IMPROVED OIL RECOVERY BY LOW SHEAR HANDLING OF INJECTION POLYMERS

INTRODUCTION

Enhanced oil recovery (EOR) is a tertiary oil recovery method used to increase the amount of oil that can be extracted from a reservoir. Primary, pressure depletion, and secondary oil recovery, like water injection, only recovers 20 – 50 % of original oil in place (OOIP), so a large amount of oil is still trapped in the reservoir after conventional oil recovery processes. There are many different tertiary EOR methods, however, polymer injection and polymer flooding is the most important chemical EOR method used in sandstone reservoirs.

Polymers

Polymers are long chain molecules composed of many repeated subunits with high molecular weight. When added to water, either as a solution or as powder, they increase the waters viscosity.

POLYMER INJECTION

When polymers, are mixed in together with injection water for enhanced oil recovery, the polymer-water injection solution becomes more viscous. As a consequence, more oil will be pushed out and recovered from the reservoir compared to only water injection flooding alone. An illustration of a typical polymer flood operation is given in Figure 1.

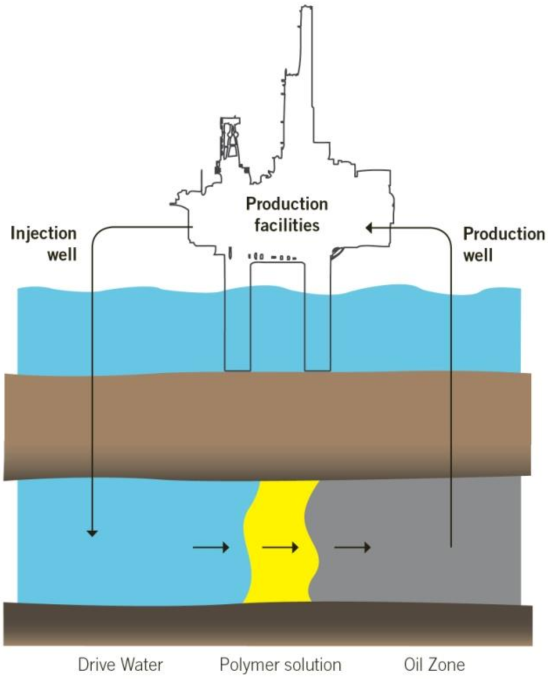

Figure 1: Illustration of a polymer flood operation

Source: Typhonix AS

Inefficient oil recovery was recognized in the early 1900's. Normally, reservoir oil is ten times more viscous than the water injection stream alone. This makes it hard for the injected water stream to sweep trapped oil from the reservoir to the production wells. By adding polymers to the injection water, the injection stream gets more viscous than the oil, reducing breakthrough (fingering) of the water to the production wells, and hence sweeps out more oil from the reservoir. Fingering of water is illustrated in Figure 2. The improved sweep efficiency when polymers are added is often called the "piston" effect, and can enhance oil recovery by 5 – 15 % compared to conventional methods.

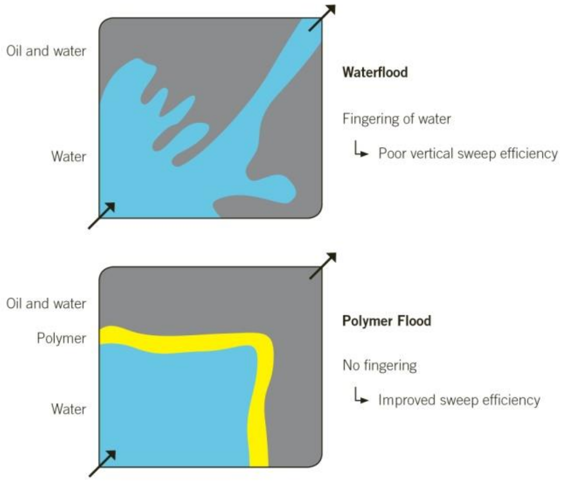

Figure 2: Fingering of water

Source: Typhonix AS

Oil recovery from a reservoir is dependent on mobility ratio, and polymer injection improves the mobility ratio. Mobility is how permeable a porous media is to a given phase, divided by the viscosity of the phase. Mobility ratio is the mobility of the displacing phase divided by the mobility of the displaced face. In polymer flooding, water containing polymer is the displacing phase, and oil is the displaced phase, as can be seen in Equation 1.

Equation 1:

$$M = \frac{\lambda w}{\lambda o} = \frac{\mu w / K w}{\mu o / K o}$$

Where:

- λ = Mobility
- μ = Viscosity
- K = Effective permeability

Typically, polymer flooding involves injection and mixing of polymer over an extended period of time, until 1/3 - 1/2 of the reservoir pore volume has been injected. Then a continued long term water flooding follows. The water flooding drives the polymer slug and the oil bank towards the production wells, as illustrated in Figure 1.

PROBLEMS ASSOCIATED WITH POLYMER INJECTION

One of the main problems with polymer injection is that polymers are very easily degraded. When a polymer solution gets degraded, the long chain polymer molecules are broken down. As a consequence the molecular weight of the polymers is decreased, and the solution looses much of its viscosity. There are many things that contribute to degradation of a polymer solution, with the most important being mechanical shear and strain rate in fluid flow devices used in connection with polymer injection operations. Other important factors are salt concentration, oxygen concentration and high temperatures.

Mechanical degradation

Mechanical shear and strain rate in fluid flow devices is the most important factor which reduces the effect of a polymer flooding operation. Shear forces are to be found in every fluid flow devices, especially valves. In valves, the pressure of the solution is reduced. The pressure drop is often obtained from passage through small holes, which subjects the solution to high strain rates. Strain rates stretches the polymer chain, up to a point where the polymer chain breaks, this is called the critical value. When this happens, mechanical degradation has occurred. Also, the energy from reducing the pressure is dissipated into the volume in the valve, which is normally small. This will in turn creates massive turbulence, hence shear forces (for a more fulfilling description about shear forces, see the article about low shear production). The potential shear locations are:

1. The polymer dissolution facilities: static mixers and pumps
2. The injection lines: particularly the wellhead chokes
3. The well bore entry

It is normal that a polymer-water injection flow loses 50 % of its viscosity from injection point and down to the reservoir, due to mechanical degradation in the injection devices. Normally, during a polymer flood operation, more polymers are therefore added, either by injecting a higher concentration of polymer in the solution, by using a higher molecular weight polymer type, or by having a longer polymer injection period to make up for this viscosity loss.
To overcome the problem of mechanical degradation of a polymer solution, Typhonix is now

developing a First Version Polymer Valve for polymer injection. By reducing the amount of degradation, the solution will remain more viscous and improves sweep efficiency and oil recovery.

Low Shear Polymer Valve

Typhonix has, since the start-up of the company (2006) focused on developing low shear fluid flow equipment, especially valves and pumps. As a result, the company has gained much expertise in particularly this field, and knowledge how to overcome these problems associated with mechanical shear in fluid flow devices. By reducing the pressure in a greater volume, or over a longer length, turbulence and shear forces are reduced. In 2012 Typhonix started the development of a Low Shear Polymer Valve. Since then, different locations were polymer degradation occur have been investigated, and new geometries and solutions have been implemented in the new polymer valve. The new valve keeps the strain rate under its critical value, which means that the polymer chain is not broken down, and polymer degradation is minimized. The main objective is to reduce mechanical degradation of a polymer solution with at least 50 %, and to increase the oil recovery with at least 12 % compared to state of the art (conventional valves). Recent testing has shown that this objective is well within reason, and that the new low shear valve can be designed for a given amount of degradation based on flow rate and pressure drop. This will not only increase the oil recovery for a given reservoir, but it will also have a huge economic benefit by reduced costs of used polymer.

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