Enhanced Heat and Mass Transfer for Alkane Solvent(s)-CO_2-Heavy Oil Systems at High Pressures and Elevated Temperatures

Sixu Zheng[1] *and Daoyong Yang*[1]

Abstract

The injection of hot alkane solvents-enriched CO_2 has a great potential to recover the tremendous heavy oil reserves contained in thin payzones less than 10 m, where conventional steam-based thermal recovery methods are generally ineffective or uneconomical due to the excessive heat losses and large energy consumptions. However, few attempts have been made to examine the effect of adding alkane solvents (i.e., C_3H_8 and n-C_4H_{10}) into the hot CO_2 stream and to determine the preferential diffusion of C_3H_8, n-C_4H_{10}, and CO_2 in heavy oil during such a coupled heat and mass transfer process. In this study, a new and pragmatic technique has been developed to determine individual diffusion coefficients of alkane solvents and CO_2 in heavy oil at high pressures and elevated temperatures. Experimentally, well-designed diffusion tests have been conducted for C_3H_8-n-C_4H_{10}-CO_2-heavy oil systems by using a visualized PVT setup. The volume change of liquid phase is monitored and recorded during the measurements, while the gas chromatography method is employed to determine the compositions of gas mixtures at the beginning and end of the tests. Theoretically, the volume-translated Peng-Robinson equation of state with characterizing heavy oil as multiple pseudocomponents has been incorporated to develop a two-dimensional heat and mass transfer model for the aforementioned systems. Both individual and apparent diffusion coefficients are determined once the discrepancy between the measured and calculated dynamic swelling factors has been minimized. It is found that alkane solvents diffuse faster than CO_2 in heavy oil, while addition of alkane solvent(s) into CO_2 stream not only enhances mass transfer, but also achieves an improved swelling effect of heavy oil. A higher concentration of C_3H_8 tends to accelerate gas diffusion and thus induces a stronger oil swelling effect. Among the C_3H_8-n-C_4H_{10}-CO_2-heavy oil systems, smaller dynamic swelling factors are obtained for the n-C_4H_{10}-heavy oil system, while the mixture of C_3H_8-n-C_4H_{10}-CO_2 contributes to the largest dynamic swelling factor of 1.118 at the end of diffusion test.

[1]Petroleum Systems Engineering, Faculty of Engineering and Applied Science, University of Regina, Regina, Canada, S4S 0A2

Sixu Zheng is currently a research associate in the Petroleum Systems Engineering Program in the Faculty of Engineering and Applied Science at the University of Regina. His major research interests include heat and mass transfer, CO_2 EOR and storage, transport phenomena, heavy oil recovery, reservoir modeling and simulation, phase behaviour, flow assurance, and production optimization. Zheng holds a B.Sc. degree in petroleum engineering from the China University of Petroleum and an M.A.Sc. and a Ph.D. degree in petroleum systems engineering from the University of Regina. He is a member of SPE.