STARS

Vedanta Ltd. uses Simulation to Develop the World's Largest Polymer Flood

Benefits

- Matched chemical EOR core flood experiments
- Utilized upscaled simulation data and design polymer and ASP pilot test program
- Confidently designed and developed a full field cEOR operation based on simulation results
- Achieved a successful ASP pilot with expansion options under review

Why Implement?

Increase recovery while minimizing water production and oil rate decline

Why Simulate?

Determine the economic value of applying chemical EOR to the Mangala field

Results

Successful pilot project results in Vedanta is now operating the world's largest polymer flood EOR project[1]

The Mangala field, in India contains an estimated 3.6 billion barrels of oil. In 2004, Vedanta Ltd., the primary operator, discovered oil and shortly thereafter realized applying chemical Enhanced Oil Recovery (cEOR) was well suited to improving production.

The waxy oil is medium gravity (20-28°API) with moderate viscosity (9-17cp), and the reservoir is clean sandstone with a permeability of 1-25 Darcy. Forecasts determined a conventional waterflood operation would produce large volumes of water due to the poor water-oil mobility ratio, and oil rates would steeply decline after reaching a plateau during the initial four to five years. Mobility control and improved sweep efficiency had the potential to provide significant economic improvement to the project. As chemical flood design is more complicated than conventional process design, Vedanta began to investigate the reservoir's response to chemical EOR.

In 2006, the EOR study began with laboratory experiments and detailed chemical flood simulations using STARS™, CMG's thermal and advanced processes reservoir simulator. Today, Vedanta is now operating the world's largest centralized polymer mixing facility and describes the Mangala Polymer Flood EOR project as "an astounding success"[2].

Workflow

A series of detailed laboratory experiments were carried out, including:

- Fluid-fluid studies between the native oil and injected aqueous mixtures
- Fluid-rock studies using native oil, water, and cores to determine how the injected chemicals interacted with the rock
- Linear and radial core floods to determine the best chemical formulations and incremental recovery gains.

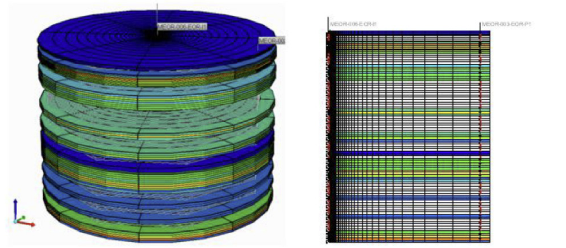
Location of Mangala field, India

The chemical floods considered were polymer, alkali-polymer, and alkali-surfactant-polymer (ASP). Next, "extensive reservoir simulation using the advanced compositional simulator STARS was used to model the corefloods in an attempt to understand the process mechanisms and to generate chemical flood parameters which were subsequently used in field scale modelling of the process"[3].

Several STARS features proved important for achieving a history match of all three chemical injection processes, including compositional dependence on Interfacial Tension (IFT) and relative permeability, shear-thinning polymer viscosity, and component adsorption. The corefloods were history matched by adjusting these parameters, as well as several others.

STARS

The pilot-scale simulation, using the history matched parameters, forecasted and optimized a normal 5-spot pattern, which utilized close well spacing to allow for results from the pilot within the project's timeline. To compare performance, Vedanta simulated both polymer and ASP cases, as well as the combination of a polymer slug followed by an ASP slug.



Radial core model used for history matching

A final set of simulations were carried out to forecast the chemical flood performance on a field scale. The normal 5-spot spacing used was significantly larger than the pilot case, 300-400m for the field versus 100m for the pilot. Again, polymer, ASP, and polymer followed by ASP were analyzed.

Results

The various chemical coreflood results were successfully history matched using several advanced chemical flood features in STARS. These history-matched parameters were used to design a tightly spaced 5-spot pattern chemical flood pilot. One key finding from the simulation showed the injected fluid rate had to be double the production rate for each pattern, to avoid oil migration between patterns.

In both the pilot and field scale simulations, a chemical flood optimization was carried out to determine the best type of flood for this reservoir. The performance comparison determined the optimal strategy was a polymer slug followed by an ASP slug.

Regarding the field scale simulations, "runs clearly show an improvement in both sweep and displacement efficiency as a result of chemical flooding"[4]. The forecasted incremental oil recovery for the polymer flood was 7-8%, and the ASP flood was ~15%. The sensitivities on the chemical flood commencement time showed an insignificant change in ultimate recovery when altering the chemical injection startup time.

The pilot polymer flood was implemented after the simulation work was completed and provided positive results. The polymer injection results showed a decline in the produced water-cut when all operational objectives were met, including surface handling, desired injection rates and blend viscosities. Vedanta scaled this program up to a US $600M project[1] with nearly 100 wells drilled and completed[2]. The next phase of the pilot study, the ASP flood, is also completed and showed a 10-15% increase in incremental oil over the polymer flood[2].

Proactive thinking and long-term planning enabled Vedanta to implement the appropriate field-wide chemical flood process early and add significant value to the Mangala field.

This case study is based upon the following:

- *SPE 154159-MS "Chemical EOR Pilot in Mangala Field: Results of Initial Polymer Flood Phase"*[†]
- *SPE 179700-MS "Results of ASP Pilot in Mangala Field: A Success Story"*[†]
- *SPE 113131-MS "Design of an ASP Pilot for the Mangala Field: Laboratory Evaluations & Simulation Studies"*[†]
- *SPE 113347-MS "Chemical Flood Simulation of Laboratory Corefloods for the Mangala Field: Generating Parameters for Field-Scale Simulation"*[†]

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[1] https://www.epmag.com/cairn-india-takes-eor-project-mangala-712896#p=full
[2] https://www.cairnindia.com/sites/default/files/investor-presentation-pdf/Cairn_India_Presentation_September_14Sept2016.pdf
[3] SPE 113131-MS "Design of an ASP Pilot for the Mangala Field: Laboratory Evaluations & Simulation Studies"
[4] SPE 113347-MS "Chemical Flood Simulation of Laboratory Corefloods for the Mangala Field: Generating Parameters for Field-Scale Simulation"