**Final report VISTA May,2012**

# Integrated Optimization of Thermal Processes in Heavy Oil Recovery

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| Project duration: | May 1, 2009 – May 1, 2012 |
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| Project number: | 6346 |

## Populærfremstilling av prosjektet

All project achievements can be categorized in three main parts:

(1) **Modeling SAGD with a black-oil proxy**. We developed a new approach to model steam-assisted gravity drainage (SAGD) using an isothermal black-oil (BO) reservoir simulator. The oil viscosity reduction caused by heating in the actual SAGD process is emulated by a *tuned* saturated pseudo-oil viscosity relation where solution gas-oil ratio ($R_s$) is used as an "equivalent temperature variable". Our work shows that developed black-oil proxy in modeling SAGD is applicable for a wide range of reservoir heterogeneity, injection and production rates, and well placement.

(2) **Modeling the thermodynamic behavior of solvent with bitumen at different temperatures.** We developed an approach to model the phase behavior of different gases/solvents (e.g. $N_2$, CO, $CO_2$, $C_1$, $C_2$ and $C_3$) with high viscous oil (bitumen) at different temperatures. The methodology for bitumen characterization in this work is based on the recent published paper of developing gamma model parameters together with Soreide and Twu correlation for wide range of heavy oil ($API^o$ 9-27). We also were able to model the viscosity of bitumen with/without gas (e.g. $N_2$, CO, $CO_2$, $C_1$, $C_2$ ) where the viscosity is significantly varies from around 1.5 million cp at 10 $^oC$ to about ~1.5 $^oC$ at 350 $^oC$. The concept of this new approach for modeling oil viscosity of pure gas (e.g. $N_2$, CO, $CO_2$, $C_1$, $C_2$) and bitumen provides good viscosity prediction for a synthetic combustion gas mixture (mixture of $N_2$, $CO_2$, $C_1$) in contact with bitumen at different temperature.

(3) **Thermal compositional simulation for investigating the effect of solvent co-injected with steam on enhancing SAGD performance**. We finally built our fluid model as input to STARS (thermal-compositional simulator) for having accurate calculation of gas (solvent) solubility and viscosity changes in the bitumen at the steam-gas front. We are now performing the simulation model of steam injection in conjunction with different gasses/solvents (e.g. $N_2$, CO, $CO_2$, $C_1$, $C_2$) to study the effect of SAGD wind-down (gas push) and the effect of using solvents on enhancing the SAGD process. We shall also do economic model of the whole SAGD (using solvent) process that probably represent the stream- related costs and revenues of the heavy oil EOR projects.

## Har det skjedd endringer i målsetning underveis?/ Oppnådde en det som ble lovet?

The main objective of the project was initially defined in two parts: (1) modeling the thermodynamic behavior of solvent with heavy oils; and (2) optimization of thermal methods in heavy oil recovery. First part has been done successfully and is described above. For the second objective, we introduced a technique i.e. black-oil proxy which enhances the optimization of thermal methods. However full-filed integration optimization of the thermal processes has not been done in this study since it requires having correct model of (a) reservoir inflow, (b) bottomhole-to-wellehad production, (c) pipeline gathering systems, (d) local processing at large-scale processing facilities which is out of scope of the work. The result of this work can be used for future study of integration optimization problems.

## Publikasjoner

Ghasemi, M., S.A. Alavian and Whitson, C.H. 2011. $C_{7+}$ Characterization of Heavy Oil Based on Crude Assay Data. Paper SPE 148906 presented at first SPE Heavy Oil Conference and Exhibition held in Kuwait City, Kuwait.

Ghasemi, M., Whitson, CH. 2011. Modeling SAGD with a Black-Oil Proxy. Paper SPE 147072 submitted to present at the 2011 SPE Annual Technical Conference and Exhibition. Denver, Colorado, USA 30 Oct-2 Nov.

## Refleksjoner om videreføring (fra prosjektleder)

The research has reached the main goals set out originally, with the exception of total integrated optimization of a SAGD process. The time and resources available were not sufficient to complete this last task, given the considerable work to achieve the results of modeling SAGD process and EOS/viscosity characterization for heavy oils. Part of the responsibility for not achieving all goals originally set out are mine, the advisor, mainly because this area (of heavy) was very new to me and it was not clear all of the challenges we met. Partly we waited for laboratory data from Statoil / VISTA related projects

which never became available, thereby necessitating the use of published data and slow communication with the authors of that work which was conducted almost 25 years ago. The results which have been obtained and which will be presented in the final thesis are substantial and will help in an extension of this work towards (1) studying impact of solvent-steam injection, and (2) SAGD optimization.