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SOLVENT BASED ENHANCED OIL RECOVERY FOR IN-SITU UPGRADING OF HEAVY OIL

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3 ACTIVITIES

During this quarter, a significant amount of effort was devoted to conducting a literature review on the super-critical behavior of CO_2/crude oil mixtures which is pivotal for the design of CO_2 injection into heavy oil. The density of CO_2 changes greatly with small changes in pressure.

Higher pressure results in a denser CO_2, which is more compatible with heavy constituents in the oil which precipitate whereas a lower pressure results in a lighter solvent and thus higher quality upgraded crude. Furthermore, near well bore pressure reduces rather quickly as distance to the well bore is reduced, which could lead to a spatial variation in the CO_2/crude oil mixtures interactions.

Because of these phenomena, the literature was thoroughly reviewed in an effort to improve our existing model. Previous studies at FIU investigated the diffusive properties of fluid injection in heavy oil reservoirs (Munroe *et al.*, 2008). A mathematical model was developed using the commercial multiphysics solver Comsol 3.4, that can solve for the mass dispersion of butane into Cold Lake bitumen. The governing equation in the solver was convection-diffusion equation coupled with the Darcy's law as given below.

$$\varepsilon \frac{\partial \omega}{\partial t} = \frac{1}{r} \cdot \frac{\partial}{\partial r}\left(D \cdot r \cdot \frac{\partial \omega}{\partial r} \right) + \frac{\partial}{\partial z}\left(D \cdot \frac{\partial \omega}{\partial z} \right) - v \frac{\partial \omega}{\partial z} \qquad (1)$$

where $v = K_r K \rho g \cos\theta / \mu$ is the Darcy velocity, K_r is relative permeability, and K is permeability of porous medium. μ is the concentration-dependent viscosity of live oil given by $\mu = \mu_o \omega^{-2}$. For the dispersion of gas in heavy oil and bitumen the following dependence was used

$$D \propto \mu^{-0.5}$$

based on an empirical model for the diffusion of butane in Peace River bitumen. The above relations can be combined to yield

$D = D_o \omega$ where D_o is the dispersion coefficient for ω=1.

Kapadia et al. has compared various values of D_o in the range of 0.194 – 1.39 cm^2/s and it was found that D_o=0.556 x 10^{-4} cm^2/s gives the optimal value when compared with the corresponding experimental mass fraction of butane.

It is aimed to replace the butane in our numerical model with CO_2 and implement its supercritical properties. First thing to do so requires to modify the D_o value for CO_2 in heavy oil. Diffusion coefficients and oil swelling factors of CO_2 in heavy oil was measured by Yang and Gu (2006) using dynamic pendant drop volume analysis (DPDVA). However, this study reported diffusivity values for Lloydminster heavy oil and Athabasca bitumen. The values of diffusivity depend on the pressure and range between 0.2-0.55 x 10^{-9} m^2/s for Lloydminster heavy oil and 0.12-0.22 x 10^{-9} m^2/s for Athabasca bitumen which are significantly smaller than butane in Cold Lake bitumen.

In addition to this, the VAPEX pressure was close to dew point was at 0.21-0.23 MPa in our previous model for butane however the pressures reported for CO_2 are at 2.0-6.0 MPa range.

FIU is currently working on literature search for supercritical CO_2 material properties in various heavy oils in order to modify the existing numerical model accordingly.

References:

Munroe, N. D. H, Cheddie, D. F., Mendez, W., Singh Gill, P., K, "Mathematical model of fluid injection in heavy oil reservoirs", 6th LACCEI Conference, June 4- 6, 2008, Honduras.

Kapadia, R. A., Upreti, S. R., Lohi, A., Chatzis, I., "Determination of gas dispersion in vapor extraction of heavy oil and bitumen", Journal of Petroleum Science and Engineering, 51, (2006), 214-222.

Yang, C., Gu, Y., "Diffusion coefficients and oil swelling factors of carbon dioxide, methane, ethane, propane and their mixtures in heavy oil", Fluid Phase Equilibria, 243, (2006), 64-73.

4 Significant Upcoming Events

An abstract is being prepared for a paper to be presented at "Clean Technology Conference & Expo 2009 to be held May 3-7, 2009 in Houston, Texas.

5 APPENDIX