Abstract

Tapping heavy-oil from fractured carbonates is a real challenge due to unfavourable rock and reservoir characteristics. Thermal or solvent injection techniques are two possible options to mobilize matrix oil of naturally fractured reservoirs by reducing its viscosity. Reservoir heating, however, becomes a necessity as the oil gravity gets lower and steam injection is the only effective way to heat the matrix containing oil using the fracture network as conduit to distribute steam. Reservoirs at marginal depths for effective steam injection (>800 m) adds more difficulty to the problem. The application eventually becomes hot-water injection but the efficiency of the process could be improved by adding a solvent component.

We introduced a new technique called Steam-Over-Solvent in Fractured Reservoirs (SOS-FR) for efficient heavy-oil recovery from fractured reservoirs, more specifically carbonates. The process consists of cyclical injection of steam and solvent in the following manner: Phase-1: Steam injection to heat up the matrix and recover oil mainly by thermal expansion, Phase-2: Solvent injection to produce matrix oil through diffusion-imbibition-drainage processes, and Phase-3: Steam injection to retrieve injected solvent and recover more heavy-oil. Our preliminary experiments run under static conditions, i.e., soaking the sample into hot water and solvent alternately (SPE 117626) showed that, under very unfavorable conditions (oil-wet carbonates and sandstones, 14,000 cp crude), oil recovery at the end of Phase-3 was around 85-90% OOIP with 80-85% solvent retrieval, which was mainly due to wettability alteration.

This paper presents further experimental results specifically on carbonates. Heptane was selected as the solvent to inject through a single-matrix/single-fracture oil-wet carbonates saturated with 14,000 cp oil. The previous static experiments were compared to the dynamic ones to reach a conclusion on optimal injection scheme; cyclic or continuous. For this analysis, the experimental results were matched to a single matrix/single fracture numerical model and parameters needed for field scale simulation (matrix-fracture interaction parameters such as thermal diffusion, solvent diffusion and dispersion coefficients) were obtained. Using the data obtained through matching, field scale simulations were performed. The main focus was the matrix size and first an up-scaling study to field conditions was performed. Then, a field-scale sensitivity analysis was carried out to identify the optimal injection scheme for different depths (soaking time for cyclic and injection rate for continuous injection) and durations, and surface steam quality.

Specific observations and conclusions as to how to apply this technique in the field economically were reported. It is hoped this new technique will be an alternative for tapping heavy matrix oil from oil-wet, fractured, deep, carbonate fields.