2-D Modeling of Underground Coal Gasification (UCG)

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Abstract

Underground coal gasification (UCG) is a process which converts coal to syn gas at the underground coal seam itself. This process involves injection of reactive gases to the coal seam and bringing the product gases to the surface through a production well. UCG can help meeting the rising energy demand by utilizing coal resources that otherwise would be too deep, or of poor quality, or simply not economical to mine. As UCG takes place, a cavity is formed underground in the coal seam which grows three-dimensionally. The growth of the cavity is affected by various factors such as flow field in the cavity, spalling of char/coal, temperature distribution in the cavity, etc. Because of complexity of the process, a simplified process model is needed to predict the performance of the UCG. This work presents one such model. The objective of this work is to develop a two-dimensional model of the cavity to analyze its growth and product gas composition during the UCG process. The two-dimensional model is a reduced form of the actual three-dimensional cavity where the geometry for modeling is a vertical plane passing through the injection and production well. COMSOL Multiphysics® used to simultaneously solve momentum (Brinkman Law), mass and energy balance equations taking into account both diffusive and convective transport. The porosity and permeability of coal are modeled as a function of solid density. The kinetics of the reactions has been obtained from literature for the coal of our interest. The resulting set of equations is solved using time dependent segregated solvers available in the software. The temperature profiles, char consumption, the concentration of the various gases as well as rate of all the reactions are obtained. Some of the representative results are shown in Figure 1, 2 and 3. The distribution of char density at time = 140 minutes is shown in Figure 1 where it can be seen that the char near the inlet has been consumed till this time. As shown in Figure 2, oxygen concentration is very low at places away from the inlet as it gets consumed very fast due to the high rate of the combustion reaction. Carbon dioxide is generated from this combustion reaction and it gets consumed due to the gasification reaction. Hence, its concentration profile depends on the position of the reaction front of these two reactions. Figure 3 shows the profile of carbon dioxide where a maxima can be seen due to this very reason. The model is also able to predict the composition of product gas and its calorific value. The important aspect of the model is that it can foresee the growth of the cavity even after it has hit the overburden, which will be the reality for the UCG of thin coal seam. The results of the model are also compared with the performance of field trials.

Figures used in the abstract

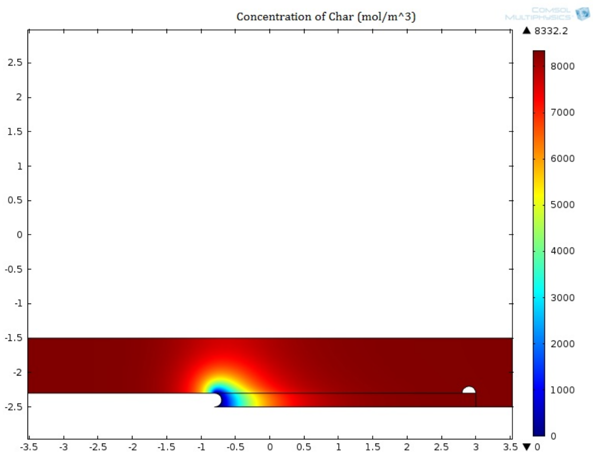

Figure 1: Concentration of char across the coal seam

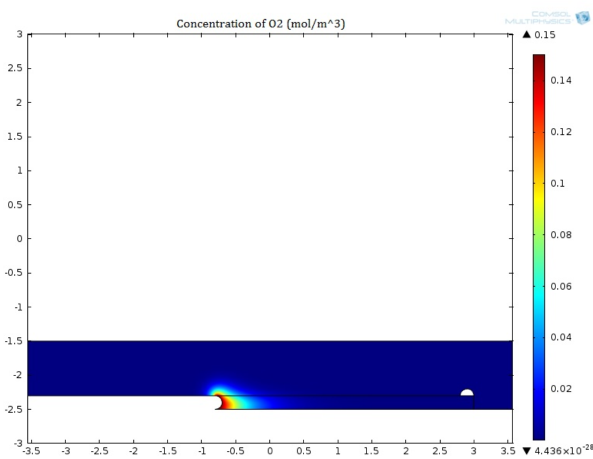

Figure 2: Concentration of oxygen across the coal seam

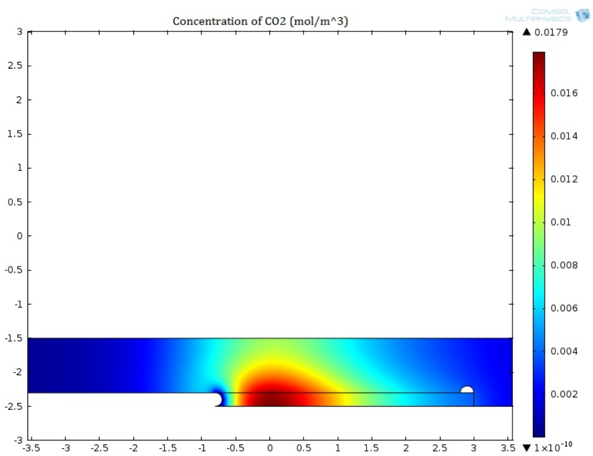

Figure 3: Concentration of carbon dioxide across the coal seam