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Miscibility Evaluation in a Compositional Model by Reservoir Fluids Characterization

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Abstract

In order to create an integrated simulation model, it is essential to have a fluid characterization based on revision and validation of the available laboratory data. These include PVT studies, production data, RFT logs, etc. In case of EOR process modeling, it is necessary to also consider the special fluid tests (swelling test and displacement measures on cores) which permit the evaluation of the injected gas effect on the original fluid properties in the reservoir, particularly at the saturation pressure.

The thermodynamic study based on the available experimental PVT data, taken from three appraisal wells of a carbonate oil field is presented. The fluid system flowing throughout two reservoir levels is characterized by means of equations of state finalised to a full 3D gas injection reservoir study. The objective is optimizing the field production strategies considering the injection of natural gas.

Overview of all the experimental data shows a good agreement among the tests performed on samples belonging to the same level. In this study two equations of state (three parameters Peng-Robinson equation) have been calibrated for the two levels. The simulated PVT parameters by the tuned EOS for the two fluids samples are in good agreement with the already measured experimental data. In addition, the swelling test simulation shows a fair match within limits of cubic EOS.

The slim tube experiments performed by OILPHASE Laboratory to state the miscibility /immiscibility condition of the reservoir oil with respect to the gas extracted at the separators are also simulated. Consequently the sensitivity of the miscibility conditions to possible variations of the composition of the injected gas is investigated.

Keywords: EOS, PVT Experimental, Miscible Gas Injection

Introduction

The success of oil and gas recovery, production, and processing operations is related to the availability of accurate and simple equations of state for prediction of thermodynamic properties of fluids. Recent developments in modeling the phase behavior of reservoir fluids indicate that more serious considerations must be given to fundamental approaches to produces Simple and accurate equations of state.

The results of the PVT analysis carried out on the fluid samples from wells have substantially confirmed the thermodynamic characteristic of the reservoir fluids and their miscibility behavior with the injection gas.

EOS CALIBRATION

A true reservoir mixture is composed of an infinite number of true pure components. An EOS calibration, however, imposes to outline an equivalent "pseudo-mixture", containing a finite number of true components and also including even fictitious pseudo-components. Pseudo-components do not correspond to any pure component actually found in any real mixtures but are introduced so as to represent a whole set (finite or infinite) of pure components actually contained in the true reservoir fluid. Pseudo-components represent therefore actually reduced mixtures themselves.

There are infinite different sets of components-pseudo-components (pseudo-fluids) that can be chosen to schematise the reservoir fluid so that, when inserted in an ordinary cubic equation of State, are able to reproduce the known experimental behaviour of the reservoir mixture, as detected during the experiments performed by the laboratories.

However each of these "pseudo-fluids", more or less equivalent within the range of the available data set, could behave differently outside of the original data set. Therefore the corresponding equation of state can become unreliable if used to predict reservoir fluid behaviours in a range not tested during the experiments. Furthermore, the predicted reservoir fluid behaviour could become even "unphysical". Therefore, in order to avoid at least "unphysical behaviour, the pseudo-components should be at least "realistic".

To get a realistic pseudo-mixture it is especially relevant when an equation of state has to simulate a gas injection process. In fact in these cases the equation of state needs to be extrapolated well beyond the original data set on which it has been calibrated. In fact even the swelling experiment investigates just saturated swollen fluids, while in the reservoir more general conditions are encountered by the real swollen fluids and no experiment gives any information about it.

SURFACE DATA

In view of its use for reservoir simulations, it is important that the EOS can give a good reproduction of the surface data. In fact gas injection in the reservoir is actually a gas re-injection process, whose gas injection-rate is thus just ruled by the rate of the produced gas.

Therefore, special care was taken to properly reproduce the cumulative GOR in the Separator Test., so as also the GOR at the producers can be reproduced in the full reservoir simulation. In this way also the following reservoir re-injection process can be properly simulated. The results obtained are shown in Table 1.

Results and Discussion

With regards to the tests needed for a proper planning of a gas injection project, swelling tests were performed. The swelling experiments have been simulated by means of the equation of state calibrated for the corresponding reservoir fluids. The comparison between the simulated and the experimental swelling tests are shown in Fig 1.

From the modelling point of view it is well known that cubic equations of state become less reliable while approaching the critical region, where flash algorithms too become less stable. This is shown by the erroneous alternation of bubble/dew points, shown by the output of PVTi software, which is the

subject of Table 2, after injecting a certain amount of gas. The phase identity is manifestly uncertain for these mixtures.
On the other hand, at the same time, it has to be observed that also from an experimental point of view, the critical region is the most difficult to be investigated. However the oil-gas transition was detected between 0.5 and 0.55 mol fractions of injected gas, that is to say, in conditions when the original oil is still present in appreciable amount and the overall composition is still well distinguished from the one of the pure injection gas.

Conclusions

As per this paper, reservoir fluids thermodynamic characterization Study has been completed based on all the PVT data acquired during the appraisal campaign.

- ✓ Equations of state were calibrated for fluid. For the fluid flowing equations of state (Peng-Robinson) had been calibrated. Their calculations, when applied to the simulation of the already performed experiments, showed a very good agreement with all the PVT results from the experimental data. The simulation of the experimental swelling test was also in agreement, within limits of cubic equations of state in critical region.
- ✓ Slim tube simulations led to a higher Minimum Miscibility Pressure, as it often happens for the calculated value which always refers to a finite grid size.
- ✓ A recent thermodynamically founded algorithm, which make use of the two approaches was good but, as expected, the algorithm which doesn't require any grid, gave a lower minimum miscibility pressure, in better agreement with the thermodynamic characterisation of a cubic equation of state, has also been applied and tested to estimate the minimum miscibility pressure.
- ✓ The agreement between the experimental evaluations. In addition, an overestimated minimum miscibility pressure creates conditions which are slightly pessimistic and therefore leading to conservative predictions.

In order to estimate the sensitivity of the miscibility condition to possible differences between the future injection gases and those considered in the laboratories, slim tube simulations have been performed while injecting pure methane, as the driest hypotheses among hydrocarbon gases. Worsening of miscibility condition revealed to be rather weak even with drastic change in the gas compositions. This guarantees a wide reservoir pressure range during which gas injection can take place in reservoir

Table 1. Comparison between the experimental data, obtained during the separator test

	(Observed) 1	(Observed) 2	(Calculated)		(Error %) 1	(Error %) 2
GOR	295.9	306.5	290.3	*(adim)*	-1.892531	-5.292647
OIL B_o	2.05	2.105	1.996	*(adim)*	-2.634146	-5.178147
Oil density	826	829	825	*(Kg/m^3)*	-0.121065	-0.482509

Table 2. Output file obtain from PVTi swelling test

Mol Frac Gas Addec	Inserted Point	------------ Calculated	------------ Observed	------------ Calculated
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0	-No Gas			335.8698
0	B		336.9479	335.8698
0.1	B	21.5833	352.2543	355.9734
0.25	B	64.7499	378.0408	386.5084
0.3	B	83.2499	384.1772	396.5611
0.37	B	114.0832	394.3814	410.2516
0.45	B	158.9317	405.4131	424.8819
0.55	B	237.4164	415.6863	440.2899
0.6	B	291.3747	421.4779	445.9837
0.65	B	360.7497		449.6075
0.7	D	453.2496		450.3446
0.75	B	582.7495		434.4698
0.8	D	776.9993		437.6192
0.85	B	1100.749		342.0007
0.9	D	1748.248		385.9298

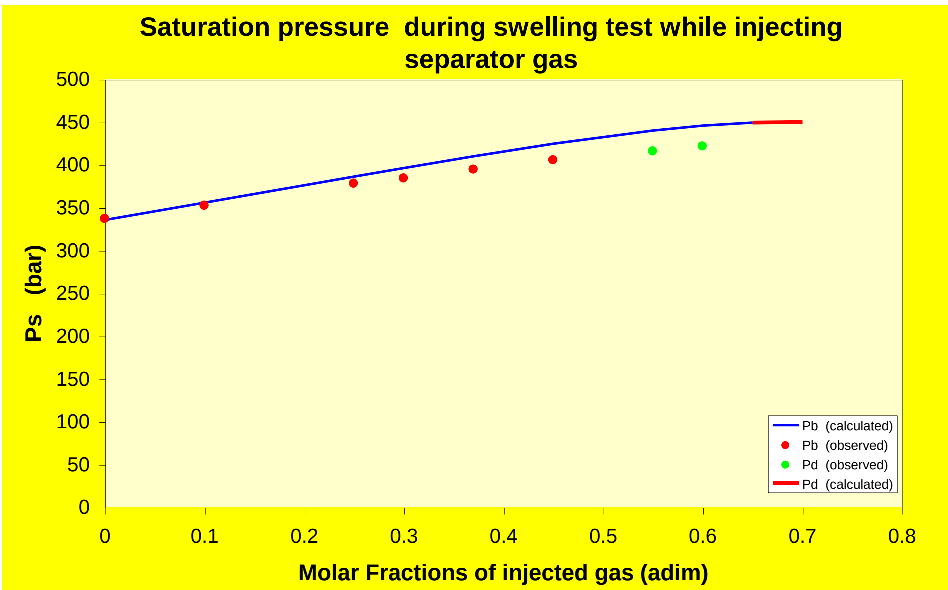

Figure. 1 Comparison between the experimental saturation pressure, obtained during the swelling test

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