Evaluating Potential CO₂ Injection Capacity of Aquifers Based on Well Testing

A. Shchipanov* (IRIS), L. Kollbotn (IRIS), R. Berenblyum (IRIS) & V. Hladik (CGS)

*Corresponding author: Anton.Shchipanov@iris.no

Outline

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  › Dynamic well skin: a simple approximation to describe CO₂ plume growth
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  › Testing dynamic skin approximation: CO₂ injection into saline aquifer (LBr-1 site)
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  › Converting water case into CO₂ case forecast
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CO₂ injection in Tubåen formation (Snøhvit field)

Depth map of top Fuglen formation (left) and geological cross-section N-S through the reservoir sections at Snøhvit (right) [from Hansen et al., 2013]

CO₂ injection in Tubåen formation

Difference amplitude map between baseline and monitor at base of the reservoir [from Hansen et al., 2011]

History of CO₂ injection in Tubåen formation

Salt precipitation followed by treatment

Interpretation of time-lapse fall-off pressure transients and matching injection history

Some observations from PTA
  › Analytical (single-phase) model is capable of reproducing injection history
  › A negative skin is necessary to match the pressure build-up
  › Better match if the skin is slightly decreasing (more negative) with time

Dynamic well skin: A simple approximation to describe CO₂ plume growth
CO₂ PVT (T = 43 °C) and rough range estimations

CO₂ PVT

\[
\begin{align*}
\text{CO₂ PVT} & \quad \text{(T = 43 °C)} \\
\text{CO₂ Viscosity} & \quad \text{(usual)} \\
\text{CO₂ Visco (T = 43 °C)} & \quad \text{(usual)} \\
\end{align*}
\]

Water/CO₂ viscosity ratio overcomes the changes in CO₂ viscosity under usual injection conditions

Background and formulations

- Skin effect to describe changing flow capacity near wellbore
- Standard approach in oil and gas industry to describe well stimulation / damage etc.
- Applications to CO₂ injection reported, see for example SPE-113937

Formulations

\[
\begin{align*}
\Delta p_{\text{skin}} = \frac{q}{2\pi h} \left( S_{\text{wi}} - S_{\text{co}} \right) \\
S = \frac{r_{\text{wi}}}{r_{\text{co}}} \\
r_{\text{wi}} &= r_w e^{-\Delta a} \\
r_{\text{co}} &= \frac{\sqrt{\mu_{\text{co}} \mu_{\text{wi}}}}{\sqrt{\mu_{\text{co}} \mu_{\text{wi}}}}
\end{align*}
\]

General formulation of Pressure drop due to skin

Skin 1 (base case)

Skin 2 (Extended Skin 1)

Background and formulations (Cont.)

1D radial two-phase (water-CO₂) simulations

CO₂ plume governs change in pressure slope near well

Ratio of CO₂/water viscosity has stronger impact on overall fluid mobility rather than relative permeability effects

Background and formulations (Cont.)

1D radial two-phase (water-CO₂) simulations

Water case with Skin 2 is close to CO₂ case

Testing ‘skin approximation’ to reproduce history of CO₂ injection in Tubåen formation

Water case with Skin 2 is close to CO₂ case

Skin 2 gives reasonable history match
Testing dynamic skin approximation:
CO₂ injection into saline aquifer (LBr-1 site)

Pressure build-up simulated for water case and conversions into CO₂ case using skin approach compared with actual CO₂ case

Dynamic well skins calculated for the injection scenario

Pressure build-up simulated for water case and conversions into CO₂ case using skin approach compared with actual CO₂ case

Dynamic well skins calculated for the injection scenario

Forecasting injection performance and pressure build-up based on well test results

Infinite reservoir

U-Shape

Closed Chamber

Injection performance forecast for the same reservoirs

PTA-based models and water injection forecast

Water injection forecast from PTA-based model

Dynamics of cumulative injection volume gives dynamic skin

Pressure / derivative in log-log scale from synthetic well tests of differently bounded reservoirs

Dynamics of cumulative injection volume gives dynamic skin

Pressure / derivative in log-log scale from synthetic well tests of differently bounded reservoirs

Dynamics of cumulative injection volume gives dynamic skin

Pressure / derivative in log-log scale from synthetic well tests of differently bounded reservoirs

Workflow:
Converting water case into CO₂ case forecast

Potential

The skin (effective radius) approximations can be used to describe effect of CO₂ banking on pressure forecast for CO₂ injection in aquifers, at least for early stage of injection

The approximations use limited set of known fluid data and basic reservoir parameters, which are usually provided by a standard well test

The analytical approximations have limitations, e.g. circle CO₂ plume is assumed. Further testing with field cases may reveal additional ones

An approach to forecast well BHP and potential site capacity at given CO₂ injection rates was suggested and consists of

PTA model matched to well test and further employed to forecast water injection

The skin approximations provide conversion of the water case into CO₂ case forecast
Acknowledgements

The authors acknowledge funding and permission to publish this paper from the REPP-CO₂ project supported by Norway Grants.

Thank you for your attention!

Zástupci projektu REPP-CO2 na konferenci EAGE 2016 ve Vídni - V. Hladík (ČGS), L. Kollbotn (IRIS) a A. Shchipanov (IRIS)