SPE 115346

Diffusion Coefficient of n-alkanes in Heavy Oil

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This paper was prepared for presentation at the 2008 SPE Annual Technical Conference and Exhibition held in Denver, Colorado, USA, 21–24 September 2008.

Abstract

The use of hydrocarbon solvents in the recovery of heavy oil has been increased because of the advantages they have over the thermal methods under some reservoir conditions. The injection of a miscible solvent in the reservoir implies a mass transfer process which is governed by a diffusion coefficient. Consequently the measurement of the diffusion coefficient is extremely important. This, however, presents a significant amount of challenges in the laboratory and in the data analysis, mainly because of the viscous and opaque nature of the heavy oil and the dependence on concentration of the diffusion coefficient. The Matano-Boltzmann method has been used in the past to obtain the concentration dependency of the diffusion coefficient of solvents in heavy oil. Although the method successfully shows that such dependency exists, the results exhibit abnormal trends.

In this work the concentration profiles of three n-alkanes in heavy oil were obtained in the laboratory using Computed Assisted Tomography (CAT), and the "Slopes and Intercepts" analytical technique was used to calculate the concentration-dependent diffusion coefficients. The results are in good agreement with the theory of diffusion in binary mixtures. In addition a comparison is presented with the Matano-Boltzmann method. Finally the Vignes model was successfully used to also perform predictions on the studied systems.

Introduction

The primary recovery in heavy oil reservoirs is very low due to the high viscosity of the oil phase. Consequently, enhanced oil recovery techniques have to be introduced to produce appreciable amounts of oil. Such methods are sometimes applied from the beginning of the production. Thermal techniques such as Cyclic Steam Stimulation (CSS), In-situ combustion and Steam-Assisted Gravity Drainage (SAGD) had proven to be useful for heavy oil recovery. However, the large heat requirements can make them inefficient and uneconomic in many reservoirs particularly those with thin pay zones, low porosity, high water saturation, low rock thermal conductivity and with aquifers **(Jiang, 1997)**. **Garnier (2002)** pointed out the issue of energy consumption and showed some of the possible solutions to the problem, but the costs are still high. Under such an environment, the non-thermal methods appear as a solution for those problematic reservoirs. Some of the most important non-thermal methods are the Cyclic Solvent Injection Process and the Vapour Extraction Process (VAPEX).

The Cyclic Solvent Injection Process is not a new technique to recover heavy oil. Several works have been published in the last 35 years showing the performance of this process **(Lechtenberg *et al.*, 1972; Stright *et al.*, 1977; Patton *et al.*, 1980; Khatib *et al.*, 1981; Sanner *et al.*, 1986; Lim *et al.*, 1995; Luo *et al.*, 2005).** The physics of the process are based on the reduction of the oil viscosity due to the mixing with the solvent although other mechanisms may help such a strong change in the water/oil permeability curves **(Miller *et al.*, 1994).** On the other hand the VAPEX process represents a unique application of the horizontal well for the recovery of heavy oil and bitumen. The heart of the VAPEX process is the reduction in the viscosity of heavy oil by dilution with solvent and its advantages have been presented in several works **(Jiang, 1997; Das, 1998; Talbi and Maini, 2003; Karmaker and Maini, 2003).** We have to consider that the injection of a miscible solvent in the reservoir implies a mass transfer process that is governed by a diffusion coefficient and consequently the measurement of the diffusion coefficient is extremely important for the characterization of the whole recovery process.

According to **Upreti *et al.*, (2007)** accurate diffusion data for solvent–heavy oil and bitumen systems are necessary to determine:

1. The amount and flow rate of gas required for its injection to a reservoir.
2. The extent of heavy oil and bitumen reserves that would undergo viscosity reduction.
3. The time required by the reserves to become less viscous and more mobile as desired.
4. The rate of live oil production from the reservoir.