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IMPACT OF PRESSURE CHANGE RATE ON CAVERN INTEGRITY THERMO-MECHANICAL ANALYSES FOR THE STORAGE MEDIA HYDROGEN AND NATURAL GAS MODELING

Rohola Hasanpour and Dirk Zander-Schiebenhöfer

DEEP.KBB, Hannover, Germany

Abstract

During storage operation of natural gas storage caverns, the question of the maximum possible rate of pressure change arises. This is not only of concerns during storage operations but also throughout special measures such as flooding the cavern or mechanical integrity tightness tests. The governing question then is, how the specifications from the rock mechanical expert opinion are to be implemented and whether there is any potential for interpretation for the execution of the operational work? Practically, this would mean to either “stretch” the requirement of pressure change rate of 10 bar/d (145 psi/d) or conduct an alternative mode such as 4 bar/h (58 psi/h) over 2.5 hours followed by a standstill period of 21.5 hours without violating the geomechanical specifications.

Thermomechanical analyses in order to investigate the effects of different pressure change rates on the integrity of a gas storage cavern were applied to answer these questions. Especially, in the area of the last cemented casing shoe, this question is of interest with regard to the tightness assessment, because the system composed of salt rock, cementation and casing is not only subjected to purely mechanical effects, but also to the thermally induced stressing due to pressure changes. Moreover, the long-term impermeability of the whole system must be guaranteed in this area in particular.

This paper deals with the investigation and evaluation of the effect of the pressure change rate on integrity of a gas storage cavern considering the coupled thermo-mechanical behavior of rock salt surrounding cavern and last cemented casing shoe. The investigations were carried out using 3D numerical simulation models for different withdrawal rates and creep behavior of rock salt. In studying the effect of the pressure change rate on cavern integrity, the operation phase at maximum storage pressure with a subsequent withdrawal phase were considered to verify the integrity of the area around the cavern and the last cemented casing shoe.

The simulation process was composed of thermodynamic simulations and thermo-mechanical modelling for different pressure change rates using Finite Difference Method (FDM), where the results of thermodynamic simulations have been applied as input in 3D numerical modeling. The evaluation of the simulation results focuses on the assessment of the long-term stability and tightness of the surrounding rock mass in the area around the cavern roof and the last cemented casing shoe.

As aforementioned, questions about the maximum pressure change rate arise for natural gas storage caverns in order to optimize operations where possible. However, similar questions are also expected for large-scale hydrogen storage applications. Therefore, the impacts of different pressure change rates are considered as meaningful for natural gas as well as for hydrogen. Thus, general similarities and differences are highlighted and compared for the storage media hydrogen and natural gas. Furthermore, the appropriate pressure change rate in order to avoid integrity cases are discussed from the perspective of rock mechanics.

Key words: Gas storage cavern; pressure change rate, withdrawal rate, injection rate, thermo-mechanical analysis; numerical simulation; cavern integrity; hydrogen, natural gas