Simulation Study of Wettability Alteration by Deep Eutectic Solvent Injection as an EOR Agent for Heavy Oil Reservoirs

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Abstract

Several oil fields in the world have already recovered the easy-to-produce oil and are now in the depletion period. Such fields need enhanced oil recovery (EOR) methods implementation to improve the recovery factor and maintain oil production rates economically. Deep Eutectic Solvents (DESs) are alternative classes of Ionic Liquids (ILs) which have been investigated as novel solvents for the chemical EOR. In this study, simulation of enhancing heavy oil recovery via Deep Eutectic Solvent injection was conducted.

Several coreflooding tests have been completed and modeled to study the effect of DES injection on the interactions of oil/brine/rock in the porous media. The performance of the Choline Chloride: Malonic acid mixture at two molar ratios (1:1) as DES1 and (1:0.5) as DES2 were studied at different temperatures. DES injection affected wettability and relative permeability of the fluids and enhanced the recovery of the oil. By applying the models to a pilot scale reservoir, for different scenarios, the DES injection approach as the tertiary recovery method was investigated and optimized. Different parameters such as DES injection rate, injection pore volumes, well patterns, and injection scenarios had been optimized for each case. Our results indicated that the wettability alteration from weakly water wet towards more water wet and mixed wet conditions was the dominant factor for the reduction of residual heavy oil saturation. DESs injection resulted in favourable and lower mobility ratio compared to the conventional waterflooding. At 45 ˚C, mobility ratio reduced by 26% in DES1 and 25.5% in DES2 compared to the waterflooding. With increasing the temperature to 80 ˚C, mobility ratio reduced by 84.8% in DES1 and 62.2% in DES2. Hence, temperature found to be a key parameter to improve the performance of DESs injection to modify the oil/brine/rock interactions. Furthermore, early breakthrough was observed to be less in DESs injection which improved the sweep efficiency. Our study showed that DESs display better performance as a tertiary recovery rather than the secondary. For 30 years injection, tertiary stage (waterflooding 20 years/DESs 10 years) increased the recovery by DES1 injection for 2-5% compared to the secondary injection. In addition, our screening study showed that DES1 worked better at lower reservoir temperature (about 45 ˚C) while DES2 was more active at higher reservoir temperature (>60 ˚C) in both secondary and tertiary recovery methods.

Our experimental and simulation studies showed the possibility of the application of DESs as cheap, non-toxic, recyclable, biodegradable and environmentally friendly chemicals for the EOR field applications. DESs injection methods are considered beneficial to enhance oil recovery due to their abilities to alter oil/water/rock interaction to more favourable condition, reduce mobility ratio, and improve the sweep efficiency at different heavy oil reservoir conditions.