Tu Gme 10

Efficiency of Shaft Sealing for CO2 Sequestration in Coal Mines

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SUMMARY

This work examined the efficiency of a shaft sealing system for the CO2 sequestration in abandoned coal mines. The particular case of the coal mine of Anderlues was considered. The performed simulation took into account the anisotropic behaviour of shale and the presence of coalbeds.

Introduction

Carbon dioxide (CO_2) is a greenhouse gas produced after combustion. The huge amounts of fossil fuels burned in the past decades has dramatically increased the CO_2 concentration in the atmosphere. It is a major cause of climate change, CO_2 contributes to more than 60% to global warming [Bachu and Adams (2003)]. Therefore, the control of the atmospheric CO_2 content is a critical issue to mitigate climate change. In this context, the geological sequestration of CO_2 has a great potential to compensate anthropogenic emissions. It consists of trapping the CO_2 into deep geological formations. There are various geological formations considered as appropriate reservoirs for the geological storage, including depleted oil and gas reservoirs, deep saline aquifers and deep unmineable coal seams.

In coalbeds, the injected CO_2 is trapped by two mechanisms: sorption on the coal surface and physical trapping in the cleats within the coal [Gale (2004)]. The high capacity of gas storage of coal is mainly due to its very high internal surface, ranging from 20 to $300m^2/g$ [Gaucher et al. (2011)]. In fact, the injected CO_2 displaces the adsorbed methane (CH_4). The large amount of CH_4 naturally adsorbed on coal particles surface indicates that gas could be safely retained for thousands of years. Moreover, the injection of CO_2 into a coalbed could improve a potential production of methane [Pini et al. (2009)].

Therefore, abandoned coal mines appear as promising reservoirs for CO_2 sequestration. So far, several abandoned coal mines have been used as gas storage facilities, but not for carbon dioxide. In Belgium, the coal mine of Anderlues was used for the seasonal storage of natural gas until 2000 [Piessens and Dusar (2006); Van Tongeren and Dreesen (2004)]. The seasonal storage of natural gas in former coal mines has shown that the efficiency of the gas storage depends in part on the shaft sealing system. In the perspective of CO_2 sequestration, it is clear that shafts have to be considered in the safety assessment of the storage.

This work studies via numerical modelling the transfer mechanisms trough a shaft and its sealing system. The geometry of a shaft from the abandoned coal mine of Anderlue is considered. The numerical modelling performed is a precious tool for analysis over large scale and long time period (the predictions cover a period of 500 years). More than the shaft sealing system, the presence of coal in the host rock is taken into account. The finite element code LAGAMINE is used for this numerical study [Collin et al. (2002); Charlier et al. (2013); Dieudonné et al. (2015)].

Anderlues coal mine

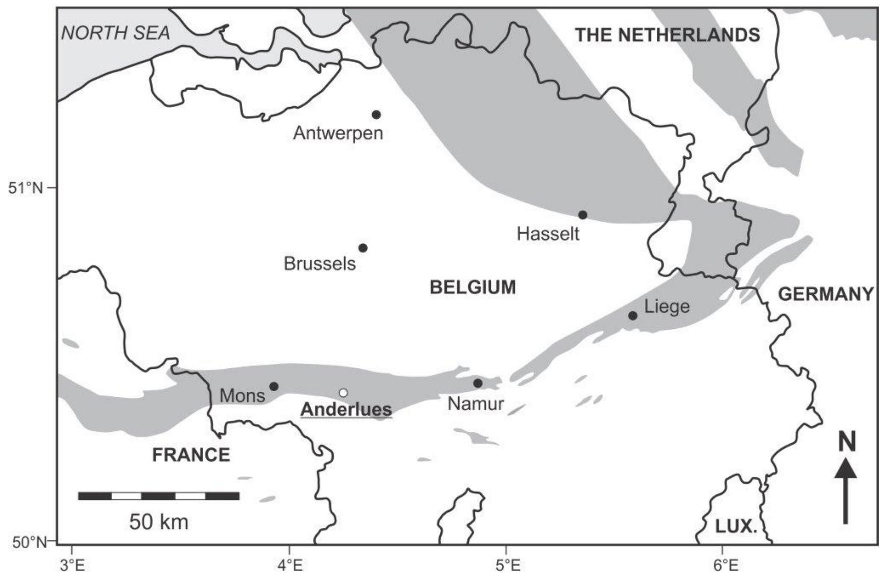

Figure 1 *Map of the outcropping or shallow subsurface coal basins (shaded area) in and around Belgium. Modified after Piessens and Dusar (2006).*

The mine of Anderlues is located in the coal Basin of Mons, in South-Western Belgium (Figure 1). The mine is hosted in rocks formed at the Upper Carboniferous Westphalian (313-304 Ma). These rocks were subjected to an important compressive tectonic setting during the Sudetian phase of the Variscan Orogeny. The Westphalian formations consist of alternating sequences of shale and plant debris turned into coal. These rocks are composed of 60% of shale, 37% of sandstone and 3% of coal [Ghiste (1990)].

The coal has been exploited in Anderlues between 1857 and 1969. During this period, only 3.5% of the total coal volume was extracted from the deposit, the remaining coal is difficult to exploit due to spatial scattering.

From 1978 to 2000, the former coal mine was used by Distrigaz (currently Fluxys) as a reservoir for seasonal storage of natural gas. 90% of the natural gas stored was adsorbed on coal. This gas was sequestrated in a deep geological formation through the shafts. Despite the sealing systems, the shafts constitute preferential pathways for gas leakage.

Figure 2 presents the geometry of the shaft n°6 and the shaft sealing system that was used in Anderlues. A bentonite plug is disposed between two concrete slabs.

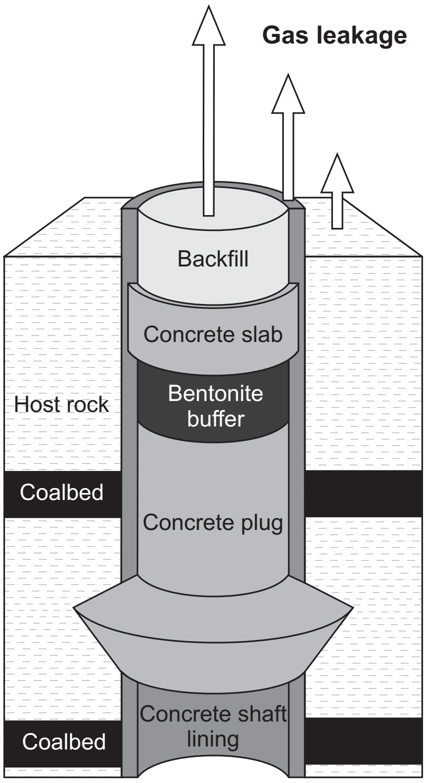

Figure 2 *Layout of the sealing system.*

Method and theory

Different materials are considered in the model: the host rock (shale) containing coalbeds, the concrete shaft lining and sealing systems, the bentonite buffer and the backfill. Realistic values of the hydromechanical parameters of these materials are considered. Nevertheless, a sensitivity analysis is carried out in order to assess the influences of these parameters on the performance of the sealing system.

The hydromechanical model is based on three balance equations: the balance of momentum (or stress equilibrium) equation and the mass balance equations for water and CO_2. A two-phases flow model is considered for the mass flow description. Two kinds of transport processes are taken into account: the advection of each phase and the diffusion of the components within each phase. The advection is described by the Darcy's law and the diffusion by a Fick's law.

The simulation comprises 4 different stages: first the shaft excavation, then the set-up of the concrete shaft lining and ventilation of the mine, later the set-up of the sealing system, and finally the injection of CO_2 into the mine.

In this analysis, the initial stress field and the rock properties are assumed anisotropic. The first three stage are performed to establish the hydromechanical conditions in the different materials before the CO_2 injection. During the shaft excavation stage, the water pressures at the shaft wall are progressively decreased during 50 days. A cone of depression is therefore created around the shaft. After that, the concrete shaft lining is set-up and a ventilation phase of 50 years corresponding to mining activities is considered. The third stage is the installation of the sealing system, water pressures are allowed to equilibrate for 50 days. Finally, to simulate the injection of CO_2, gas pressures at the shaft wall are gradually increased and then maintained constant.

Conclusions

This work examined the efficiency of a shaft sealing system for the CO_2 sequestration in abandoned coal mines. The particular case of the coal mine of Anderlues was considered. The performed simulation took into account the anisotropic behaviour of shale and the presence of coalbeds. When the permeability to gas of the concrete is higher than the permeability of the host rock, it appeared that CO_2 preferentially flows though the concrete elements and then the backfill. Therefore, the major contribution to the release of CO_2 comes from the backfill.

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