Convergence-induced Stresses on Casing and Cementation due to Salt Cavern Operation

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Theoretical Background
Convergence-induced Stresses

Case Study
Design and Analysis
Results and Discussion

Conclusion
THEORETICAL BACKGROUND

Convergence-induced Stresses
Convergence-induced Stresses

- Surface subsidence
- Stressing due to operation
- Rock mass deformation

Diagram showing subsidence maximum, casing strings, cavern, and rock layers.
Convergence-induced Stresses

volume of the subsidence bowl = \( f(\text{convergence volume, time}) \)
CASE STUDY

Design and Analysis
Simulation Model

- Quarter-segment section
- Horizontal overburden layers
- Oil storage cavern

- Selected outer boundaries of the simulation model do not represent the real pillar dimensions in the cavern field.

⇒ Investigation of deformation status close to wellbore axis and up to the surface

- Borehole completion elements were discretized by circular ring elements.

- 600 m
- 2,110 m
- Zoomed top view (ca. 1 x 1 m)

- Geology:
  - Quaternary
  - Claystone
  - Limestone
  - Marlstone
  - Anhydrite
  - Salt
  - Cavern

- Cementation of anchor pipe
- Anchor pipe
- Cementation of last cemented casing
- Last cemented casing
Essential borehole completion phases were discreetly integrated into the numerical simulation.

Connection between casing/cementation/rock mass assumed as completely intact.
History-Match – CONVERGENCE

CAVERN VOLUME LOSS

⇒ operation / stressing
⇒ creep of salt
Initial Calculation

- connection casing/cementation/rock mass
- material parameters overburden
- realistic estimate of creep behaviour
- cavern contour and volume
- quality of casing
- cavern operation mode
- quality of cementation

basic configuration
Various Calculations

- basic configuration
- connection behaviour of casing/cementation/rock mass
- reduced stiffness of overburden
- modified cementation of LCC
- reduced stiffness of overburden and modified cementation of anchor pipe
- reduced stiffness of overburden
- modified cementation of anchor pipe
Basic Configuration
Von Mises Comparative Stress

start of operation

in comparison to plasticity limit

LCC
- cementation LCC
- anchor pipe
- cementation anchor pipe
- geology close to wellbore
- geology
- geology apart from wellbore
CASE STUDY

Results and Discussion
Basic Configuration
Von Mises Comparative Stress

Von Mises Equivalent Stress $\times 10^3$

after 30 years of operation

- LCC
- cementation LCC
- anchor pipe
- cementation anchor pipe
- geology close to wellbore
- geology
- geology apart from wellbore

plasticity limit exceeded

- surface quaternary claystone
- limestone
- marlstone
- anhydrite
- salt

Von Mises Equivalent Stress $\times 10^3$
Reduced Stiffness of Overburden
Von Mises Comparative Stress

after 30 years of operation

- LCC
- cementation LCC
- anchor pipe
- cementation anchor pipe
- geology close to wellbore
- geology
- geology apart from wellbore

- surface quaternary claystone
- limestone
- marlstone
- anhydrite
- salt
Modified Cementation of LCC
Von Mises Comparative Stress

after 30 years of operation

- LCC
- cementation LCC
- anchor pipe
- cementation anchor pipe
- geology close to wellbore
- geology
- geology apart from wellbore

surface quaternary claystone
limestone
marlstone
anhydrite
salt
Connection of Casing/Cementation/Rock Mass

Von Mises Comparative Stress

**after 30 years of operation**

- LCC
- cementation LCC
- anchor pipe
- cementation anchor pipe
- geology close to wellbore
- geology
- geology apart from wellbore

Diagram shows stress distribution with layers labeled as:
- surface quaternary claystone
- limestone
- marlstone
- anhydrite
- salt

Reduced maximum stress observed.
Summary

✓ Calculated stressing of cementation remained below assumed ultimate strength.

✓ In the overburden section the calculated stressing is below the plasticity limit of steel.

  o Plasticity limit of steel was exceeded in the salt section close to the casing shoe
    ⇒ as wireline measurements show steel can sustain relative large plastic strains

  o Variation of the connection behaviour casing/cementation/rock mass shows a reduction of the casing stressing.

after 30 years of operation
CONCLUSIONS
Conclusion

Convergence-induced stresses

Stressing of LCC increases over time

$\Rightarrow$ creep of salt

Limited monitoring methods from surface

$\Rightarrow$ numerical modelling in addition

LCC can withstand the induced stressing

$\Rightarrow$ pronounced ability for plastic deformation
Conclusion

Site Specific Assessment

- Numerical Modelling
  - Behaviour of complex system casing/cementation/rock mass
  - Integration of joints of LCC

Site-related Input Data

Monitoring
Thank you for your attention!
Questions?

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