Redevelopment of the compacting and subsiding Valhall and Hod fields

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Overview

• Introduction of Valhall and Hod field
• Compaction and subsidence
• Technology developments
• Computational geomechanics
• Seismic surveillance
• Integration of data
• Use of data to reduce risk
• Valhall and Hod redevelopment
Valhall and Hod field

- Located in the southern part of the North sea, in the North Sea Central Graben
- The Valhall Field
  - First oil 1982
  - Produced: 829 mmboe
  - Field life until 2050
- The Hod Field
  - First oil 1990, unmanned platform
  - Produced: ca. 73 mmboe
  - Field life 2050
- Valhall and Hod
  - Under-saturated Upper Cretaceous Chalk
  - Tor and Hod formations
  - 0-77m reservoir thickness
  - Low permeability
  - High porosity
Valhall and Hod reservoir are high porosity chalk. Initial porosity 40-50%.

**Compaction** – important drive mechanism accounting for more than 50% of the drive energy the first 20 years.

Compaction results in seafloor **subsidence**
- Seafloor subsidence (Valhall) >6m
- Reservoir compaction (Valhall): ~10m in places
- Reservoir compaction Hod: ~4m

Subsidence rates:
- 25 cm/year (first 20 years)
- 11cm/year (after 2003)
- Hod: 1 cm/year (after 1999)

Subsidence/Compaction data from:
- Seafloor bathymetry, GPS and radioactive markers
Compaction. Good or Bad?

Compaction is the most important drive mechanism during primary depletion, but it is generating challenges during drilling and production time for both the wells and the platforms.

Challenges:
- Seafloor subsidence. The air gap on the original platforms became too small leading to the need to replace the production and hotel facilities.
- Casing and tubing deformation and collapses are occurring during production life, resulting in a reduced well life for the wells.
- Overburden drilling has become more and more challenging due to varying compaction over the field causing wellbore stability issues, mud losses/gains and cavings.

Casing deformation in lab

Tubing deformation in well

Production zone

Bending

Compression

Tension
Technology developments

- New technology and workflows were needed to mitigate the increasing challenges in Valhall and Hod
- Integration of the different data across disciplines
- Two important tools that will be discussed in this presentation are:
  - Computational geomechanics
  - Seismic surveillance
Computational geomechanics

- The Computational geomechanical technology was developed and implemented to assist drilling in the highly depleted and compacted crest of Valhall
- **History matched** 3D full field finite element based geomechanics model for overburden and reservoir
  - Similar cell size as the dynamic model
  - Populated with rock mechanical properties
  - Dynamic data input: pressure and water saturation changes
  - Includes the effect of water weakening, repressurization and creep
  - The model is simulating history and predicting the future
- The model is used to calculate:
  - Displacements
  - Strains
  - Stresses across the field
- The results are exported to a 3D visualization tool to do wellbore stability calculations and optimizations of well trajectories and placements

Compaction at reservoir level at Valhall and Hod

March, 2010
Seismic surveillance

• The world’s first permanent field wide seismic arrays was installed in 2003 covering 70% of the Valhall field
• 14 surveys to date (Nov 2003 – Sep 2011)
• Compaction has a strong impact on the seismic response
• Historically, images over the crest of Valhall have been poor due to a gas cloud covering the area
• High end imaging and Full Waveform Inversion has resulted in:
  − Significant improvement of the seismic images
  − Improved detailed 4D interpretation under the gas cloud
  − Stand alone high resolution velocity volumes for interpretation
• Acquiring one to two seismic surveys per year reflecting:
  − Fluid and saturation changes
  − Reservoir pressure changes
Integration of data – Geomechanics

• Operating the complex fields like Valhall and Hod requires integration of all data and disciplines
• Iteration process between geomechanic model and dynamic flow simulator
  – Pressure and water saturation predictions exported from dynamic flow model
  – Updated rock compaction tables exported from geomechanic model to dynamic model
  – Historic manual iteration between models
  – Current model iterative coupled
• The geomechanical model predictions are verified by:
  – Seafloor bathymetry, GPS and radioactive markers in wells
  – The deformation seen on 4D seismic, both in overburden and in the reservoir
  – Historic field drilling data
Integration of data - seismic surveillance

- The 4D seismic response in the reservoir is integrated with surveillance data and offset well production
  - (Dedicated) monitoring wells for pressure
  - Repeat saturation logs
  - Prod/inj data (water breakthrough & and pressure communication)
- The frequent 4D surveys (1-2 a year) make it possible to track lateral movements of the 4D response against different well observations
Use of data to reduce risks

- The geomechanical model
  - Has proven to be reliable and is used in new well planning for calculating the required mud weights in the overburden
  - Guides the trajectory planning and gives a good overview of non-disturbed vs. disturbed areas, that should be targeted or avoided for drilling and well-life
  - Evaluations of well failure risk across the field with time
- Seismic surveillance:
  - Improves the understanding of fluid movements, compartments and faulting. Depletion plans are optimized based on these observations
  - Guides detailed well planning
  - Well placement
  - Pressure prediction for new wells
  - Informs well intervention decisions
  - Helps understanding sweep patterns

Well failure risk attribute

High
Low
Example of geomechanical model use (1 of 2)
G-14 Wellbore Stability assessment - initial trajectory

MW Window: 因 No Go
Example of geomechanical model use (2 of 2)
G-14 Wellbore Stability assessment- optimized trajectory

G-14

MW Window: ✔ OK
Valhall and Hod Redevelopment

- New PH platform with design life through 2050 creates a great basis for future developments:
  - Hod Redevelopment project (HRD) currently in Select Stage – looking at 25-slot platform, start waterflood, doubling recovery factor
  - New wellhead platform on the west flank of Valhall and potential additional drill centers currently in the Appraise Stage – looking at similar platform dimensions and resources as for HRD
  - Further options in Appraisal as part of the Greater Valhall Program:
    - Extension LoFS array to Hod and West Flank
    - Brownfield modifications to accommodate future projects

- Valhall and Hod are challenging fields but with the right technology implementation and people they will have a bright and long future
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Valhall and Hod Subsurface Team