Comparison of Xanthan and HPAM Solution Rheology in Berea Sandstone

Syringe Pump Application Note
AN11

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Introduction

Rheology in porous media has an important impact on enhanced oil recovery (EOR) projects where polymer solutions are used. If the effective viscosity of the polymer solution is large at the high velocities experienced near an injection well, the rate of polymer injection, and of oil production may be decreased. On the other hand, if the effective viscosity of the polymer solution is too low at the low velocities experienced deep in a reservoir, oil displacement may be inefficient. In this report, we employ Teledyne ISCO 1000D Syringe Pumps [see note] to examine how the effective viscosity (i.e., the resistance factor) in Berea sandstone varies with flow rate (actually with flux or superficial velocity) for solutions of the two polymers that are most commonly used in EOR—xanthan and partially hydrolyzed polyacrylamide (HPAM).

Experimental Procedures

The xanthan had a molecular weight of 15 million Daltons, while the HPAM had a molecular weight of 21 million Daltons and degree of hydrolysis ~30%. Both polymers were prepared in synthetic seawater (4.195% seasalt in distilled water). The polymer concentration was 0.1% for both cases.

The Berea sandstone cores were cast in a metal alloy, each with two internal pressure taps—one located 2 cm from the inlet sand face and one located 2 cm from the outlet sand face. The cores had three sections, with a central section length of 10 cm. Permeabilities were fairly uniform through the cores, averaging about 550 md. The core cross-sections were 11.34 cm^2, porosities were 0.217, and the pore volumes (PV) were 36 cm^3.

Four Teledyne ISCO 1000D syringe pumps were plumbed in parallel (Figure 1). These pumps were ideal for this study because they provided stable flow and a wide range of rates. Pressures were measured with quartz transducers. Experiments were performed at room temperature.

Polymer solutions were injected using a wide range of rates to determine the rheology in porous media. For both polymers, several liters of solution were forced through a core (separate cores for each polymer) at 139 ft/d flux to imitate the shearing experienced near wellbore in a field application. The effluent was then re-injected into the same core using a variety of rates to imitate flux values experienced as the fluid flows radially away from the wellbore.

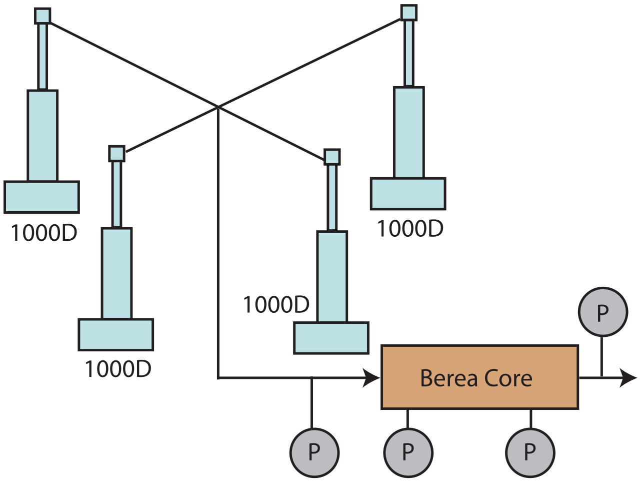

Figure 1: Schematic of pumps and core configuration

Xanthan Solution

For the xanthan solution (solid circles in Figure 2), re-injection rates varied from 0.5 to 32,000 cm^3/hr, translating to fluxes from 0.035 to 2,222 ft/d and frontal velocities from 0.16 to 10,240 ft/d. For flux values below 10 ft/d, the xanthan resistance factors (apparent viscosities in porous media relative to water) fit nicely using a power-law model, with a power-law index of 0.54 (i.e., slope of the log-log plot was -0.46). As flux increased above 10 ft/d, resistance factors approached a fixed value of 2.5 (i.e., in the "second Newtonian region"). Our rates were not sufficiently low to observe a "first Newtonian region."

HPAM Solutions

For the pre-sheared HPAM solution, polymer re-injection rates varied from 2 to 8,000 cm^3/hr, translating to fluxes from 0.14 to 555 ft/d and frontal velocities from 0.64 to 2,550 ft/d. The open circles in Figure 2 plot resistance factors for this pre-sheared HPAM solution. They showed a very mild shear-thinning behavior, with a slope of -0.085 (power-law index of 0.915). Thus, the rheology in porous media for this HPAM solution was nearly Newtonian.

In the same core (where pre-shear HPAM was injected), we injected the freshly prepared HPAM solution using flux values ranging from 0.14 to 1,110 ft/d. The open triangles in Figure 2 plot HPAM resistance factors for this un-sheared polymer. Resistance factors showed a very mild shear-thinning behavior, with a slope of -0.2 (power-law index of 0.8). This behavior was slightly more shear thinning than the pre-sheared HPAM but much less shear thinning than the xanthan solution.

At the lowest flow rates (i.e., at 0.14 ft/d flux), resistance factors were 2.9 times greater for the un-sheared HPAM than for the pre-sheared HPAM, but were still 2.4 times less than for xanthan. Larger resistance factors at low fluxes are desirable since fluid velocities are low in most of the reservoir, and most oil will be displaced at low velocities.

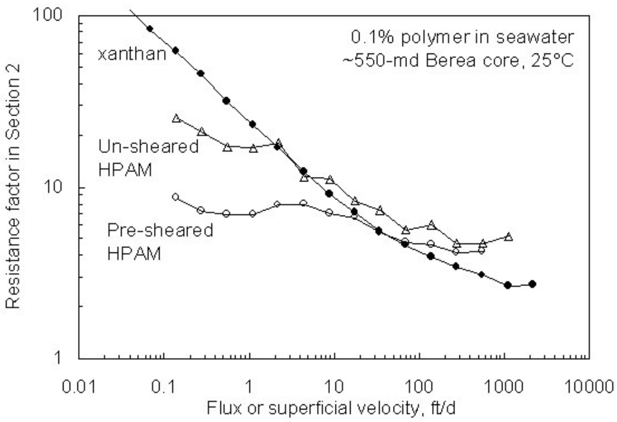

Figure 2: Resistance factors in Core Section 2 versus flux

Fluid velocities tend to be high near injection wells, so resistance factors at high velocities directly impact injectivity. At 550 ft/d flux, resistance factors were about the same for the un-sheared HPAM than for the pre-sheared HPAM, and were 35% greater than for xanthan.

Conclusions

Using Teledyne ISCO 1000D syringe pumps, we injected xanthan and HPAM solutions using a wide range of rates to determine the rheology in porous media. The xanthan solution exhibited shear-thinning rheology in porous media, while the HPAM solutions showed slight shear thinning. At low velocities typically experienced deep within a formation, the resistance factor (effective viscosity in porous media) provided by xanthan was 2.4 times greater than that for un-sheared HPAM, and about 7 times greater than that for HPAM that was first forced through a core at a typical near-wellbore flux (139 ft/d).

Note:

The 1000D model pump, which was used during the original experiment, is discontinued. Current model 1000x is the recommended replacement for the older 1000D model.

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Product model names have been updated in this document to reflect current pump offerings.

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