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МОДЕЛИРОВАНИЕ ПОЛИМЕРНОГО ЗАВОДНЕНИЯ В ОДНОЙ ИЗ ИРАНСКИХ ЗАЛЕЖЕЙ ТЯЖЕЛОЙ НЕФТИ

SIMULATION OF POLYMER FLOODING IN ONE OF IRANIAN HEAVY OIL RESERVOIR

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Аннотация. Полимерное затопление является наиболее важным процессом повышения нефтеотдачи (МУН), улучшающим соотношение подвижности воды и нефти. Полимеры действуют в основном, увеличивая вязкость закачиваемой воды и уменьшая проницаемость зоны качания, подтверждая увеличение эффективности вертикальной и поверхностной развертки закачки воды и, следовательно, увеличивая добычу нефти.
В данном исследовании, первоначально на основе экспериментальной работы, были исследованы свойства полимера и концентрация раствора полимера. Затем было смоделировано полимерного заводнения.

Ключевые слова: иранский резервуар тяжелой нефти, полимерное затопление, эксперимент, моделирование.

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Annotation. Polymer flooding is the most important enhanced oil recovery (EOR) process, improving the water-oil mobility ratio. Polymers act basically increasing the viscosity of the injected water and reducing the swept zone permeability, approving an increase in the vertical and areal sweep efficiency of the water injection, and, consequently, increasing oil recovery.
In this study, initially based on experimental work the polymer properties were investigated the concentration of polymer solution. Then the polymer flooding was simulated in different scenarios.
This study shows the optimum concentration could improve polymer properties.

Keywords: Iranian heavy oil reservoir, polymer flooding, Experiment, Simulation.

There is now a general agreement that the oil and gas resources most easily recovered have already been discovered [1]. Heavy oil and bitumen sources are required to be produced by new technologies to catch future needs in the energy market. The economical and environmental obstacles according to the application of thermal methods in deep and thin reservoirs are crucial challenges for the oil and gas industry not only in North America, but also in other spots such as Latin America, Middles East, and China. The most costly step in a thermal process like SAGD is the required energy for turning water into steam. This makes such type of recovery processes to be cumbersome in terms of energy supply and usage. Fresh water supply which is an environmental concern is also another example of associated drawbacks with the thermal methods [2].

One of the most essential techniques for enhancing oil recovery is waterflooding or water injection, which is categorized as a secondary recovery method. Water injection into a reservoir results in a phenomenon called voidage replacement in which we intend to deliver pressure support to the reservoir. Ultimate reservoir dynamic performance and recovery assessment in water flooding process has been extensively studied and evaluated during past few years [2–8]. This method which is the most common practice implemented at the end of primary production have potential problems associated with. Considering the issues and challenges related to the application of water-flooding in heavy oil reservoirs, polymer flooding has become a more desirable choice for EOR processes than waterflooding.

The objective of this study based on the results of experimental study of polymer flooding in heavy oil reservoirs [9–10]. we simulate different scenario with different concentration and check the results of the experimental study.

Experimental studies of polymer flooding were carried out on a special filtration unit using a core holder with dimensions of 12–4 cm to study the effect of viscosity of the polymer solution and heterogeneity of the porous medium on the increase in oil production after flooding.

In this work was selected polymer HPAM in sea water for polymer solution for the study. In the framework of the presented study, we studied the effect of the polymer concentration in the solution on the recovery of heavy oil from the formation.

Table 1 – Property of the sample

Parameter	Value	Unit
Reservoir temperature	100	°C
Oil Density	948	kg/м³
Oil viscosity	204	cp
permeability	0,01	мкм²
Porosity	18	%
Type of reservoir	Sand stone	–

To simulate changes in the properties of the polymer solution in reservoir conditions, the polymer solution prepared on the basis of sea water was placed in a thermostat at a temperature of 100 °C.

Under these conditions, the state of the polymer solution was evaluated within four weeks after the start of the experiment, the results are shown below. All measurements were done by Rheometer Antonpaar.

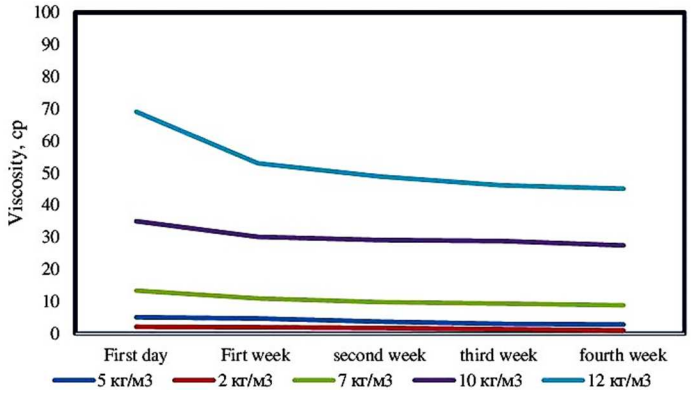

Figure 1

Based on rheological studies, it can be concluded that the polymer concentration below 3 kg/m^3 is not very suitable for flooding. Subsequently, experiments were carried out on polymer flooding with a concentration of 2, 5, 7, 10 and 12 kg/m^3. The experimental results are given below.

An analysis of the results shows that with an increase in concentration from 2 to 5 kg/m^3, an increase in oil recovery of up to 13 % is observed, with an increase in concentration from 7 to 12 kg/m^3, the increase in oil recovery is approximately the same – 27–29 % and practically does not depend on increase in the concentration of the polymer solution. The dependence of the increase in the oil recovery coefficient during polymer flooding after water flooding on the polymer concentration in the solution is shown in Figure 1, 2. Under these conditions, it can be assumed that the threshold value of the rational polymer concentration during polymer flooding does not exceed 7 kg/m^3. The above is markedly correlated with the results of the authors' studies [13, 14], who also noted the irrationality of the excessive increase in the concentration of the polymer solution, and, consequently, the viscosity of the polymer solution. In this case, commercial introduction may require a change in concentration, taking into account the sorption of the polymer by the porous medium, and various types of destruction. Excessive concentration can not only not be economically justified, but also not give a significant technological result.

The main objective of polymer flooding is to control the viscosity of water by adding polymer to the injected water to reduce its mobility. The decrease in the relative permeability of water that occurs as a result of polymer adsorption is not as obvious as in the case of rocks with low permeability. The greatest benefit from flooding polymers is to increase the viscosity of the aqueous phase, which improves driving efficiency.

As indicated [9, 10] and experimental results, a methodology was developed to determine the rational value of the viscosity of the polymer, and by this method we determined the optimal value of the polymer concentration.

We consider a polymer with a concentration of 2 kg/m^3, 5 kg/m^3, 7 kg/m^3 and use the ECLIPSE 100 simulation package, simulate the studied field.

The reservoir model consists of three layers (grid size) with different values of permeability and porosity. In this case, the following average values of permeability and porosity were set in layers: for the upper layer k_1 = 100 mD and m_1 = 18 %, for the middle layer k_2 = 30 mD and m_2 = 15 %, for the lower k_3 = 200 mD and m_3 = 21 %. The spread in the values of porosity and permeability of formations is in the range of 10–600 mD and 8–24 %. The image of the model is shown in the figure 3, 4.

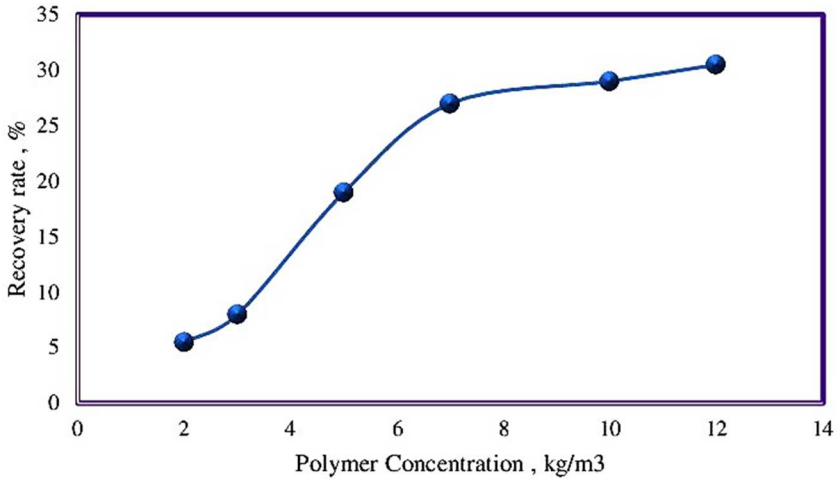

Figure 2

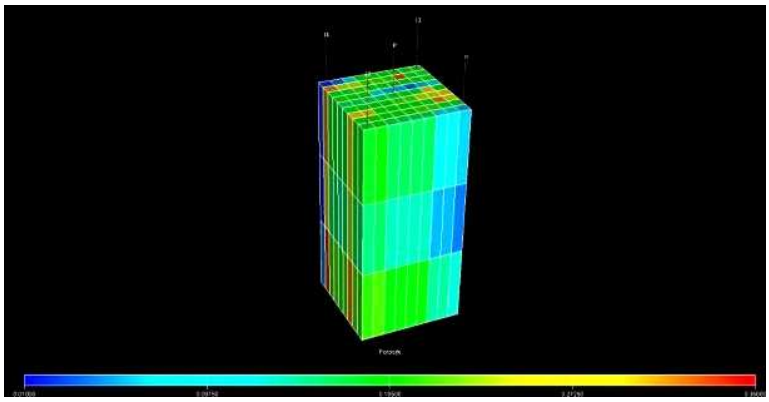

Figure 3 – The reservoir model with a porosity distribution

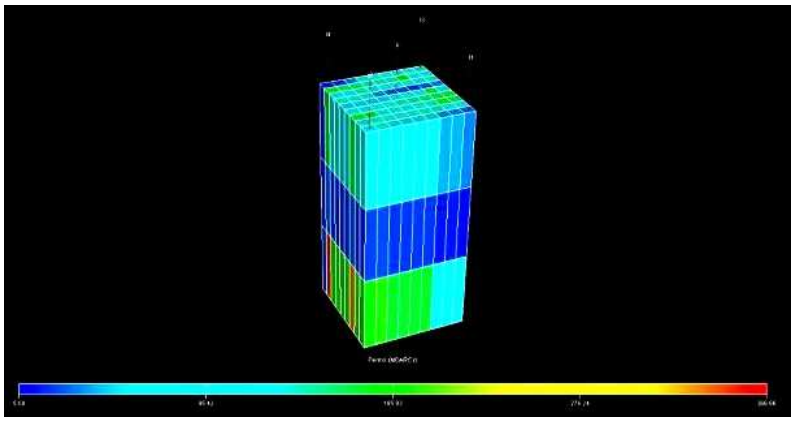

Figure 4 – The reservoir model with a permeability distribution

We consider a polymer with a concentration of 2 kg/m^3, 5 kg/m^3, 7 kg/m^3 and use the ECLIPSE 100 simulation package, simulate the studied field.

Based on the results of the above experiments, the following conclusions are made:

1. Polymer water flooding can increase oil recovery in the studied conditions, when displacing heavy oil with a viscosity of 204 mPa·s.

2. For effective polymer flooding of a heavy oil formation, the concentration of the polymer solution should not be lower than the threshold value of the rational concentration. For the experimental conditions presented in this article, the threshold concentration is about 5–7 kg/m^3.

3. In field conditions, it should be higher to take into account the processes of polymer sorption and degradation of the polymer solution.

In conclusion, it can be noted that polymer flooding is not only a promising technology for the extraction of heavy oil, but is already now effectively used by companies operating fields containing heavy, extra heavy oil.

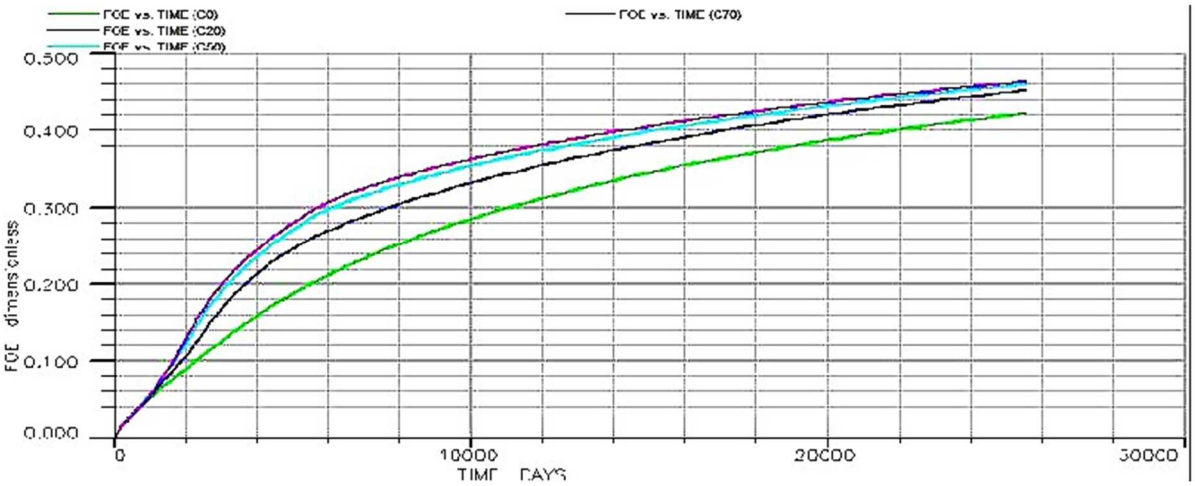

Figure 5 – The results of the simulation

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