Fuel 223 (2018) 63–73

Contents lists available at ScienceDirect

Fuel

journal homepage: www.elsevier.com/locate/fuel

Full Length Article

A random forest approach for predicting coal spontaneous combustion

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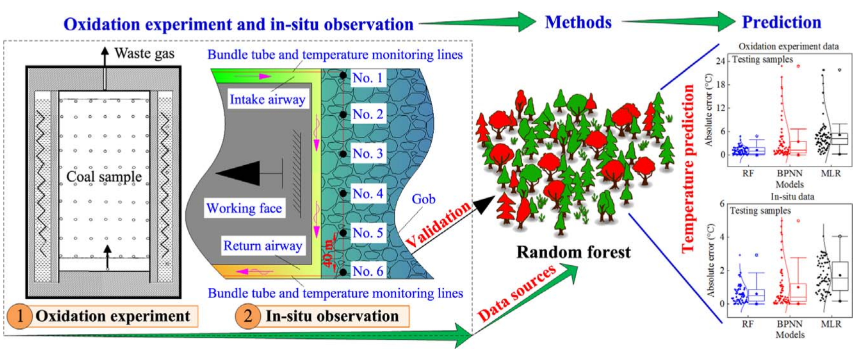
GRAPHICAL ABSTRACT



ARTICLE INFO

Keywords:
Coal spontaneous combustion
Gas concentration
Random forest
Coal temperature
Modeling

ABSTRACT

The accurate prediction of coal temperature plays a vital role in preventing and controlling the spontaneous combustion of coal in coal mines. In this study, a large-scale 2-ton experimental furnace was constructed to implement an oxidation experiment by using a Dafosi coal sample. The aim was to simulate the spontaneous combustion of coal at low temperatures (< 100 °C). A random forest (RF) approach based on the oxidation experiment was proposed to predict coal spontaneous combustion, which exhibited satisfactory results. Moreover, to verify the performance and effectiveness of the RF approach in a practical application, a long-term in-situ observation test was conducted in a fully mechanized caving mining face (the Dafosi Coal Mine), where the in-situ data were employed to establish the RF model. Methods such as back-propagation neural network (BPNN) and multiple linear regression (MLR) were also adopted and compared with the RF model. The results indicated that the MLR model had the least reliable predicted results, regardless of whether the model was based on the oxidation experiment data or the in-situ data. This demonstrated that linear regression methods are not ideal for determining the complicated relationship between the temperature and gaseous products of coal spontaneous combustion. The BPNN model exhibited the most reliable prediction results during the training stage; however, overfitting occurred in the training stage, and the predictive performance at the testing stage was poorer than that of the RF model. The RF model accurately predicted the temperature of coal spontaneous combustion when it was applied to the in-situ data, and almost no deviation existed in the predictive performance indicators between the training and testing stages. The modeling and application results suggested that the RF model, which possesses high precision, strong generalization ability, and sound

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https://doi.org/10.1016/j.fuel.2018.03.005
Received 12 November 2017; Received in revised form 9 February 2018; Accepted 2 March 2018

practical performance is more suitable for the prediction of coal spontaneous combustion. This method can potentially be further applied as reliable approach for the assessment of intricate relationships through fuel and energy investigations.

1. Introduction

Coal spontaneous combustion is a major disaster in underground coal exploitation, and seriously threatens the safety production of coal mines [1]. The resulting fire wastes valuable resources, damages equipment, destroys the ecological environment, threatens human health, and leads to gas and coal dust explosions, resulting in casualties and considerable economic loss [2–5]. Gobs are particularly prone to coal spontaneous combustion, especially following the application and popularization of fully mechanized top-coal caving mining technology; as the output and benefit of the coal mining face greatly improves, its high-yield and high-efficiency characteristics increase the gob area, resulting in more residual coals left in the gob [6]. Furthermore, gas emissions, air pressure, and the unavoidable ventilation intensity in the working face increase significantly with increased mining intensity, which increases the risk of coal spontaneous combustion in the gob. The inherent traits of the gob determine the concealment and inaccessibility of coal spontaneous combustion, which presents enormous challenges in preventing and controlling it.

In terms of mine safety, timely and accurate prediction is a prerequisite for the prevention and control of coal spontaneous combustion. Numerous methods have been developed to predict and determine the state of coal spontaneous combustion, which include the coal spontaneous combustion tendency method, the experiential statistics analogy, the comprehensive assessment method, the spontaneous combustion experiment method, the temperature measurement method, and the gas analysis method [7–11]. The coal spontaneous combustion tendency method is mainly based on the differences of coal spontaneous combustion tendency to divide the level of coal spontaneous combustion, which then distinguish the risks of coal spontaneous combustion in different coal seams. The experiential statistics analogy, which analyzes and predicts the risk of spontaneous combustion in real mining conditions, is based on statistical data of accidents relating to coal spontaneous combustion. The comprehensive assessment method uses statistics such as geological conditions, the technical factors of mining, ventilation conditions, and preventive measures to make subjective judgments of the main factors that contribute to spontaneous combustion and thus establish approximate predictions for the likelihood of coal spontaneous combustion in coal seams. In the spontaneous combustion experiment method, an experimental system is used to determine the characteristic temperatures, spontaneous combustion period, heat release, gaseous products, and other parameters of coal spontaneous combustion and thus predict the risk factors for in-situ mining conditions. The temperature measurement method determines and predicts the spontaneous combustion state of coal by directly monitoring the temperature of a gob. In the gas analysis method, which is one of the most frequently used approaches in underground coal mines, the state and development of coal spontaneous combustion are indentified according to the appearance or concentrations change of some gaseous products in coal oxidation [12].

Coal spontaneous combustion is a complex physicochemical process resulting from a coal-oxygen compounding reaction [13]. Corresponding gaseous products, such as O_2, CO, CO_2, CH_4, C_2H_6, and C_2H_4, are released during coal oxidation and self-heating, and their concentrations change regularly as the coal temperature increases. Thus, the state and trend of coal spontaneous combustion can be determined and predicted by monitoring the gas indexes [14]. However, the relationship between coal temperature and gas indexes is extremely

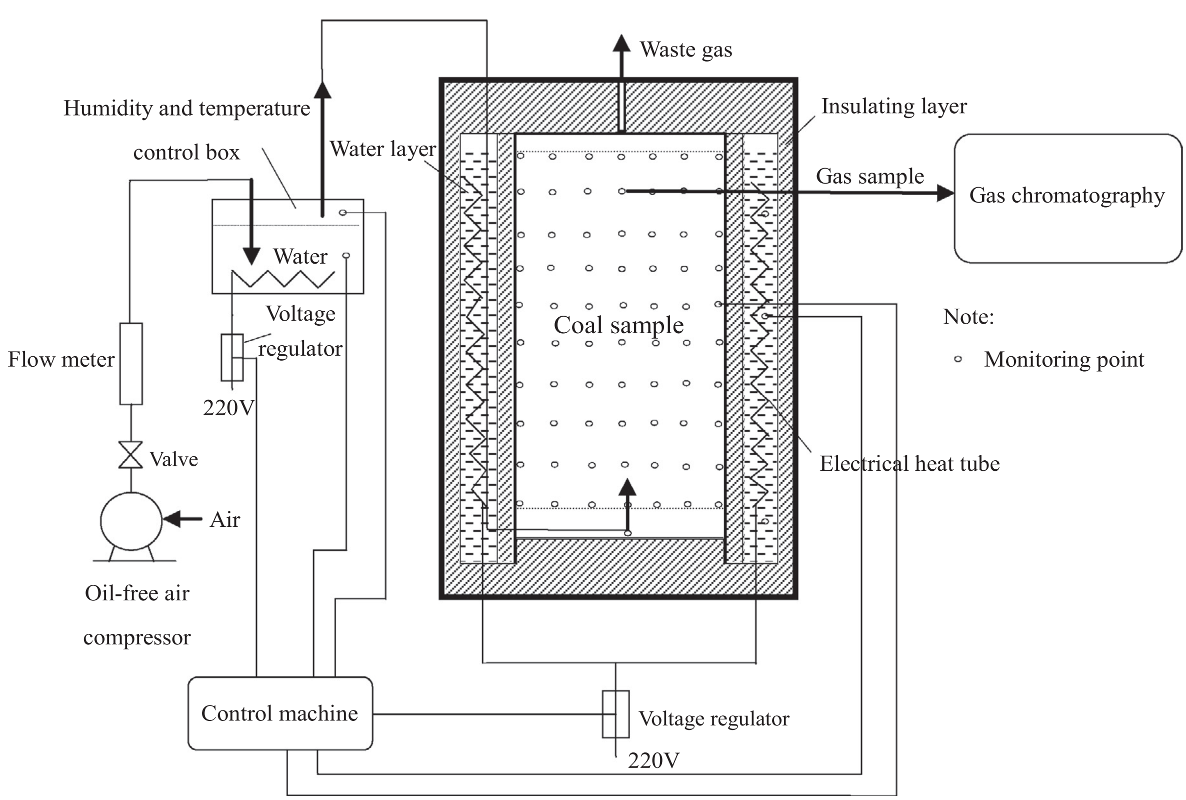

Fig. 1. Schematic of oxidation experimental system.