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Analysis of geological and physical characteristics of hydrocarbon reservoir effect on the polymer flooding

Tomsk Polytechnic University

Soboslai M.G.[a]

[a] School of Energy Engineering, Tomsk Polytechnic University

Abstract
In the context of «aging» of oil fields and unstable prices for oil, enhanced oil recovery methods are becoming especially topical. At present the average global oil recovery factor (ORF) is around 35 % of the initial reserves associated with the use of secondary methods that increase the reservoir recovery rate, mainly by water injection. In such a case, some extracting companies deem it necessary to use enhanced oil recovery methods starting from the very beginning of field development. Technologies, which allow increasing the ORF, include polymer flooding whose significant advantage, in comparison with other chemical methods, is a low risk and a wide range of application. The technology involves injecting water into the reservoir with an addition of polymer to increase reservoir volumetric efficiency by increasing viscosity and water-oil mobility ratio. At present the polymer flooding method is used both at light oil fields and heavy oil fields. Polymer used in this technology can withstand high temperatures and mineralization for a long period.
As a rule, polymer flooding is used either in the context of unfavorable mobility ratio in the course of water-flooding or when there is a certain degree of inhomogenuity of the reservoir when a polymer injection can help decrease water mobility in high-permeability areas by supporting oil displacement from low-permeability areas.
The article reviews the main peculiarities when designing polymer injections into oil-bearing reservoirs, formulates criteria for the selection of fields and reservoirs.

Keywords: Well test, polymer flooding, injection performance enhanced, geological and physical characteristics, oil recovery (EOR); Daqing Oilfield; flow deviation technology, polymer flooding, pilot project (PP) with polymer flooding;

1. Introduction

A tendency towards a rapid increase in the number of "aging" oil fields, characterized by a decrease in the level of oil production, and a high increase in the water cut of the produced products is observed. The oil recovery factor, as a rule, keeps approximately 0.35%, and significant volumes of so-called hard-to-recover oil remain behind the displacement front, which is practically impossible to recover by traditional methods.

In this regard, the high-quality withdrawal procedures of existing reserves are of crucial importance, and therefore the issues of development and improvement of field development technologies at later stages should be given maximum attention from oil companies and science in general.

Polymer flooding is one of the technologies that enable to increase the oil recovery factor. The technology includes the water injection with polyacrylamide into the reservoir to improve the sweep efficiency due to an increase in viscosity, as well as the ratio of water and oil mobility. The displacement front is aligned and the number of highly permeable channels decreases [1].

2. Materials and methods

The first stage and the most important in the application of the polymer flooding is that to consider the geological and physical conditions. In recent years, the range of application conditions for polymer flooding has expanded significantly. Polymer flooding is used in both terrigenous and carbonate reservoirs. Currently, the polymer flooding can be used even in fields where earlier this technology of enhanced oil recovery was impossible to apply. Researches in the petrochemical industry have made it possible to create polyacrylamides that are more resistant to temperature, mineralization and shear coefficient. Special protective additives have been developed to increase the stability of polymers in harsh environments. In addition, new developments in equipment designed specifically for polymer flooding with the specifics of the injection process increase the overall efficiency of polymer solution injection and minimize the risks of its degradation before entering the reservoir. Thus, today polymer injection is carried out at high temperature, salinity and in reservoirs with heavy oil, which was previously impossible [2]. Modern polymers provide effective application satisfying several main parameters:

Table 1. Polymer flooding parameters

Reservoir characteristics	Current range of application
Permeability, μ	0,01 - 10
Temperature, °C	> 140
Oil in-place, cP	> 13 000
Oil density, kg/cm3	> 965,9
Salinity, g/l	< 280
Oil saturation, %	> 20

As can be seen from the characteristics that satisfy the basic requirements of the polymer flooding the permeability of the formation, the temperature and the salinity of the formation water play an important role. It should be noted that the application of the polymer flooding in carbonate reservoirs requires a good study and thorough laboratory studies to select the most effective petrochemistry since carbonates reservoir content the ions such as Ca2 + and Mg2 + , hence, the polymer precipitates with magnesium and calcium salts. ...

One of the main parameters is the target viscosity (resistance coefficient) of the injected agent. In the case of a heterogeneous reservoir in the presence of cross-flows between reservoirs the calculation using Darcy's law shows that the ideal viscosity should be: μ polymer = mobility ratio * permeability contrast [3].

Permeability contrast can be calculated as the ratio of the highest permeability interlayer to the permeability of the lower for adjacent cross-flow layers. In the absence of cross- flows, this term can be removed from the equation simply by considering the mobility ratio. Explanation [3] describes in detail in the case of Daqing, where the end point mobility ratio is 10, and the permeability contrast is 4, which gives an optimal polymer viscosity of 40 cP. In some heavy oil fields, this strategy is barely applicable taking into account the required viscosity and the associated costs (excluding injectivity aspects). To consider heterogeneity the target value for the mobility ratio must be below 1.

The sweep efficiency, especially for a watered formation, is influenced by the mobility ratio of the displacing agent ($\lambda_{в}$) to the mobility of the displaced agent (λ_{o}): $M = \frac{\lambda_o}{\lambda_w} = \frac{\frac{\mu_o}{Kro}}{\frac{\mu_w}{Krw}}$

where, Krw is the relative permeability of water; Kro is the relative permeability of oil; μw- effective water viscosity; μo - effective oil viscosity.

When oil is displaced by water, the mobility ratio (M) is usually greater than one, since the viscosity of water is usually less than the viscosity of oil. This leads to water breakthroughs in the direction of the fluid withdrawal and causes rapid watering of the wells.

A number of polymer compositions contribute to selective plugging of high-permeability zones of the producing interval, resulting in flow redistribution, flooding profile conformance that makes it possible to increase the penetration rate of the displacing agent into the area of lower permeability (Fig. 1). As a result, the displacing agent can cover an additional area that usually could not be reached before and displaces oil not only from highly permeable seams, but also from less permeable intervals that become involved to the developing process that increases the efficiency of the flooding process (Fig. 2).

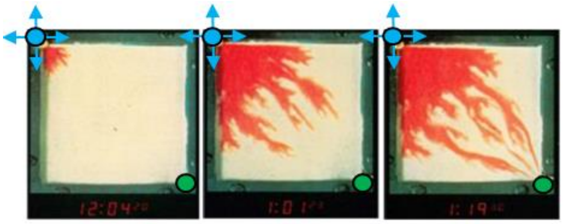

Fig 1. Mobility ratio >1 (Water)

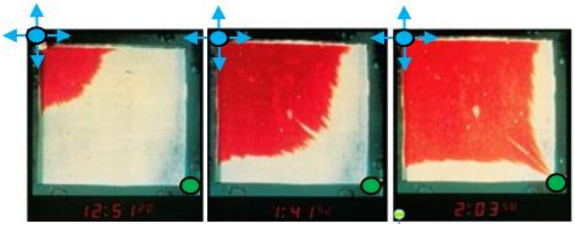

Fig 2. Mobility ratio <1 (Polymer)

Due to an increase in the viscosity of the displacing agent, additional resistance appears in the formation. The pressure for injecting polymer solutions into the reservoir must be higher than the waterflooding pressure. Increasing the injection pressure is necessary to maintain the well injectivity and maintain reservoir pressure. The viscosity of a polymer is a consequence of the interaction between macromolecules with a certain hydrodynamic volume in a solvent. The rupture of polymer molecules in order to reduce particles will lead to destruction, which will lead to a decrease in flooding efficiency

There are three types of polymer degradation:

Chemical destruction - the formation of free radicals occurs, which is a consequence of the interaction of polymer molecules and oxygen. The polymer must be dissolved in water before being injected into the reservoir. Water contains elements that are capable of reacting with such elements as: oxygen O_2, hydrogen sulfide H_2S, iron Fe^{2+}, etc. As a result of the interaction of the oxidizing agent and the reducing agent, free radicals arise, the polymer is destroyed. Fig. 3 shows the chemical degradation of the polymer at 46 ° C using NaClO.

Mechanical destruction occurs when a certain jump in velocity is applied to the polymer backbone chain of a high shear stress. "Critical points" are chokes, valves and certain pump types, as well as the type of well completion. Separation of the polymer into individual parts occurs under the shear. As a result of this process, free radicals are formed, which, as in the case of chemical destruction, are capable of destroying polymer molecules in the course of a chain reaction. The main shear is observed in the discharge line. Shear can also be observed when fluid flows through pumps or in the bottomhole zone. In pipes and equipment, during polymer flooding, it is recommended not to exceed the fluid flow rate of more than 5 m / s [4, 5]. Figure 4 shows the shear destruction of the polymer through a 1.75 mm perforation.

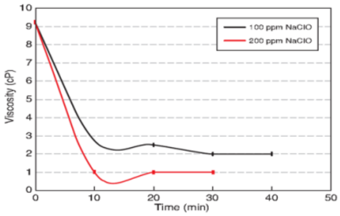

Fig 3. Chemical destruction

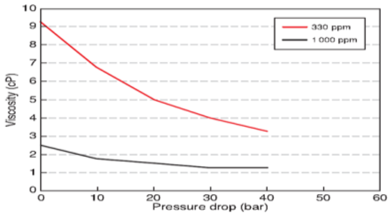

Fig 4. Shear destruction

Thermal destruction develops under the influence of reservoir conditions including temperature. Precipitation reactions between hydrolyzed PAM and divalent ions of formation water ($Ca2^{+}$,$Mg2^{+}$) occur on the basis of partially hydrolyzed polyacrylamide, the reaction leads to a loss of viscosity of the injection solution. Polymer hydrolysis can also occur at low temperatures (50 °C) at certain pH values of the solution. This process will lead to an increased anionicity of the polymer, as a result of which calcium and magnesium salts will precipitate the polymer. Therefore, at high temperatures, a polymer with low anionicity or with a low apparent viscosity should be chosen [6,7].

3. Conclusion

Thus, the polymer flooding technology is one of the promising technologies that will be actively implemented in the coming years. The use of this technology leads to significant changes in flows in the porous medium of the reservoir, in this regard, the choice of polymer and analysis of the geological and physical characteristics of the reservoir when choosing a polymer is an important part in the process of polymer flooding.

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