Impact of Micro-Emulsion Phase Behavior on Near Wellbore Associated Emulsification Properties during Chemical Enhanced Oil Recovery

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Abstract. In several applications of chemical enhanced oil recovery, thermodynamically stable micro-emulsions can form under reservoir conditions. Due to reservoir pressure gradients, micro-emulsions can go through additional stresses which can change the apparent properties of micro-emulsions. These apparent changes in rheology should be accounted for in CEOR operations since they could affect the displacement efficiency.

In this paper, we compare the properties of Windsor Type I, III and II micro-emulsions before and after shearing. Alpha Olefin sulfonate (AOS) surfactant with crude oil and with a Mixture of Dodecane and Tetradecane were selected for the formation of oil-brine micro-emulsions in a 95C oven. In order to alter the phase behavior, NaCl concentration was incremented from sample to sample. In addition to the visual inspection and the viscosity measurements, micro-emulsion phase behavior studies before and after shearing were carried out using a low resolution Nuclear Magnetic Resonance (NMR) equipped with gradient coils. The average and spatial T2 along the sample length were conducted to confirm stability of micro-emulsions with temperature, oil type, and the range of salinity. In addition, pulsed field gradient (PFG) NMR technique was used to measure the diffusivity of dispersed oil and continuous water phases under the various conditions and vice versa. Also, the diffusivity measurements were used to identify discrete and bi-continuous phase structures along with the size and shape of the dispersed droplet. In order to simulate reservoir shearing forces, samples were emulsified using different techniques, which include rotor-stator homogenizer, and a micro fluidizer.

Prior to shearing, micro-emulsions exhibited two viscosity peaks at phase types III and II. Also, the viscosity was thinning by shearing around these two maxima. The Relative diffusivity of each component was calculated with respect to its free phase diffusivity. The oil and water relative diffusivity values for each sample were plotted against the corresponding salinity (phase type). The plot showed that the relative diffusivity of water was decreasing with increasing salinity while the opposite behavior was observed for the oil. Moreover, the intersection between the oil and water relative diffusivities at medium salinities (Windsor phase type III) indicated a bi-continuous structure. On the other hand, the disparity between the two components relative diffusivities at low and high salinities (Windsor phase type I and II) revealed discontinues droplet structures. Following the shearing process, the additional emulsified free phase experienced disaggregation as shearing was increased, evidenced by the droplet size reduction, which could be explained by the shear thinning viscosity behavior.

Through the current study, we demonstrated the usefulness and the robustness of PFG NMR technique for monitoring micro-emulsion phase behavior. Moreover, the changes in actual and apparent viscosity by altering the salinity and the shearing forces, respectively, where confirmed by NMR diffusivity and droplet size measurements. The findings of this paper will be important for the screening and the study of displacement efficiency of chemical EOR agents.