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Thermal characteristics and evolution model of coal fire at surface and underground coal mine

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Abstract

Many surface or underground coal fires are believed to exist worldwide. They keep burning and extend the areafor many years more. The main objective of the study is to gain fundamental understanding of coal fire thermal characteristics and to design the thermal evolution model. Fire propagation over periods of time were analyzed and the model assists to locate the fire zone areas indicated by the temperature changes and other thermal related variables of natural burning coal so that it can be used to develop the predictive model dynamic of burning front. The model is crucial for spontaneous coal combustion prevention study which responsible for many coal mine accidents. Burning coal involved complicated and complex processes that are difficult to predict. The methodology is modeling coal as a physical process of a porous media (heat transfer in a porous media) and heat transfer in fluids. The dynamic burning front of coal fire simulation will be carried out using COMSOL Multi-physic®. The process is mainly the coal oxidation during the low and high temperature. The typical chemical reaction of the coal decomposition is shown as $C_{156}\ H_{74}\ O_{30}\ N_2S_2 \rightarrow 138C + 12CO_2 + 6CO + 37H_2 + N_2 + S_2$. The thermal evolution model was determined to be the coupled conduction and convection heat transfer phenomena. The temperature changes and fire propagate after the simulation along the coal cylinder model. The study found that by increasing the heat flux and the prescribed temperature, it will increase the temperature gradient and the distribution of temperature from the heat flux inward.

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1. Introduction

Natural burning coal or coal fire at surface or underground mines are one of the most difficult phenomenon to prevent since the knowledge of this area is still limited. Coal fire causes many problems to economic, social and ecological impacts.Burning coal seam emits dangerous GHG emission (CO_2, CO, H, N, NO, S, SO_2) and causes the land destruction such as subsidence, fractures cracks, etc. The burning can continue to burn for decades or even centuries until either the fuel source is exhausted, a permanent groundwater table is encountered, the depth of the burn becomes greater than the ground's capacity to subside and vent, or humans intervene[1]. Coal fire may happen as the result of natural occurrence or as an industrial accident. They are often started by lightning, grass, or forest fires, and are particularly insidious because they continue to smoulder underground after surface fires have been extinguished, sometimes for many years, before flaring up and restarting forest and brush fires nearby. They propagate in a creeping fashion along mine shafts and cracks in geologic structures[2]. The countries that suffer a lot of this issue are mostly the world producing coal countries such as China, U.S.A, India, E.U, Australia and Indonesia.

2. Objectives

The main objective of the study is to gain fundamental understanding of coal fire thermal characteristics and to design the thermal evolution model. The model was used to analyse fire propagation over periods of time and to locate the fire zone areas and see the temperature changes in a steady state condition and other thermal related variables of natural burning coal so that it can be used to develop the predictive model dynamic of burning front. The model is crucial for spontaneous coal combustion prevention study which responsible for many coal mine accidents. Burning coal involved complicated and complex processes that are difficult to predict.

3. Methodology

Burning coal involved a complicated and complex processes that is difficult to predict especially if it is underground and not too many researches has been done in this area. The burning coal consists of three categories of multi-physics models, namely fluid dynamics, heat transfer and mass transfer. The proposed model will concentrate on modellingthe coal as a physical process of a porous media or heat transfer in a porous media and heat transfer in fluids. The dynamic burning front of coal fire simulation will be carried out using COMSOL Multi-physic® software Ver. 4.0a. The multi-physic models will be integrated in a model and interactive each other. Since the burning coal phenomena is a multi-physical process, the simulation tool must be multi-physics capable in order to correctly capture the important aspects of the design and COMSOL has that capability. COMSOL Multi-physics delivers the ideal tool to build simulations that accurately replicate the important characteristics of the designs. COMSOL works based on finite element (FE) analysis, solving the differential equations of the problems. FE can handle complex geometries and boundary and compared with other methods of modeling COMSOL are relatively easy to use graphical interface, uses state-of-the-art solvers and optimizers, runs well on a suitably-equipped (lots of RAM) desktop PC, lots of default options / hidden parameters, and interface changes based on what type of physics to be solved[3].

4. Predictive Model Dynamics of Burning Front

Coal oxidation during coal fire progressed from low to high temperature, therefore the reaction mechanism is referred to the combustion of solid fuel. Since this study considered only the oxidation of carbonaceous solid material, the reaction mechanism can be written as the following[4]:

$$C + O_2 \rightarrow CO_2 + \text{ ash/solid products} \tag{1}$$