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An overview of polymer-based conformance treatment from past to present

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Abstract

Conformance treatment becomes significant not only because of the matured oil fields but also as a means to improve the oil recovery. In relation to this, polymer-based systems show their applicability to the conformance treatments with various materials and methods. However, there are many issues limiting the performance of the present technique. Herein, this poster introduces conventional methods, commercial products, and recent developments, including their principles and the limitations.

Methods

There exist many different methods based on the polymers shown above. In general, they are categorized according to where the gelation occurs; in-situ gel and preformed gel. These two gel systems can be sub-categorized by whether it forms 3-D network or particles (in the case of in-situ gel) and by the size of the particles (in the case of preformed gel) [table 1].

General problems

The different methods of EOR and the issues within reservoirs are shown in [figure 3 and 4]. However, no matter which methods are used, many problems can limit the EOR treatments. In this regard, [figure 5] shows the possible problems within reservoirs. Apart from the adsorption, the early gelation also causes a plugging behavior. On the contrary, the delayed gelation (or no gelation) can result in wash-off. With respect to this, [figure 6] shows parameters that can cause loss of gelation control together with some other issues.

Solutions

The terpolymer of PAM, AMPs, and VP shows better stability than the single PAM system [ref. 1]. The further advanced systems have been achieved by different monomers and crosslinkers shown in [figure 7]. As the degree of hydrolysis increases, the degree of crosslinking cannot be controlled and the gel can be precipitated out. Therefore, the functionalized PAM, such as [3, figure 7], can protect the amide group. Furthermore, cationic monomers can be used for controlling the adsortion on rocks [5, figure 7].

Two zwitterionic monomers are shown in [6 and 7, figure 7]. The zwitterionic polymers can self-assemble in a solution, of which the viscosity is well-maintained regardless of the salinity. Furthermore, the zwitterionic polymer gel binds to water molecules better than any other polymer gels do [ref. 2].

The organic crosslinkers are less sensitive to the environments within reservoirs, which gives better control and stability. Furthermore, ester-bearing crosslinkers, such as PEGDA, can be hydrolyzed at a high temperature. Brightwater®), which is nano gel system, utilizes PEGDA as one of the crosslinkers. Therefore, it is often considered as a thermo-responsive gel system.

Further development

Further advanced methods are achievable by different polymer systems such as self-healing polymers and stimuli-responsive polymers. The gel made of thermo-responsive polymers can expand its volume by temperature change [a, figure 8][ref. 3].

The self-healing gel polymer shows gel sol transition depending on the shear stress. Therefore, the preformed bulk gel can be easily injected and then behave as a gel when it reaches in-depth reservoirs [b, figure 8]. Furthermore, the PPG system made of self-healing polymers can increase its particle size by recombination [c, figure 8][ref. 4].

Table 1. The variety of methodologies for polymer systems.

<table>
<thead>
<tr>
<th>Method</th>
<th>Characteristics</th>
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</thead>
<tbody>
<tr>
<td>Bulk gel</td>
<td>Inter- and intra-molecular crosslinking</td>
</tr>
<tr>
<td>CDG</td>
<td>Weak gel</td>
</tr>
<tr>
<td>Microgel</td>
<td>Performed gel</td>
</tr>
<tr>
<td>PPG</td>
<td>Nano-gel</td>
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</tbody>
</table>

Reference

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Figure 1. Monomers for synthetic polymer system (left) and bio polymers (right) for the conformance treatment. Synthetic monomers; acrylamide (AM), 2-Acrylamido-2-methylpropane sulfonic acid (AMPS), vinylpyrrolidone (VP), biopolymers; xanthan, chitosan, and hydroxyethylcellulose (HEC).

Figure 2. Structures of inter- and intra-molecular crosslinked polymer system and reversible (self-healing) bond. a. Inter-molecular crosslinking bond. b. Intra-molecular crosslinking bond. c. Reversible crosslinking bond. Polymer (black line), crosslinking bond (red circle), and reversible bond (blue and red).

Figure 3. Different methods for EOR by relative permeability modifier (RPM), a. Preformed particles (5), and plugging by bulk gel (6). The grey color indicates the polymer. The black arrows indicate the flow of either injected water or oil (c).

Figure 4. Possible near-wellbore (1 and 2) and far-wellbore issues (3, 4, 5, and 6) within reservoirs. The white arrow indicate the water (or injected fluid) flow. Leakage through the well can be caused by small fractures on tubes (1), or a small gap between two tubes (2). The flow through fractures is always faster than normal, which can cause an unequal flood front. This behavior can result in direct channeling between injection and production well (6). The connection between production well and the aperture, where the water is produced, can cause water production (4). Washout or channeling can cause a thief zone where injected fluid is wasted (5).

Figure 5. Adsorption (a) and syneresis (b) of polymer gel within reservoirs. (a) the plugging area is highlighted with blue color. The early adsorption limits the correct placement of the gel and then ends up plugging the pores. This unwanted plugging behavior results in injection problems after all. (b) the syneresis, or dehydration decreases the volume of the gel, which can be washed off later.

Figure 6. Parameters that can cause problems within reservoirs.

Figure 7. Structure of the repeating units (3-7) and crosslinkers used in commercial products. Polyethyleneimide (PEI), hexamethylene diamine (HMTA), hydroquinone (HQ), polyethylene glycol diacrylate (PEGDA), N, N’-methylene bisacrylamide (MB). HMTA is used for the source of formaldehyde. Ester-bearing crosslinkers, such as PEGDA, can be hydrolyzed at high temperature.

Figure 8. Volume expansion of the gel (a), gel-sol transition of self-healing polymer bulk gel (b), and recombination of particle gel made of self-healing polymers (c).