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Advanced Flow Analysis of Viscoelastic EOR Polymers in Porous-media-resembling Micromodels

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Abstract

Subsequent to the initial production phases, chemical enhanced oil recovery (EOR) methods such as polymer flooding are applied to oil reservoirs in order to increase its lifetime and production. Although polymer flooding is widely used, its viscoelastic flow effects, namely shear thickening and elastic turbulence, are not fully understood. Therefore, this work focuses on the investigation of viscoelastic flow behavior in real porous media resembled by a glass micromodel. Thereby, streamline visualization and pressure response measurements during polymer flooding in Glass-Silicon-Glass (GSG) micromodels were performed.

For evaluation purposes, a 1 µm polystyrene tracer is added to the aqueous polymer solutions that are injected subsequently into the quarter-of-a-five-spot micromodel. The GSG micromodel, resembling real porous media, is placed under an inverted epi-fluorescence microscope equipped with a CCD high speed camera to enable particle tracing during flooding experiments. Furthermore, a sensitive differential pressure sensor (0-30 bar) allows an extensive quantitative flow characterization of EOR polymers (apparent viscosity and fluid flow mechanics parameters). The experimental workflow consists of two steps, namely (1) permeability measurement and (2) differential pressure measurement with an additional streamline visualization.

Experimental results show that a change in polymer concentration, solvent salinity, induced degradation condition as well as molecular weight, has a direct impact on the elastic turbulence, observed in most cases at high shear rates (> 100 s-1). By that, the onset and degree of elastic turbulence decreases with an increase in concentration, decrease in brine salinity and increase in polymer molecular weight. The impact of induced mechanical degradation conditions appears to be insignificant. Moreover, it was possible to describe the main characteristics of elastic turbulence in porous media, namely streamline crossing, vortices and spontaneous changes of the flow direction. Additionally, a comparison of experimental results and rheometer data shows a distinctive correlation between the onset of elastic turbulence and the relaxation time (a quantity of polymer viscoelasticity). Finally, the broad quantitative and qualitative polymer flow analysis reveals that elastic turbulence during polymer flooding causes an additional pressure drop in porous media which results in the shear thickening behavior. As a consequence, the viscosity of the injected polymer solutions start to increase again with an increase in shear or rather flow rate.

The polymer flow analysis performed in the state-of-the-art GSG micromodels contribute to a better understanding of the viscoelastic flow behavior of polymers in porous media and thereby, a correlation between viscoelastic fluid properties and elastic turbulence is shown. Moreover, elastic turbulence is believed to enhance oil recovery and therefore, 2-phase floods are planned in the next step of this research. Furthermore, the polymer flow evaluation procedure used in this work can be implemented as a standard evaluation procedure in the E&P industry prior to polymer flooding in the field.