump jacks. In fact, the potential well recovered from primary recovery is around 5% to 15% only.

Next, the secondary recovery employs the injection of water or gas which will shift the oil and driving it to the surface. The typical successful of this recovery in targeting an additional 30% of the possible reserves. According to the US Department of Energy, utilizing the primary and secondary oil recovery production can leave up to 75% of the oil in the well (Rigzone, 2018).

The way to increase the oil production is through tertiary oil recovery known as enhanced oil recovery (EOR). Even though this technique is more expensive to directly implement into the well, but it promised can increase the production up to 75% of the recovery. EOR works by altering its physical and chemical properties to make it more conducive for extraction. There are three main types of EOR which are thermal recovery, gas injection and chemical flooding. Figure 1.2 shows how the chemical flooding works.

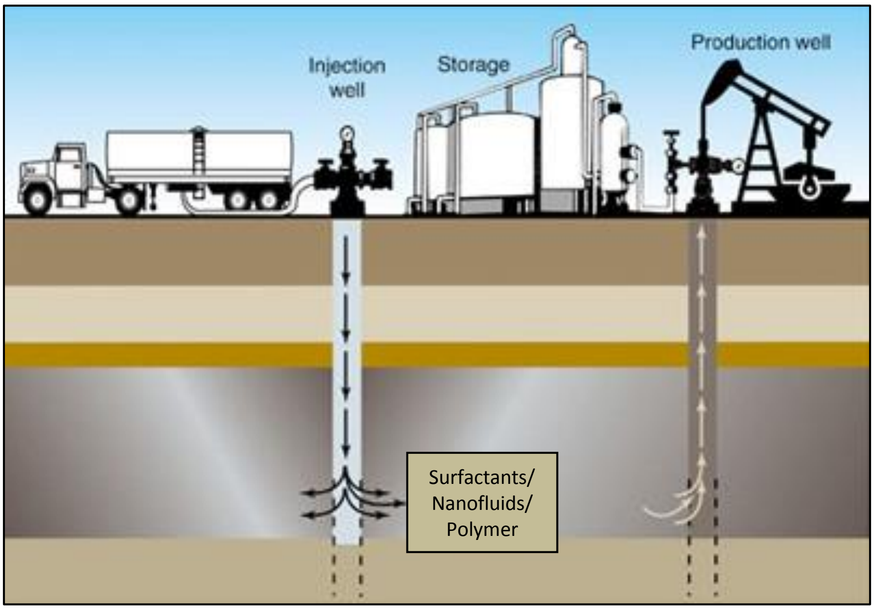

Figure 1.2 Chemical flooding techniques in enhanced oil recovery

Thermal energy introduces a method of heat to the reservoir. This method is widely using as early 1960s. The purpose of this method is to lower the viscosity or thinning the heavy viscous oil then enhancing its ability to flow through the reservoir. In addition, the gas injection is a technique which applies gases such as carbon dioxide, natural gas or nitrogen into the reservoir. The gases will expand and push the remaining oil to the production wellbore or it will dissolve within the oil to reduce it viscosity and accelerate its flow rate.

Furthermore, the chemical flooding presented as one of enhances oil recovery (EOR) technique. This technique helps to free trapped oil within the reservoir. It will introduce long chained molecules to improve the properties of the reservoir make it easy to flow to the production wellbore. Polymers, surfactants and nanofluids are the types of chemical that broadly been studied and used as chemical flooding in EOR.

Nanofluids become popular in enhancing oil recovery due the cost effective manners and environmental friendly. Negin, Ali and Xie (2016) stated that the size of nanoparticles for EOR usually in range of 1 – 100 nanometers (nm). The fascinating and valuable property of these particles is it creating massive diffusion driving force due to large surface area especially at high temperatures.

Besides, surfactants and polymers become an attention because of their characteristics. They have an amphilic structure consists of hydrophobic and hydrophilic head group (Hajibgheri, 2017) and polymerized vinyl double bonds in their molecules structure. Thus, shows an ability to improve the reservoir properties in order to increase the production through enhanced oil recovery techniques.

The properties of the reservoir that affected by enhanced oil recovery are reservoir viscosity, wettability, interfacial tension, density, emulsion, chemical and biochemical aspects. Going down to the deeper depth, the formation consists of heavy oils that are more viscous. So, by using the chemical flooding, it will reduce the viscosity and drive the reservoir to flow to the surface.

Khusainova and Nielsen (2015) explained that wettability is as the tendency of one fluid (wetting fluid) to spread on or adhere to a solid surface in the presence of another immiscible fluid (non-wetting fluid). Reservoir wettability is vital and elusive petro physical parameters in all types of core analysis, which affects the enhanced oil recovery processes (Das, Tundat, Mitra, Surf, 2014). The reservoir is preferable to be more water wet than oil wet because more oil is recovered in the chemical flooding thus increase the production.

Interfacial tension is a property of the interface between two immiscible phases (Kumar and Mandal, 2016). Term of interfacial tension refers to the interface of both liquid phases while if one of the phases is an air, it known as surface tension. The unbalanced molecular attractive and repulsive forces cause a tension always exists at the interface of fluid phases. Surfactant molecules preferentially position themselves at the interface and thereby lower the interfacial tension thus can push the potential reservoir to flow.

Therefore, enhanced oil recovery required deeply study and improvement to increase the production of reservoir then can ensure the continuously supply of the fuel energy for few hundred years more. Application of chemical flooding should be widely introduced because referring to the previous study, it proven that it can help to drive the oil to the production wells.

1.2 Problem Statement

Based on the recent survey of oil production, it shows that a depleting of oil production in the world (John England, 2017). This is very worrying situation because nowadays oil is a major of fuel energy compared to the natural gas and coal that is widely been used in transportation and power generation. Figure 1.3 shows the primary energy consumption by fuel.

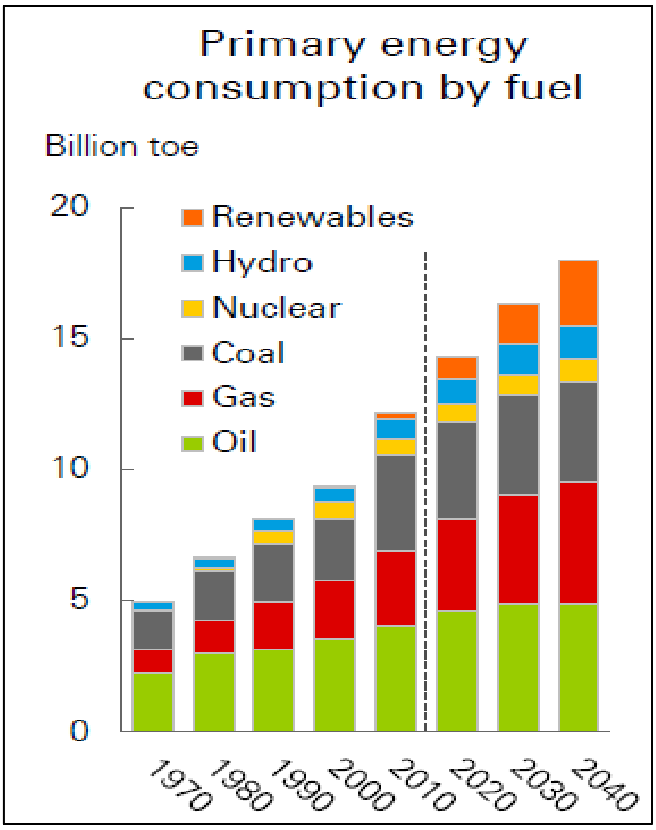

Figure 1.3 Primary energy consumption by fuel (Source : BP Energy Outlook, 2018)

The oil production is low comparing the oil possible reserves. Oilfield engineers faced many difficult problems even the modern techniques have been applied to the deep drilling activities. This is due to the difficulty in improving the oil production. Some of the problems may be the expansion of gas, the viscosity of the reservoir, its interfacial tension and wettability.

Capability of the reservoir viscosity is one of the concerns in this study. Going down to a deeper depth, the reservoir pressure keeping tremendously drop because it consists of heavy oil (Kumar and Sharma, 2018). Heavy oil is a weak nature of rock matrix. It relatively has large pore throats, high absolute permeability of the reservoir and also the displacement instability from an adverse mobility ration. The reservoir viscosity becomes very low as the reservoir pressure decrease cause low oil flow.

The other highlight of the problems is the interfacial tension between the molecules of reservoir increase at deeper depth and the reservoir wettability turn to low water-wets when the reservoir pressure drops thus resulting the low oil production. Deeply study is required to settle the reservoir properties problems, hence enhance the oil recovery expecting the high oil production.

1.3 Objectives

The objectives of this study are as per below.

a) To synergize the Silica Oxide nanoparticles and Sodium Dodecyl Sulfate with different concentrations in determination of oil recovery in the reservoirs.

b) To evaluate the surface tension and interfacial tension of Silica Oxide and Sodium Dodecyl Sulfate in identifying its optimum concentration.

c) To determine the effectiveness of synergy between Silica Oxide nanoparticles and Sodium Dodecyl Sulfate by varying the injection ratio in measuring the oil recovery.

1.4 Scope of Study

This study covered the synergy of Silica Oxide nanoparticles and Sodium Dodecyl Sulfate as chemical flooding in enhance oil recovery application later.

Then surfactant was used as combination with nanoparticles is an anionic surfactants. The anionic surfactant used in this study is Sodium Dodecyl Sulfate (SDS) where it is an amphilic structure consists of hydrophobic and hydrophilic head group. The molecular structure of SDS is $NaC_{12}H_{25}SO_4$ with 348.48 of molecular weight.

The element that has been identified in this study was the surface tension of the synergy between the Silica Oxide nanoparticles and Sodium Dodecyl Sulfate (SDS) to identify the critical micelle concentration (CMC). The other element that was measured is the effectiveness the interfacial tension of the reservoirs.

The study conducted under room condition at 14.7 psia and 25°C. The concentrations of surfactant were in range of 1000 ppm to 3000 ppm to get the optimum concentrations that also known as critical micelle concentration (CMC). After that, the optimum concentration presented as a base in adding the different concentration of Silica Oxide nanoparticles in between 1000 ppm to 10000 ppm also to identify the optimum concentration after the syenergization of the surfactant nanosilica.

In addition, the oil recovery took place where different injection ratios were the manipulated variables in this study. The injection ratio that used in this study were 10:90, 20:80, 30:70, 40:60 and 50:50 that were slug 20000 ppm of brine and surfactant nanosilica solution. Finally, the oil recovery is the final elements that were determined in this study.

1.5 Significant of Study

The significant of this study is to design a material that good to reservoir and environmental friendly. The materials can increase the oil production and also do not harmful to the marine life and sea water. The materials also cheap to ensure it is applicable to be implement in the reservoirs. The materials also can handle the higher and lower condition of pressure, temperature and salinity of the reservoirs. It also stable and not aggregation in room condition.

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