Internet-based monitoring and prediction system of coal stockpile behaviors under atmospheric conditions

Nihat Yilmaz · A. Hadi Ozdeniz

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Abstract Spontaneous combustion on industrial-scale stockpiles causes environmental problems and economic losses for the companies consuming large amounts of coal. In this study, an effective monitoring and prediction system based on internet was developed and implemented to prevent losses and environmental problems. The system was performed in a coal stockpile with 5 m width, 10 m length, 3 m height, and having 120 t of weight. The inner temperature data of the stockpile was recorded by 17 temperature sensors placed inside the stockpile at certain points. Additionally, the data relating to the air temperature, air humidity, atmospheric pressure, wind velocity, and wind direction that are the parameters affecting the coal stockpile were also recorded. The recorded values were analyzed with artificial neural network and Statistical modeling methods for prediction of spontaneous combustion. Real-time measurement values and model outputs were published with a web page on internet. The internet-based system can also provide real-time monitoring (combustion alarms, system status) and tele-controlling (Parameter adjusting, system control) through internet exclusively with a standard web browser without the need of any additional software.

Keywords Coal · Stockpile · Spontaneous combustion · Internet-based measurement · Prediction

Introduction

Although storing coal is so easy and practical with respect to other energy resources, it has serious risks due to its spontaneous combustion property. For instance, besides the fact that coal storage at the thermal power plants has the advantages of being spare fuel against production disruptions in a coal mine and providing continuous energy production without any interruption, it has some economical and environmental hazards like spontaneous combustion and reduction in their calorific values (Ozdeniz et al. 2008).

The event beginning with coal’s oxygen absorption from air during its contact with atmosphere, continuing with oxidation and probably ending with a flaming fire caused from heat accumulation in the medium is called spontaneous combustion (Gill and Browning 1971). Spontaneous combustion event is a result of temperature increase...
occurred in coal structure because of producing more heat occurred during many reactions than the excess heat given to the environment due to various factors (Unver and Ozozen 1998). When coal is stored, there arise some problems such as air pollution, decrement of the calorific value, and finer size of the coal during storage. Therefore, parallel to environmental concerns, there are some economical problems as well.

Modeling of the factors, especially the atmospheric factor, is so significant to prevent the losses and the environmental problems. If the modeling studies can be supported with effective presentation and alarm systems, then we obtain more suitable solutions for the problem. Nowadays, internet is the most popular presentation area due to its high speed and accessibility from all over the world. Additionally, internet provides great potential for the high-level control and measurement systems. An internet-based measurement and control system is a new concept attracting attention in recent years (Yang et al. 2003). However, little work has been performed to develop real-time prediction methods for the design of such internet-based measurement systems. In literature, there are many internet-based measurement systems. Especially, telerobotic and telemedicine application systems contain web-based measurement systems having different types (Song et al. 2005; Yilmaz et al. 2006).

In this study, due to the causes mentioned above, the behaviors of spontaneous combustion of coal in stockpile areas were investigated by an internet-based measurement and prediction system in which artificial neural network (ANN) and the statistical methods were used on internet.

**Internet-based measurement and analysis system**

The industrial-scale coal stockpile on which the tests were performed was formed in a stock area of a company in Turkey–Konya which annually consumes great amounts of coal. The coals obtained from both open and underground mines of Western Lignite Corporation are enriched in coal preparation plants. The coals used in this study were the enriched coals with particle sizes between 10 and 18 mm. The length of the stockpile was about $10 \times 5$ m in width with a height of $3$ m, while the mass of it was approximately $120$ t of coal in total. The general view and location of the stockpile shaped as a triangular prism is given in Fig. 1.

There were placed 17 heat sensors (Pt100) at the preset points of the stockpile which can sense the temperature values precisely. Ten of the sensors, namely T1, T2, T3, T4, T5, T6, T7, T8, T9, and T10, were placed at the first meter of the stockpile from the bottom, and seven of them that are T11, T12, T13, T14, T15, T16, and T17 were placed at the second meter. The distances between the sensors at the first and second layers were set as homogeneous as it can be. The plan view of the sensors and measurement system can be seen in Fig. 2.

The measurement unit is connected to internet directly. All measured values and prediction system outputs are sent to a server machine shown

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**Fig. 1** General view from the coal stockpile formed at Konya-TURKEY