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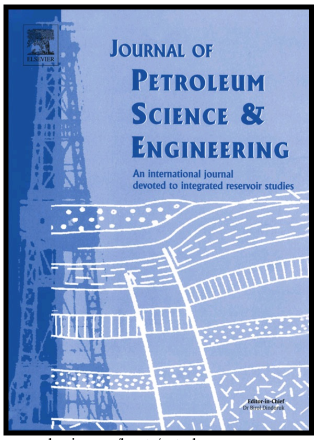

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Effect of Various Coal Constitutive Models on Coupled Thermo-Mechanical Modeling of Underground Coal Gasification

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Abstract

Underground coal gasification (UCG) is an advanced method that can address the high energy demand in future by adding new resources to the proved reserves. The high temperature nature of the gasification reactions along with the formation of cavities within a coal seam necessitates a comprehensive analysis of mechanical and thermomechanical impacts on the UCG process. On the other hand, geomechanics plays a significant role in the efficiency of the UCG process by varying the reaction rates, porosity, and permeability in a flow model. More importantly, geomechanical modeling of UCG is necessary to mitigate the associated environmental hazards such as land subsidence and groundwater contamination.

In this study, the results from a reservoir simulator are coupled with a geomechanical module to solve for the displacement and stress variations. A controlled retracting injection point (CRIP) method is applied in the reservoir simulator to model reactions and geochemistry. By performing sensitivity analyses using the linear elastic, hyperbolic, and elasto-plastic constitutive models, the two compelling factors of high temperature and cavity evolution, which have the highest contributions to the geomechanical responses of the UCG process, are comprehensively investigated. At the end, a stress rebalancing technique is imposed on the linear elastic model to mimic the elasto-plastic solution by capturing the shear softening and the post-failure behaviour of coal.

Keywords: Geomechanics; Underground coal gasification (UCG); Cavity; Coupling; Thermal; Constitutive model.

1. Introduction

Coal accounts for over 40% of global power production, which makes it the largest provider of electricity. Coal is also the second largest primary energy source in the world after oil (International Energy Agency, 2015). The significant position of coal in the global energy mix is mainly because it is abundant, low cost, and the most wide-spread fossil fuel in the world (World Energy Council, 2013). According to International Energy Agency (2015), the coal demand growth is forecast to increase by almost 1% per year through 2020, which is mainly due to the escalating electricity rates in the developing countries. Therefore, more coal extraction is necessary to meet the global future energy demand. However, due to the recent concerns and constrains on the environmental hazards and greenhouse gas emissions associated with current coal production methods, the contribution of coal in future energy mix relies on developing clean coal technologies. In this context, underground coal gasification (UCG), which is a cleaner process compared with conventional coal extraction methods, can add new resources to the proved coal reserves. The main environmental hazards associated with UCG are the ground subsidence, underground water contamination caused by failure in the sealing layers, and the slope change caused by the veridical displacement in underground aquifers. This necessitates conduction of a comprehensive geomechanical study in any UCG modeling analysis.

In the underground coal gasification (UCG) process, air or oxygen is injected in-situ through an injection well in order to gasify coal and convert it to a useful product gas, known as synthesis gas or syngas. The synthesis gas is then transported to the surface through a production well, and can be used as a fuel for power generation or as a chemical feedstock for different chemical products like ammonia. For the produced synthesis gas to flow from an injection well toward a production well, a high permeable path (link) within a coal seam requires to be established.

A UCG process can be compared to an in situ combustion technique in an enhanced oil recovery process in a sense that high temperature chemical reactions occur in both processes. However, the flow modeling of a UCG process can be more complex as it incorporates cavity propagation calculations and a wide variety of chemical reactions. On the other hand, coal seam characteristics can be compared with shale oil