CMG COMPUTER MODELLING GROUP LTD.

GEM

CEPSA Evaluates Application of Foam Injection to Mature WAG Field

Benefits

- Achieved valuable insights into foam application for a unique, unexplored scenario
- Fine grid and history-matched sector models indicate foam has potential to reduce GOR and lead to incremental oil production
- CMG support team assisted CEPSA engineers throughout the study

Why Implement?

Management of high GOR and achieve facility imposed gas production limits

Why Simulate?

Determine applicability and benefits of foam injection to a mature miscible WAG project

Results

Reduced GOR, increase oil production and delayed onset of limiting GOR by one-year

Since 2003, CEPSA was involved in a miscible Water-Alternating-Gas (WAG) injection strategy to a giant oil field in northern Africa. The WAG development strategy has succeeded in achieving a high recovery, however, the gas production limits require better management of the high Gas-Oil-Ratio (GOR) during the later stages of the project.

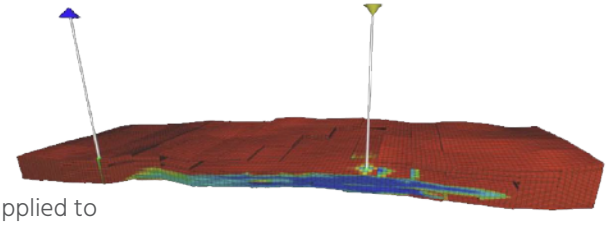
Prior to beginning this project, there were no known published studies on the application of foam in a mature miscible WAG project with rich hydrocarbon gas injection. Therefore, CEPSA considered the feasibility of foam injection for the GOR and gas channeling management by extending the laboratory studies to include extensive compositional numerical simulation.

Workflow

The two-stage field scale foam feasibility study included: (1) foam creation analysis in the laboratory, and (2) numerical simulation. The laboratory work used static mixing experiments to determine surfactant compatibility with injected brine, formation oil and formation brine. In addition, CEPSA tested in-situ foam generation in corefloods and applied those results to reduce the uncertainty in the empirical foam model parameters used in the simulation study.

The foam EOR numerical simulation was conducted with GEM™, as it contains two models for foam simulations: a simplified empirical model and a mechanistic model. The empirical model has a practical approach for matching experimental results and predicting foam performance at a field scale. In addition, the empirical model estimates the reduction of gas mobility due to foam using a gas relative permeability interpolation factor that is dependent on several foam parameters.

CEPSA completed two simulation studies to predict the effects of foam in this reservoir. The first study provided an accurate estimation of foam effects for a representative model. CEPSA used a small sector model with fine gridding and two wells (WAG injector and producer) spaced one kilometer apart to minimize numerical dispersion. Data from the preliminary experimental results was applied to the simulation model. Critical experimentally determined data including foam apparent viscosity versus gas saturation, and foam strength versus oil saturation, were incorporated and captured in the GEM foam model.



3D view of fine grid simulation model, showing the property N_aCl mole fraction. Injected water has a lower salinity than formation water

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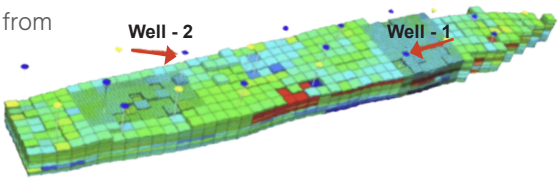
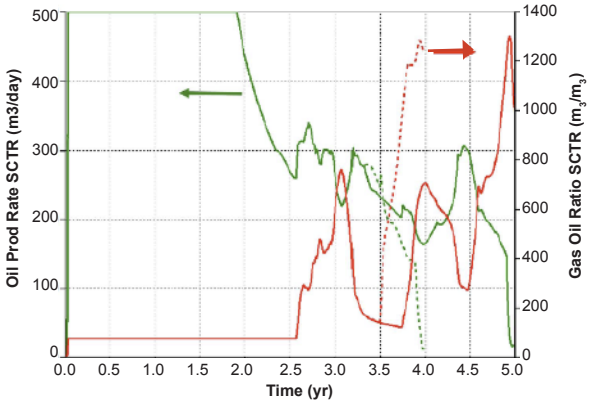
The second simulation study used a sector extracted from a history matched full-field model to forecast the benefits of a commercial application of foam, using real field data. The sector model contained 23 history matched wells, and two WAG injectors were converted to a Surfactant-Alternating-Gas (SAG) scheme.



3D view of 23 well history matched model, indicating the producers that benefit from foam injection

Results

The first study, using the fine gridded, representative, simulation model, showed the foam application successfully reduced the GOR and increased the oil rate. By applying foam injection, the simulation results showed the limiting GOR (1200 sm3/sm3) onset could be delayed by one year, pushing it to five years after initial production. The injected gas rates dropped drastically in the perforated layers with high permeability, thereby effectively managing the heterogeneity and providing a better sweep efficiency. Using GEM's advanced foam modelling capabilities, the simulation model successfully incorporated the experimental data and estimated the foam effectiveness. Subsequently CEPSA decided to carry out a second, more detailed phase, of the study.



Comparison of oil production rates (green lines) and GOR (red lines) for foam case (solid lines) and no foam case (dashed lines)

As a result of the foam injection, the coarse full-field sector model showed two of the 12 producers benefited from foam injection, when two injectors are converted to SAG. The producers showed incremental oil production, mainly due to the delayed GOR. These results indicate that foam has the greatest impact when injectors and producers are directly connected through a high permeability channel. The combined GOR delay and oil rate lift shows the potential for foam treatment to manage the high GOR and gas channeling operational challenges. Finally, to determine the best well candidates, cycle timing, and surfactant concentrations for foam treatment, a full-field optimization on foam application is necessary.

With the success of this foam feasibility study, the next steps will involve additional simulation studies on foam application, and a pilot test to understand and confirm the effectiveness of the foam injection.

This case study is based upon SPE 188424, "Feasibility of Foam Application in a Giant Mature Field under Miscible WAG Injection". To read the full technical paper, please visit www.onepetro.org.

Read more: cmgl.ca/resources

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