University of Mosul

College of Petroleum & Mining Engineering

Department of Petroleum & Refining Engineering

Enhanced Oil Recovery Processes

Fourth Year

Lecture 9

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Polymer flooding process

One of the main types of enhanced oil recovery is the use of water-soluble polymers. Their use to improve the sweep efficiency of standard waterfloodings has been practiced since the early sixties. A polymer is a chemical that is composed of a number of molecules that are attached in some manner. These units usually associated in a pattern that repeats itself throughout the length of each polymer. The repeating units are calledmonomers, and the polymer can be either a homopolymer (one monomer), a dimer (two monomers), etc.

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Some water-soluble polymers have large sizes that do not readily flow through formation pore throats. The size of the hydrated polymer molecule is important in designing a polymer flood for a specific formation.

Properties of polymer solutions:

a- Viscosity:

Both polyacrylamide (PAM) and xanthan gum (XG) polymer solutions give high viscosities at relatively low concentrations. Viscosity is also affected by salinity and divalent ions, such as calcium and magnesium, which cause difficulty in polymer hydration.

The viscosity of polymer solutions decrease with increasing temperature. At moderate temperatures, this change in polymer viscosity with temperature is less than the drop in brine water viscosity caused by the increase in temperature.

b- Stability:

Stability refers to the maintenance of the integrity of the polymer molecule during oilfield operations. Polymers must have: (1) mechanical strength, (2) thermal stability, (3) bacteriological stability, and (4) chemical stability.

Mobility control and profile control processes:

Polymer flooding can be used in place of waterflooding, or to augment an existing flood. In mobility control processes, the polymer is used to alter the fractional flow characteristics of the water phase which is displacing the oil. In profile control processes, polymer gels are used to block water channels and divert flow to portions of the reservoir which have not been properly swept.

Definition of mobility:

The function of any type of water-soluble polymer in enhanced oil recovery is to increase the viscosity of a brine and to reduce the relative permeability to water in the formation. If the flow of brine in a porous medium is decreased in relation to the flow of oil, then the oil's relative flow is improved. ***Mobility*** is a measure of the flow of a fluid through a permeable formation. It is the ratio of the relative permeability of the fluid divided by the apparent viscosity of the fluid. ***Relative mobility*** is the ratio of the displaced fluid's mobility to the mobility of the displacing fluid.

Figure 1 shows a schematic of displacement process. The first diagram, an areal view of an inverted five-spot with water injection into the center well, has created channels to the producing wells, causing breakthrough of injection brine to those wells and increasing the producing water/oil ratios, perhaps to uneconomic values. Most of the oil in the pattern is left unproduced.

The second diagram in Figure 1 shows the same pattern response to injection of fluid with reduced mobility in relation to the oil-in-place. In this case, the brine-polymer bank sweeps evenly out from the injection well resulting in increased sweep efficiency and more oil production at the producing wells with less produced brine.

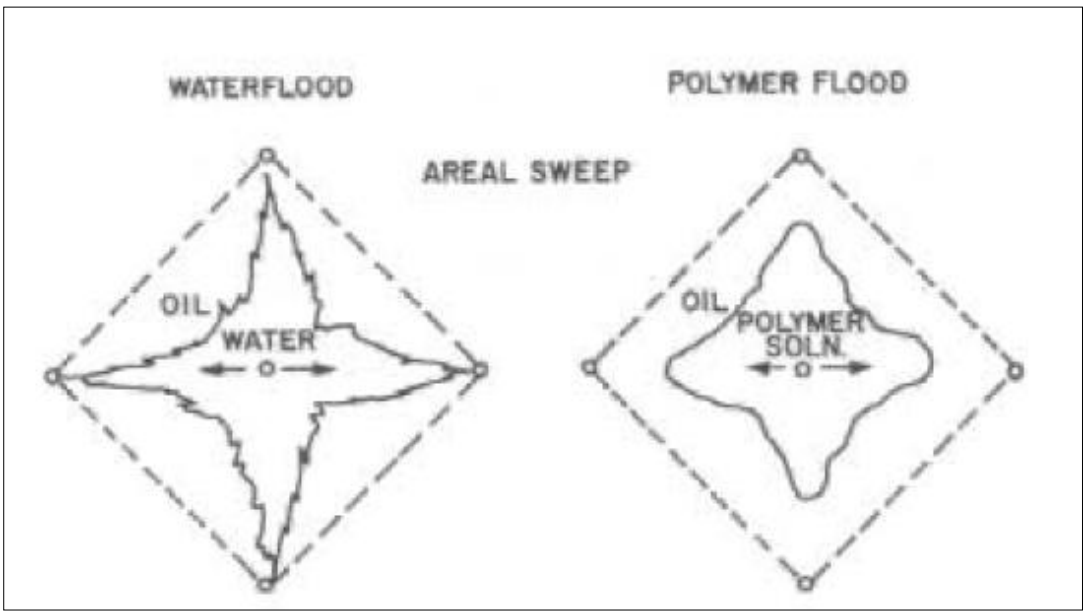

Figure 1: Areal sweep schematic diagram showing mobility control with a polymer solution.

The same phenomenon occurs in the vertical plane of the well, as shown in Figure 2. In fact, the poor sweep efficiency of water injection is made more pronounced by the vertical permeability variation encountered in most reservoirs. As shown in the figure, the majority of the flow is travelling through a relatively small percentage of the total reservoir height.

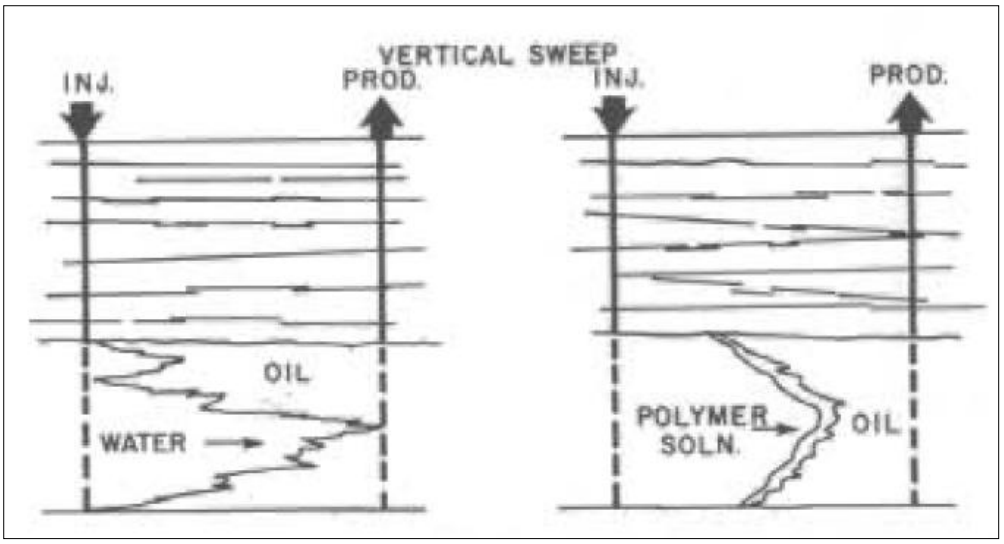

Figure 2: Vertical sweep schematic diagram showing mobility control with a polymer solution.

Through mobility control, polymers improve oil recovery by changing the fractional flow characteristics of the oil and water flowing through the porous media. Volumetric sweep efficiency is improved because of the decreased mobility ratio. A decrease in mobility ratio means that more oil is produced for a given volume of water injected. Large mobility ratios denote inefficient displacements.

Resistance factor:

Resistance factor is a term referring to the relative pressure drop caused by polymer solutions in porous media, and normally only applies to polyacrylamide solutions. If a solution of polyacrylamide is passed through a reservoir core at a constant rate, the pressure drop of the system is much greater than would be calculated by the viscosity change using Darcy's law. This effect is caused by the polyacrylamide adsorbing onto the walls of the rock pore spaces and restricting flow.

Resistance factor, R, is defined by the following equation:

$$R = M_w/M_p = (k_{rw}/\mu_w)/(k_{rp}/\mu_p)$$

where M_w = mobility to water; M_p = mobility to polymer; k_{rw} = water relative permeability, mD; k_{rp} = polymer relative permeability, mD; μ_w = water viscosity, cP; and μ_p = polymer viscosity, cP.

Injectivity behaviour:

The injectivity behaviour of a polymer solution is one of its most important characteristics. Polymer solutions with good injectivity behaviour are necessary for successful field use. Systems with poor injectivity behaviour must be physically or chemically treated before field injection. This treatment can be very expensive and severely affect the overall economics of a polymer flooding operation.

Poor injectivity behaviour may be caused by:

1- Incompatibility between the polymer and its makeup brine.

2- Incompatibility between the polymer solution and the formation rock.

3- Contamination, which can result from the polymer manufacturing process or makeup water.

Wellbore profile control:

The second important function of polymers is the improvement of vertical sweep efficiency around the vicinity of injection wellbores. Figure 3 shows schematically the process of profile control. The top diagram shows the floodwater fingering through a high-permeability streak. The bottom picture represents the same formation after being treated by a gelled solution, which lowered the relative permeability of the streak allowing more of the water to sweep the rest of the formation.

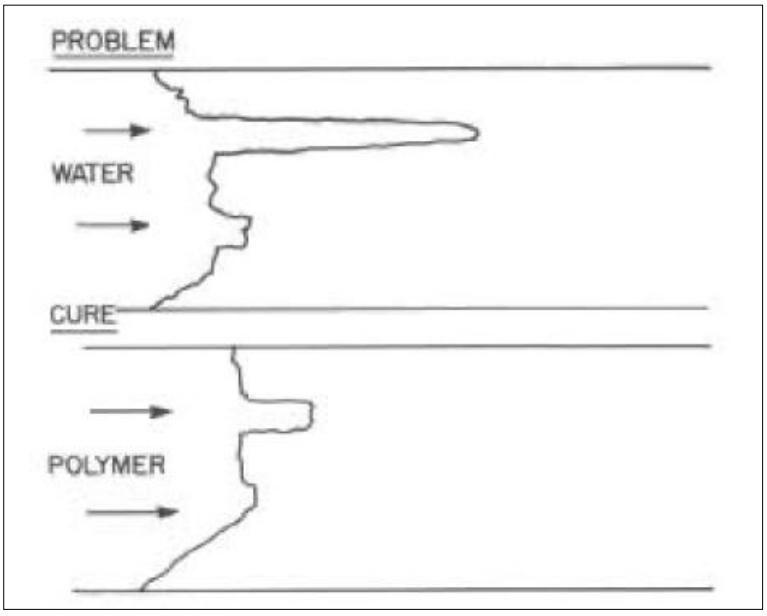

Figure 3: Diagram showing water breakthrough in high-permeability streaks being controlled by crosslinked polymers.

In profile control treatments, solutions contain higher concentrations of polymer than do the solutions designed for mobility control. Additionally, the polymer can be gelled or crosslinked to increase moleculer weight and further restrict the flow of water.

Planning polymer flood projects:

The chemistry of polymers must be considered from the very beginning of the polymer flood design. The salinity of the injection and formation waters dictate both the type and the concentration of polymer to be used. Water must be of high quality to avoid injection-well plugging. The amount of water needed for the project depends on the response of the producing zones to more favourable water/oil mobility ratios.

At the outset of the polymer flood design, the reservoir must be screened to determine if it is suitable for this type of EOR process. The various options for polymer treatment must also be considered. Design criteria for mobility control projects differ from wellbore profile control projects. If the project is to be a mobility control project, then a rather large slug of polymer is injected, beginning early in the life of the waterflood. On the other hand, remedial wellbore profile control treatment use small slugs of crosslinked polymer.