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Effect of CO2 dissolution on elastic instabilities of the polymer through porous media

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CO2 flow in porous media often results in poor reservoir sweep efficiency. To mitigate this problem alternate injection of a polymer solution and CO2, known as Polymer-assisted Water-Alternating-Gas (PA-WAG), is applied. The objective of PA-WAG is to improve mobility control, thus sweeping a larger part of the reservoir. Therefore, it is of great importance to study the effect of CO2 and polymer interaction to address the feasibility of PA-WAG.

The objective of this study was to investigate the impact of CO2 dissolution on (a) physical polymer properties (e.g., viscosity and pH), and (b) elastic instabilities of polymer flow in porous media. The following experiments were performed. Firstly, an ATBS-based polymer (SAV 10) solution was prepared in synthetic seawater in an oxygen-free environment. The polymer solution was afterward saturated with CO2 at the reservoir conditions (i.e., T=40 degrees Celsius and P=20 bar) and then it was forced through a capillary while maintaining the same temperature and pressure. Consequently, the apparent viscosity and pH were recorded in real time over the course of 29 days. The CO2 molar concentration in the polymer solution was around 0.3 mol/L which was the solubility limit of CO2 in water at the reservoir conditions. Secondly, the polymer solution with and without the dissolved CO2 was injected into a microfluidic system of periodic arrays of circular pillars in a staggered layout at negligible inertial effect. Apparent viscosity was measured at various shear rates (or Weissenberg numbers). Moreover, the instabilities of polymer flow through porous media were visualized using an inverted fluorescence microscope connected to a high-speed camera.

As a result of the flow of CO2-saturated polymer into the capillary, the viscosity dropped to around 53.5 of its initial value after one day but recovered some of it, and after 29 days, the polymer maintained around 83.5 of its initial viscosity. The initial decrease was due to the formation of carbonic acid and neutralization of the charges on the polymer backbone leading to a decrease in both pH and viscosity. The recovery of viscosity was because of the evolution of the ammonium ion due to the hydrolysis of the amide groups resulting in an increase in pH as well as viscosity. Moreover, the CO2 dissolution had the following impacts on the viscoelasticity of the polymer: (a) under a rheometer, it delayed the onset of shear-thinning from 4.2 1/s to 10.0 1/s (b) in the microfluidic, it also delayed the onset of shear-thickening from 15.5 1/s to 20.5 1/s. Elastic flow instabilities beyond the onset of shear-thickening were evident from visualization of the flow streamlines. We present the mechanism of the elastic instability and characterize it based on strong temporal fluctuations in pressure drop.

Participation

In-Person

References

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