APPROPRIATE DATA PREPARATION FOR POLYMER FLOOD PROCESS

by
Herlan Adim

ABSTRACT

Oil production from reservoirs by natural (primary) drive mechanisms is often an inefficient process which may leave considerably more "residual" oil trapping behind the reservoir than can improve mobility and sweep efficiency where permeability variation occurs. Polymer flood recovery.

This paper discussed the major reservoir data preparation for polymer flood processes of oil fields in order to achieve and optimize the expected performance and evaluate the feasibility of polymer flood process. One of the primary objectives of this information study is to provide additional assistance of oil recovery abtainable by polymer flood projects for oil-industry, which may be more pratical to proceed such polymer project step by step, rather than going into a pilot stage from the beginning.

I. INTRODUCTION

Many kinds of fluids are injected into the reservoir through injection wells in order to maintain the natural reservoir energy and recover additional oil at the end of its primary phase. Since water is generally the cheapest and most familiar fluid, water flooding is the most popular secondary recovery technique. Water flooding in most cases is a very profitable techique for recovering additional oil from the reservoir. The amount of additional oil recovered by this secondary techniques is dependent on how efficiently the driving fluid can sweep the reservoir.

Sweep efficiency is the term used to describe the effectivenes of this drive process. Sweep efficiency is dependent mainly on two factors, the mobility ratio and the heterogeneity of the reservoir formation. During water flooding, various techniques have been used to over come the poor sweep efficiency that is common in most floods. This poor sweep efficiency is caused by the heterogeneity of the reservoir formation.

In fact, an injection profile often shows that as little as ten percent of the reservoir is being flooded. To improve the heterogeneity of the reservoir or injection profile, new techniques have been developed using crosslinked water soluble polymer. These techniques are referred to as profile modification.

Once the macroscopic sweep efficiency is improved by profile modification, polymer flooding becomes more effective to recover oil. This is possible because the polymer slug enters into all of the oil bearing zones and effectively sweep the oil in place (not only macroscopically, but also microscopically) due to the favorable mobility ratio resulting from the high viscosity of the polymer solution.

The displacement of oil from reservoir rock by the injection of water is less efficient for viscous oils than for light oils. When the oil is very viscous, the water fingers through the oils, or it seeks opportunities to by pass the oil rather than displace it. The heterogeneity of the formation, in a given reservoir, makes piston like displacement less likely.

A process which would convert a heavy oil to lighter oil insitu would be of value in improving water flood performance. This is not possible. However, it is possible to improve the effectiveness of the water which flows through the rock instead of changing the properties of the insitu. It is the mobility ratio between the water and the oil which governs the efficiency of the displacement process.In most cases, the mobility of injected water or brine can be reduced by a factor of about 10 through the use of economic levels of mobility control polymers. The lower the economic levels of mobility of the water, the more effective it will be, within practical limits.

II. REVIEW OF POLYMER FLOOD METHOD

Polymer flooding is an improved water flooding technique in which high molecular weight water – soluble polymer are added to water prior to injection to increase its ability to displace oil more efficiently. This is achieved as the polymer increases the viscosity of the injection water resulting in more favorable oil – water mobility ratio in the reservoir.

With the mobility control, improved sweep efficiency is expected. The method is also efficiency in stratified reservoirs and reservoirs in which a high degree of permeability variation exists. It is to be noted that polymer flooding improved the sweep efficiency, but does not reduce the residual oil saturation.

The injection of water- soluble polymer can improve mobility and sweep efficiency where permeability variation occurs. Polymer injection does not, however, improve on the ultimate water flood recovery. Therefore it should be initiated as soon as possible after the start of water flooding (secondary recovery). Additional Polymer does not normally decrease residual oil saturation, but reduces the water cut oil is recovered.

Two basic types of polymer used to:

a. Polyacrylamide (a flexible linear chain polar polymer with variable molecular weigh composed of linked acrylamide molecules).
b. Polysaccharide (a more rigid chain type polymer produced by microbes).

III. TECHNICAL BACKGROUND

The mobility of the water as it flows through the microscopic pore spaces in the rock depends on the viscosity of the water and the effective permeability of the rock to it. The mobility of the water is thus given by the equation:

$$\tau w = Ko / \mu w \quad \text{.......}(1)$$

and the mobility of the oil is given by:

$$\tau w = Ko / \mu o \quad \text{.......}(2)$$

Where:

- τw = mobility of water
- τo = mobility of oil
- Kw = permeability to water
- Ko = permeability to oil
- μw = viscosity to water
- μo = viscosity to oil

The mobility ratio (M) which governs the effectiveness of the oil displacement process, is thus:

$$M = \tau w / \tau o = Kw\mu o / \mu w \quad \text{.......}(4)$$

The lower the value of M, the more effective the process will be. In general, a mobility ratio of less than one is said to be favorable, while a mobility ratio greater than one is unfavorable.

Dissolving high molecular weigh polymer in water will increase the viscosity of the injected fluid, and consequently decrease the mobility ratio.

This effect is often reported as the resistsnce factor. It is measured core tests by determining the mobility of water first, and mobility of polymer solution next. This is a number which indicates how much more difficult it is, for polymer solution to move through a rock than water without polymer added. This is expressed as:

$$RF = \frac{(Kw/\mu w)}{(Kp/\mu p)} = \frac{\tau w}{\tau p} \quad \text{.......}(4)$$

Where:

- RF = Resistance factor
- Kp = Permeability to polymer solution
- Kw = Permeability to water
- μp = Viscosity of polymer solution
- μw = Viscosity of water
- τw = Mobility of water
- τp = Mobility of polymer solution

In addition, experiment run on oil field core samples have shown that polyacrylamide polymer interacts with the reservoir rock in such a way that the permeability to water is decreased while the permeability to oil is essentially unchanged. It is determined from core test by measuring the mobility of water before and after a polymer flood.

This effect is referred to as the residual resistance factor, and is expressed as:

$$RRF = \frac{(Kw/\mu w)Before}{(Kw/\mu w)After} = \frac{\tau wBefore}{\tau wAfter} \quad \text{.......}(5)$$

Where:

- RRF = Residual Resistance Factor
- Kw = Permeability to water
- μw = Viscosity of water
- τw = Mobility of water

As an approximation, a resistance factor of eight might be through of as having about the same effect on water flooding as decreasing the viscosity of the oil by a factor of eight. The end result is better overall areal and vertical sweep efficiency in the field.

Mobility control polymers are most often used to improve the effectiveness of water floods. Polymer concentrations are usually in the 0.025 to 0.5% range (250 to 5000 ppm). Both higher and lower concentrations may be used to deal with specific reservoir conditions. Increases in the total amounts of oil economically obtained from a given reservoir through the use of polymer ranges from around 5 to 50%, although increases about 10 to 20% are common.

In order to accomplish this, the total volume of polymer solution injected in the field ranges from 0.10 to 0.30 pore volume (PV). A project such as this may easily require two or three years of polymer injection time. Water without polymer would follow until the economic production limit is reached.

IV. SCREENING CRITERIA

Before applying technical sreening criteria, some general considerations should be given to eliminate reservoirs not suitable for EOR methods such as.

- Low permeability
- Permeability variations, areal variation, vertical, stratification and directional permeability
- Extensive fractures and faults
- Little remaining reserves
- Existence of bottom water existence of large primary gas cap

Many of the screening criteria are the reservoir properties that are normally available for developed fields. However, the quality of available data has to be assessed, and if necessary, new data should be obtained. Polymer process is site specific and a careful screening process and an examination of implementation strategy of the selected process is extremely important in order to achieve and optimize the expected performance. Screening criteria for polymer process is summarized in Table 1. This screening is useful as primary feasibility study.

V. ECONOMIC FEASIBILITIES

Talking about the feasibility for polymer process, it should analyze the following items based on the passed experience. There are:

- Oil Recovery Efficiency (3-10%)
- Process Efficiency (0.55-2lb.polymer / bbl oil)
- Example polymer pilot project costs.

Estimated cost for 2,5 acre polymer flood pilot project:

- Drill and complete 5 (five) wells (Inverted 5-spot).................................US$	306,270
- Surface equipment............	80,000
- Chemicals......	50,000
- Transportation chemicals......	3,000
- Laboratory work prior to project	75,000
- Operation cost for 2-years proje	250,000
Total costs	US$ 764,270

VI. RESERVOIR DATA PREPARATION

Engineering efforts to assess the polymer flood potential in major fields should be initiated as early as possible so that planning and consideration of reservoir data provide sufficient lead time to develop any viable projects.

I. General Description

1. Identification
   a. Name (field or reservoir)
   b. Location
   c. Operation
   d. Formation

Table 1
Polymer flood screening criteria

RESERVOIR PARAMETERS	DIMENSIONS	POLYMER
Rock type	-	sst*/lm
Net thikness	ft	NC
Depth	ft	< 9000
Temperature	F	< 2000
Avg. permeability	md	> 40
Avg. porosity	%	20
Avg. oil saturation	%	> 40
Pressure	psi	NC
Oil gravity	API	> 25
Oil viscosity	cp	< 200
Oil composition		NC
Salinity (TDS)	ppm	< 50,000
Wettability		WW
Kh/μ		NC
ϕ.So		NC
Injection water salinity	ppm	< 50,000
Clay content	%	< 10

Note:
NC: Not critical
WW: Water wet
sst: sandstone is preferable*
Lm: Limestone (carbonate rock)

2. Reserved Volume
   a. Area
   b. Thickness (gross and net)
   c. Original oil in place
3. Number of Wells
   a. Producer
   b. Injection
   c. Shut-in
4. Pattern Size
   a. Spacing
   b. Type of pattern
   c. Total acreage
   5. Properties
   a. Depth
   b. Rock type
   c. Porosity (average and range)
   d. Permeablity (average, range, K-vertical / K-horizontal and variation)
   e. Temperature
   f. Pressure (original and current)
   g. Fracture pressure
   h. Oil saturation (initial and current)

II. Production History

1. Primary
   a. Data initiated
   b. Reservoir drive mechanism
   c. Commulative production (oil, water and gas)
   d. Oil Saturation at end of primary
   e. Reservoir pressure
2. Water Flood
   a. Date initiated
   b. Injection rate
   c. Injection pressure (BHP)
   d. Commulative injection
   e. Commulative production (oil, water and gas)
   f. Current WOR
   g. Current oil saturation
   h. Predicted SOR at the end of water flooding
   i. Current reservoir pressure

III. Fluid and Rock Properties

1. Oil
   a. Bubble point or vapor pressure at reservoir temperature
   b. Viscosity at reservoir temperature
   c. API gravity
   d. Interfacial tension
   e. Acid number
2. Water
   a. Salinity (At formation, and injection)
   b. Hardness
   c. PH
3. Rock
   a. Clay content
   b. Rock sensitivity, wettability and others
   c. Availability of core

IV. Map, Record and Analysis

1. Map
   a. Structure map
   b. Isopach map
   c. Counter map.
2. Record
   a. Production decline curve
   b. Injection vs. time plot
   c. WOR vs time plot
3. Analysis
   a. Water
   b. Oil
   c. Rock.

V. Miscellaneous

1. Utilities
   a. Electrical power
   b. Fuel gas
   c. Nitrogen gas
   d. Others.
2. Supporting Facilities
   a. Road
   b. Truck
   c. Lift
   d. Others.
3. Storage warehouse

VII. INDIVIDUAL WELL DATA

I. Injector

1. General
   a. Reservoir name
   b. Well name
   c. Well location
   d. Problems.
2. Injection History
   a. Date on injection
   b. Injection (rate, pressure and total commulative inection)
4. Tubular Goods
   a. Casing (diameter, depth intervals)
   b. Tubing (diamater, depth intervals)
5. Completion
   a. Type of well completions (open / linear / perforated)
   b. Perforated casing (perforated interval, perforation density and perforation method)
   c. Liner (slottèd / screen / perforated liner)
   d. Packers
   e. Workover history (reasons and stimulation)
   f. Injection profile
   g. Injection profile
   h. Well log data
   i. Core analysis data (permeability distribution,oil saturation. porosity, sor and relative permeability curve)
   j. Pressure transient test (pressure fall-of test step rate test)

II. Producer

1. General
   a. Reservoir name
   b. Well name
   c. Well location
   d. Problems
2. Production History
   a. Date on production
   b. Production method (flowing / pumping / gas lift)
   c. Production (current production rate, total cumulative production of oil-water-gas)
3. Tubular goods
   a. Casing (diameter, depth intervals)
   b. Tubing (diameter, depth intervals)
4. Completion
   a. Type of well completion (open / Liner / Perforated casing, single/multiple)
   b. Perforated casing (perforated interval, perforation density, perforation density, perforation method)
   d. Liner (slotted / screen / perforated liner)
5. Workover History
   a. Reasons
   b. Workovers
6. Stimulation History
   a. Reasons
   b. Stimulation
7. Production profile
8. Well log data
9. Core analysis data
   a. Permeability distribution
   b. Oil saturation / porossity
   c. Sor
   d. Relative permeability curve
10. Pressure built-up test

III. Fluids Analysis

1. Water
   a. Produced (Ion Na+, Ca++. Mg++, Fe++, Cl-, HCO_3, CO_3, SO_4, H_2S level , pH, TDS, hardness, SS, solid size distribution, solid content (>2 um).
   b. Injection (ion Na+, Ca++, Mg++, Fe++, Cl-, HCO_3, CO_3, SO_4, H_2S level, pH, TDS, hardness, SS, solid size distribution, solid content (>2 um)

   Since HCO_3^-, pH, H_2S level and bacyeria contents in water may change with time, these constituent should be analysed on site.

2. Oil

   Gravity, (g/cm^3)
   Viscosity, cp
   Acid No.,mg KOH / g
   Asphaltenes, wt%
   Interfacial tension, dyne / cm

VIII. CONCLUSION

Based on the number and types of projects that are being implemented around the world, Polymer process is going to be an important factor in increasing both production levels and future reserves in areas where major projects are located.

The polymer flood method is effective in stratified reservoirs and reservoirs in which a high degree of permeability variation exists. It is to be noted that polymer flooding improved the sweep efficiency, but does not reduce the residual oil saturation.

Geological and reservoir engineering data and production operating data such as depositional environment, rock, fluids properties, heterogeneity, result of past water flooding and types of stimulation and workover should be studied.

Engineering efforts to assess the polymer flood potential in major field should be initiated as early as possible so that planning and consideration of polymer can provide sufficient lead time to develop any viable projects.

The initial evaluation based on suggested screening criteria is followed by laboratory and field test. The detailed laboratory studies are required to achieve a reasonable estimate of polymer flood potential.

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