An Investigation of Practical Upscaling Parameters for Enhanced Water Alternating Gas Processes from Laboratory to Field-scale

Introduction

Water alternating gas (WAG) injection is one of the established enhanced oil recovery (EOR) methods for the recovery of light oil reservoirs. The process includes alternate injection of water and gas slugs. However, it is also reported that field performance of WAG process is not high as expected due to some operational and mechanistic issues. Apart from operational problems in WAG field projects, a low recovery of the WAG process is associated with water blocking, gravity segregation, unfavourable mobility control, and decreased gas injectivity.

Ideally, in WAG injection both gas and water slugs displace oil in a piston like manner to sweep horizontally the entire depth of the reservoir and move the oil to the production well. However, this is impaired due to gravity effect. In near wellbore region, where gas and water are alternately injected, the WAG process has a good conformance, and the sweep efficiency is fairly good, but as the injected fluids progress into the reservoir and move towards the producing well, the gas tends to rise upward due to its low density, and the water tends to descend because of its higher density. This results in a poor efficiency during the WAG process.

Foam injection helps to mitigate the above shortcoming by increasing the apparent viscosity of gas phase. By increasing apparent gas phase viscosity, the mobility of gas will be reduced, hence the gas will be diverted from high permeability zones to low permeabilities areas of the reservoir and therefore sweep efficiency of gas will be increased.

Methodology

The proposed practical workflow to an upscaling process is as follow: First, empirical coreflood model was introduced to get acceptable match with laboratory data. Second, 1D field-scale model was developed to verify the resolution from core-scale into Field-scale such as grid dimensions, time, average petrophysical and fluid properties, dynamic data and observed all important parameters that required to be upscaled or not. Finally, we translated the upscaled and verified the parameters into full field model and observed the impact of upscaled EWAG parameters for prediction purposes.

Before the coreflood data set can be used for field size applications, it must be scaled up to field model size grid blocks. Up-scaling of laboratory data is useful to verify that the field scale model will duplicate the lab scale results. It also helps to verify whether reaction rates need to be upscaled. Due to field scale model run times, many times the grid block size is larger than required for proper foam simulations. A general rule of thumb is that the optimum grid block size in the field model should be about 30 feet (10m) in the flow directions.

Due to velocity dependence of foam flooding, the scale up process should be performed to preserve velocity of fluids during core flood experiment. It is also important to preserve the pressure of the experiment due to dependency of many properties such as viscosity to pressure. The modified scaling parameters are presented in Table 1 as follows:
Table 1 Modified scaling parameters

<table>
<thead>
<tr>
<th>Property</th>
<th>Ratio (R_L = Model/Field)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>R_L</td>
</tr>
<tr>
<td>Width</td>
<td>R_L</td>
</tr>
<tr>
<td>Height</td>
<td>R_L</td>
</tr>
<tr>
<td>Permeability</td>
<td>R_L</td>
</tr>
<tr>
<td>Time</td>
<td>R_L</td>
</tr>
<tr>
<td>Injection rate</td>
<td>R_L^2</td>
</tr>
<tr>
<td>Cumulative production</td>
<td>R_L^2</td>
</tr>
<tr>
<td>Porosity</td>
<td>1.0</td>
</tr>
<tr>
<td>Pressure drop</td>
<td>1.0</td>
</tr>
<tr>
<td>Velocity=Q/A</td>
<td>1.0</td>
</tr>
<tr>
<td>Slug size</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Results and Discussion

The original lab match is used to scale up in terms of grid size, rock properties and injection and production data. Changing the grid size to similar with full field size e.g. in I-direction shows that it is possible to get same quality of history match as coreflood model with similar foam parameters. Figure 1-3 shows that field scale model duplicate the scale-up lab results. The upscaling parameters from empirical and 1D Field-scale model got acceptable calibrations and showed similar quality and consistency between them. The history match quality index of pressure, gas and oil achieved above 90%. The similar foam parameters used in coreflood history match can give this history match. The parameter values are as follows:

- Mobility reduction (FMMOB) = 20000
- Surfactant fraction (FMSURF) = 8.45E-05
- Surfactant Exponent (EPSURF) = 4
- Foam dry out Sw (SFDRY) = 0.39
- Foam dry out factor (SFBET) = 280
- Foam dry out sat (SFSURF) = 5.00E-05
- Foam dry out exp (EFSURF) = 2.33333
- Reference capillary number (FMCAP) = 6.62E-08
- FMCAP exponent (EPCAP) = 0.4
- Critical So (FMOIL) = 0.5
- Lower So (FLOIL) = 0.1
- So exponent (EPOIL) = 1
**Figure 1** Cumulative oil and cumulative water production

**Figure 2** Cumulative gas injection
Conclusions

Since our focus in this study is mostly to foam parameter, we observed from this scale up full field model can keep remain unchanged from laboratory-scale. Introducing foam into WAG process in the field-scale modelling gives more complex and challenge in doing full field prediction.

The proposed upscaling workflow can be useful to investigate the important parameters to be scaled up and tuning. In addition, this investigation offers a lesson learned to achieve more efficient in doing scaling up important parameters from laboratory measurements to field deployment.

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References
