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Depletion-induced Stress Changes in a HPHT Reservoir: Calibration and Verification of a Full-field Geomechanical Model

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Abstract

The Kvitebjørn field is a high pressure and high temperature gas-condensate field offshore Norway seated at a depth of 4000 meters. The field is produced by pressure depletion and therefore many geomechanical risks are at hand. In order to be able to forecast the geomechanical risks a full three-dimensional finite element model of the Kvitebjørn field has been built. We use four types of field measurements for initialisation, calibration and verification of the model:

1. Surface subsidence measurements at the platform location
2. In-situ compaction measurements from radio-active marker logging
3. Material properties from core and log measurements
4. Stress measurements from extended leak-off tests

Repeated compaction logging and global positioning measurements are used to calibrate the deformations at the surface and the reservoir level. The geomechanical model is populated by material properties based on core and log measurements. Four extended leak-off tests have been performed at different stages of reservoir depletion. The main application of the model is to determine and predict the depletion-induced stress changes for the entire Kvitebjørn field, to assess geomechanical risks related to infill drilling and collapse of production wells. It is concluded that the calibration and verification of the geomechanical model giving confidence in the prediction of the depletion-induced stress changes and the related geomechanical consequences.

Introduction

Pressure depletion of reservoirs causes changes in the Earth's stress field. Especially for HP-HT fields where large pressure depletion is planned geomechanical risks are at hand. This study shows how in-situ field measurements are used to calibrate and verify the full-field three-dimensional geomechanical model. The workflow used to build and run the geomechanical model is described in detail elsewhere[1].

The Kvitebjørn field is an HP-HT (High Pressure and High Temperature) gas-condensate field offshore Norway. The water depth is about 190 meters and the BRENT reservoir formations are seated at a depth of 4000 meters below sea-level. The initial reservoir pressure is 770 bars and the initial reservoir temperature is 150 ^{o}C at datum depth (4000 m TVD-msl). The field has been developed by originally 10 production wells, however more wells are planned to improve the recovery. The production strategy is pressure depletion, planned improved by pre-compressor and reduced well-head pressure when the total field production starts to decline. The production of the field started in October 2004. The maximum production rate is in excess of 20 MSm^3/d however the production have been reduced and shut in for periods in order to postpone the pressure depletion to ensure safe drilling of the last production wells and for repair of export pipe line.

To date the reservoir pressure has depleted on average 200 bar but some smaller segments have been depleted 300 bar. The expected reservoir pressure depletion at the end of the production period is expected to be 600 bars. The major geomechanical consequences anticipated are related to drilling infill wells and the stability of production wells. Stress changes cause significant changes in the mud weight window during drilling of infill wells while reservoir compaction and/or fault re-