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Radial-symmetric well design to optimize coal yield and maintain required safety pillar width in offshore underground coal gasification

Natalie Christine Nakaten*, Thomas Kempka

GFZ German Research Centre for Geosciences, Fluid Systems Modelling, Telegrafenberg, 14473 Potsdam, Germany

Abstract

Underground coal gasification (UCG) enables utilization of coal seams, currently not economically extractable due to complex geological boundary conditions. The technical and economic feasibility of onshore UCG operation has been extensively investigated in the past decades, while studies on offshore UCG operations are rare. We propose a radial-symmetric well design and validate it by means of geomechanical simulations. Our calculations and simulation results demonstrate that a coal yield of 46% can be achieved with safety pillar widths of 100 m. For an extracted coal seam thickness of 11 m, seabed level subsidence amounts to 0.16 m.

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Keywords: Underground coal gasification (UCG); Parallel Controlled Retracting Injection Point (P-CRIP); Geomechanical simulation; Rock failure; Ground surface subsidence; Build-up rate; Well diameter

1. Introduction

Underground coal gasification (UCG) can support extraction of so far unmineable coal reserves, whereby its technical and economic feasibility has been investigated by means of numerous interdisciplinary studies in the past decades [1–44]. In order to implement the UCG process, the target coal seam is developed by vertical and deviated wells, which are linked to establish an initial gasification reactor. Following coal seam ignition, a sub-stoichiometric gasification process is controlled by the injection of a gasification agent (Fig. 1). UCG produces a high-calorific synthesis gas, applicable for different end-use options, e.g., provision of chemical raw materials, liquid fuels, fertilizers or electricity [4, 13, 16, 20, 28].

Besides additional energy reserves from unmineable coal seams, and thus reduction of energy import dependency, UCG has significant advantages compared to conventional coal mining. These are, e.g., a higher resource utilization

* Corresponding author. Tel.:+49-331-288-28722 ; fax: +49-331-288-1529.
E-mail address: natalie.christine.nakaten@gfz-potsdam.de

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efficiency and straight implementation options for frontier Clean Coal Technologies (e.g. CCS, increase of production efficiency). On the other hand, environmental impacts may occur due to the complex chemical and physical processes involved in the gasification process [4, 6, 9, 13, 30–32, 43]. Besides ground surface subsidence, resulting from the

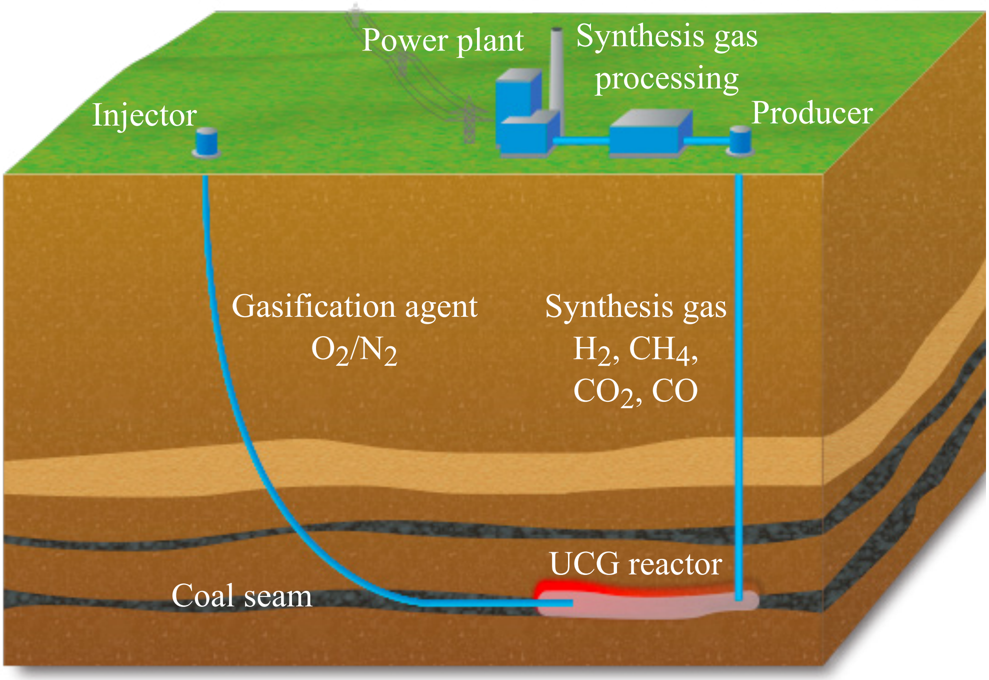

Fig. 1. Schematic of the UCG process with gasification agent injection as well as synthesis gas production, its processing and end-use at the surface

extraction of larger coal amounts, UCG may contaminate adjacent aquifers in case of gas escapes from the reactor. Hereby, changes in the hydraulic conductivity of the hanging wall may establish potential pathways for UCG contaminant migration [14, 15, 24, 26, 30, 44, 45]. While numerous studies on onshore UCG operation exist, offshore UCG application has rarely been addressed in the literature. Since ground surface subsidence is only relevant in view of well and UCG reactor integrity but not for surface infrastructure in offshore applications, a higher coal yield can be achieved by implementation of enhanced UCG well designs.

In the present study, we propose a radial-symmetric UCG well design, developed to be employed from a single offshore platform and supply sufficient amounts of synthesis gas to feed commercial-scale fertilizer or ammonia production. For that purpose, a computer-aided design (CAD) model is developed for integration with geomechanical simulations. These are employed to investigate whether the chosen safety pillar widths (safety distances) between the single UCG reactors are sufficient to avoid formation of hydraulic short circuits. Hereby, hydraulic communication between different UCG reactors is known to compromise UCG operation due to the likely consumption of UCG product gases in reactor zones representing earlier gasification stages (”synthesis gas cannibalism”), resulting in a degradation of synthesis gas quality [32]. Further, hydraulic short circuits may trigger synthesis gas and UCG by-product escapes into the coal seam’s overburden and adjacent groundwater aquifers [32, 45].

2. Radial-symmetric well design to optimize coal yield

The proposed radial-symmetric well design for offshore UCG was developed to achieve a maximum coal yield of 46%, while maintaining sufficient safety pillar widths to avoid formation of hydraulic short circuits between the single UCG reactors (Fig. 2). This enables the UCG operator to apply a single offshore platform for drilling and subsequent operation of multiple UCG reactors at the same time. Our design is somewhat different from the Super Daisy Shaft concept introduced by Zakiewicz [46], since it does not comprise a shaft for the sake of economics and technical