CATO-2 Deliverable WP3.03-D01

Computational facilities for advanced geomechanical modelling

(1st Year Progress Report, 2010)

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1 Executive Summary (restricted)

Subsurface storage of CO2 poses new challenges to the geomechanical analysis of caprock and fault integrity. Compared to conventional geomechanical analysis of hydrocarbon depletion, advanced analysis techniques need to be developed accounting for changes in stress state due to injection and changes in the mechanical and transport properties of faults and caprock due to reactions with CO_2-rich fluids.

This report describes the status of computational facilities (both hardware and software) for advanced geomechanical modelling at TNO available to the CATO-2 project (deliverable WP3.3-D01).

Most of the hardware and software facilities were already available at the start of the project. During the first project year the existing software was updated where applicable, initial simulations were run to test computation requirements and boundary conditions, and the feasibility and value of coupling of different modelling techniques was investigated.

Hardware and various commercially available numerical codes, including (i) the finite element code DIANA, (ii) the finite difference codes FLAC and FLAC3D and (iii) the discrete element codes PFC2D and PFC3D, are now available for geomechanical simulations and tested. TNO has vast experience in using these software packages as well as in exchanging the models and data between geological modelling packages, reservoir simulators and geomechanical simulators. The computational facilities can now routinely be applied in research on caprock and fault integrity analysis performed in the work package.

Distribution List

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Document Change Record

(this section shows the historical versions, with a short description of the updates)

Version	Nr of pages	Short description of change	Pages
2010.08.30	6	Initial report by TNO	1-6

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2 Applicable/Reference documents and Abbreviations

2.1 Applicable Documents

(Applicable Documents, including their version, are documents that are the "legal" basis to the work performed)

	Title	Doc nr	Version date
AD-01	Beschikking (Subsidieverlening CATO-2 programma verplichtingnummer 1-6843	ET/ED/9078040	2009.07.09
AD-02	Consortium Agreement	CATO-2-CA	2009.09.07
AD-03	Program Plan	CATO2-WPD-3.03-D.01	2009.09.29

2.2 Reference Documents

(Reference Documents are referred to in the document)

	Title	Doc nr	Version/issue	Date

2.3 Abbreviations

(this refers to abbreviations used in this document)

FLAC	Fast Langragian Analysis of Continua
PFC	Particle Flow Code
UCG	Underground Coal Gasification

3 General Text

3.1 Introduction

For assessment of fault and top seal integrity at subsurface storage of CO_2 some new aspects in geomechanical analysis techniques are required. Compared to conventional analysis assessing fault and caprock integrity during hydrocarbon depletion, the main new aspects are that (1) changes in stress state around the fault and caprock are the result of increasing pressure in aquifers or hydrocarbon reservoirs in a depleted state, (2) long-term chemical reactions with CO_2-rich fluids may change the mechanical and transport properties of fault and caprock. To cover these new aspects advanced geomechanical modelling techniques need to be developed which require some new computational facilities.

This is a first year progress report on "*Computational facilities for advanced geomechanical modelling".* This report is deliverable D01 of the WP-3.3 *"Caprock and Fault Integrity"* of the CATO-2a project. The report covers the period from project start 2009.04.15 until 2010.08.31 and addresses task T3.3.1 related to "*Geomechanical evolution of the reservoir-seal system and induced deformation*". The objective is to develop numerical modelling capability allowing prediction of the stress-strain evolution in and around a generic reservoir-seal system. This will be applied to specific sites to evaluate reservoir deformation (heave vs. compaction), caprock deformation and ground deformation at the surface, as well as the reactivation and seismic risk potential of pre-existing faults. Deliverable D01 describes computational facilities for advanced geomechanical modelling at TNO available to the CATO-2 project.

Most of the hardware and software facilities were already available at the start of the project. During the first project year the existing software was updated where applicable, initial simulations were run to test computation requirements and boundary conditions, and the feasibility and value of coupling of different modelling techniques was investigated. The computational facilities can now routinely be applied in research on caprock and fault integrity analysis performed in the work package.

The deliverables achieved in the 1st year of the project are in agreement with the project plan.

3.2 Hardware and software facilities

The hardware available at TNO for geomechanical simulations is based on Quad Core Intel Xeon processors with 32 GB of RAM, running Windows x64 XP operating system.

The software codes available at TNO for geomechanical simulations comprise various commercially available numerical codes:

- the finite element (FEM) code called DIANA, Release 9.3 (2008) (http://tnodiana.com/),
- the finite difference (FDM) codes called FLAC, Version 6.0 (main release 2008, and later updates) and FLAC3D, Version 4.0 (2009, and updates) (http://www.itascacg.com/), and
- the discrete element (DEM) codes called PFC2D and PFC3D, Version 4.0 (2008, and updates) (http://www.itascacg.com/).

3.3 Application of the computational facilities to model fault and caprock integrity

All the selected packages are advanced software products well established in various application areas and also used in oil and gas applications. TNO has vast experience in using these software packages as well as in exchanging the models and data between geological modelling packages, reservoir simulators and geomechanical simulators. However, additional software for geomechanical simulations may be acquired in the course of the project if necessary.

The finite element code DIANA is frequently used at TNO to perform site-specific geomechanical analysis of risks of fault reactivation and caprock fracturing. It will be used in the CATO-2 project for site-specific evaluation of seals at CO_2 storage sites. The finite difference code FLAC have been used at TNO for generic research on thermo-hydro-mechanical modelling (e.g., for temperature distribution and induced fractures around UCG sites). It will be used in the CATO-2 project for generic thermo-hydro-mechanical modelling of CO_2 injection and reactive flow. TNO has extensive experience with the use of the discrete element code PFC in simulating clay smear development for fault seal analysis. The code will be used in CATO-2 for generic chemo-hydro-mechanical modelling, focussing on coupling between reactive flow and mechanical behaviour of fault and caprock.

The different numerical codes are incorporated into two separate workflows for geomechanical modelling, which are currently under development, as described in the deliverable D02 of WP3.3.