Parametric Study of Heavy Oil Recovery By Electromagnetic Heating on a Horizontal Well

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Abstract

Downhole electrical heating has proven to be an effective way of lowering the oil viscosity by raising the temperature in the formation. The application of low-frequency resistance heating (ERH) limits the heating rate as well as the production rates. Electromagnetic heating (EMH) can be used instead. This study presents a oil-gas two-phase linear flow EMH model using COMSOL Multiphysics simulator. Special attention is focused on reservoirs with characteristics for which steam injection is not attractive or feasible such as low permeability, thin-zone, and extra-heavy oil reservoirs. Comparisons showed that cumulative oil production obtained by EM heating is better than what is achieved by a similar enhanced oil recovery technique called single well steam assisted gravity drainage (SW-SAGD) process for reservoirs with the above mentioned characteristics using simulator STARS. Firstly, it is the comparison of ERH and EMH heating schemes. COMSOL Multiphysics simulator was chosen to solve the inter-connected equations in EMH process. The same amount of power source 10kW is used to compare the performance of EMH to ERH simulated using STARS. Secondly, single well SAGD was chosen to compare the energy efficiency of this process with steam injection primarily because of the use of a single horizontal well scheme same as EMH. To investigate EMH performance compared to SW-SAGD, two cases were run for oil reservoirs in both COMSOL and STARS, where the application of other thermal techniques are difficult or have proven to be unsuccessful: 1) thin-pay zone, 2) low-permeability. Figure 1 shows a comparison of temperature profile obtained by STARS-ERH model and COMSOL-EMH model with the same power input. As can be observed, the heating area by EMH spreads double of the distance that ERH can reach. Figure 2 gives the temperature profile at the end of 365 days for 2D linear flow model with a horizontal well. Cumulative oil production for the base case reservoir for cold production, EMH and SW-SAGD during approximately 3 years are in Figure 3. The cumulative oil production from EMH increases from the beginning and increment is maintained throughout the process as shown in the Figure; however, the SW-SAGD gives smaller improvement due to the lack of mobility of the extra heavy bitumen. The EM adsorption coefficient plays an important role for EMH, which allows for the heat to penetrate further in the reservoir. Compared to ERH, EMH can operate with higher power sources and reach higher temperatures. A sensitivity analysis performed on the electrical operating parameter showed that the higher the frequency the higher was the cumulative oil recovered. This trend was obtained for frequencies up to 915 MHz. Above this value, although very high temperature are obtained at the wellbore, there is a very low peneratration of the EM energy. EMH has shown its potential as an alternative to steam injection, and yields better recovery factors especially for thin-zones as shown in Figure 4 and low-permeability reservoirs.

Reference

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Figures used in the abstract

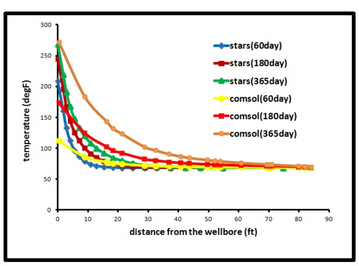

Figure 1: Temperature profiles from STARS_ERH and COMSOL_EMH models under the same power input of 10KW

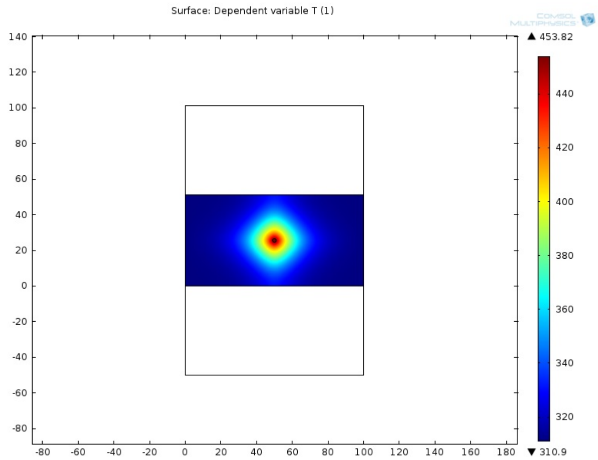

Figure 2: 7 Temperature profile for 2-D two phases linear flow EMH models (in COMSOL)

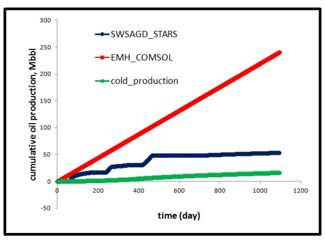

Figure 3: cumulative oil recovered in Mbbl for EMH, cold production (no heating) and SW-SAGD for the base case

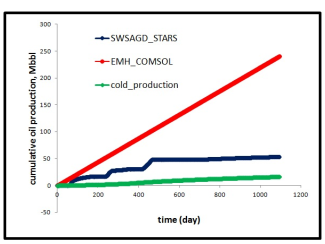

Figure 4: cumulative oil recovered for EMH and SW-SAGD for the low permeability reservoir simulation