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Direct imaging of surfactant/polymer floods in sandstone cores utilising a combined PET/ X-ray CT approach

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With the ongoing transition towards net-zero, focus has been gradually shifting away from exploration and into the maximisation of production from already existing reservoirs. Here, traditional oil recovery methods typically extract around 30% of the oil in place –giving large opportunity for more efficient recovery techniques. Among which, surfactant/polymer methods have the capability of increasing recovery up to 70% by both liberating trapped oil and improving the displacement efficiency. However, the relatively high cost of the surfactant is a major concern and, as such, ensuring its efficient and maximum utilisation is pivotal to a successful operation. To this end, methods are needed to understand the mixing process within the surfactant/polymer slug. Traditional approaches use a surfactant effluent breakthrough curve, but the results are associated with significant uncertainty due to the complexity of the flow dynamics present within a surfactant/polymer flood, with the formation of an oil bank and sharp saturation fronts. As such, extrapolation to in-situ behaviour remains a major challenge.

In this work we present results from a coupled experiment employing both PET and X-ray CT as imaging techniques aimed at the direct visualisation of both saturation profiles (by X-ray CT) and tracer propagation within a surfactant/polymer flood (by PET). The overall experiment consisted of two identical surfactant/polymer corefloods –conducted on Bentheimer –with the individual imaging techniques applied independently. Both experiments employed surfactant/polymer flooding as a tertiary recovery method –following a waterflood. The flooding scheme consisted of a 0.7 PV surfactant/polymer slug (L-145-10s 90/HPAM) followed by a 0.5 PV polymer slug (HPAM) to displace the residually trapped oleic phase (decane). For the PET experiment, two radiotracer pulses (FDG) were injected at the front and rear of the surfactant/polymer slug to investigate the mixing dynamics within the slug.

Via the use of X-ray CT, and the visualisation of the saturation profiles, the chosen combination of flooding regime and fluids was shown to both increase recovery, up to 86%, and form an oil bank –characteristic of a surfactant-based displacement process. Via the use of PET, the concentration profiles of the injected tracer pulses were reconstructed in up to three-dimensions as they progressed through the core. Mixing indices, such as the dilution index, spreading length and segregation index, were computed and compared to available single phase tracer experiments conducted on Bentheimer and other rock samples of varying heterogeneity. Notably, the calculated indices indicate comparatively enhanced mixing for Bentheimer – with behaviour mimicking that of more heterogenous systems. Lastly, via the combination the two imaging techniques, qualitative observations regarding the influence of the saturation fronts on the shape of the tracer concentration profiles was made. Overall, through this work, we demonstrate the feasibility of utilising PET in more complex flooding environments to investigate mixing, but also highlight the complementary nature of X-ray CT and PET as imaging methods.

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