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Characterization of some Indian coals to assess their liability to spontaneous combustion

D.S. Nimaje *, D.P. Tripathy

Department of Mining Engineering, National Institute of Technology, Rourkela 769008, Odisha, India

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ABSTRACT

Mine fires are a major problem in global coal mining industry and most of them are caused by spontaneous combustion that needs proper attention in strategic planning. The operational management must pay attention to an inbuilt system management for timely detection at the initial stage prior to devastating effect. To assess the spontaneous combustion liability of coal, intrinsic properties and susceptibility indices play a vital role. Forty-nine in-situ coal samples were collected from different coalfields of India. Experimentation of the samples was carried out for proximate, ultimate, and petrographic analysis; crossing point temperature; flammability temperature; Olpinski index; wet oxidation potential analysis; and differential thermal analysis to ascertain the proneness of coal to spontaneous combustion. From the statistical analysis of the samples, it was established that the parameters of the ultimate analysis show significant correlation with Olpinski index as compared to other susceptibility indices and, hence, it can be used as a reliable index to assess the susceptibility of Indian coals to spontaneous combustion.

1. Introduction

Fire due to spontaneous combustion is a perennial danger in global coal mining industry. It may be exogenous or endogenous in origin. Mine fires in Indian coalfields, whether surface or underground, are caused by spontaneous combustion (endogenous fires) of coal, and extend from seam to seam. Several methods have been devised by academicians, scientists, researchers, etc., across the globe to assess the liability of coal to spontaneous combustion.

Coal reacts with oxygen in the air, and an exothermic reaction occurs, even in ambient conditions. The heat of the reaction accumulates, and the reaction becomes progressively faster and thermal runaway may take place to the point of ignition [1]. Congruence of three elements viz., coal, oxygen, and igniting source represented by the 'fire triangle' is a potential threat and results in a risk of spontaneous heating in mines [2]. The spontaneous heating susceptibility of different coals varies over a wide range and it is important to predict their degree of proneness in advance for taking preventive measures against the occurrence of fires to avoid loss of lives and property, sterilization of coal reserves, and environmental pollution besides concerns about safety and economic aspects of mining, etc. [2]. In India, spontaneous combustion is noticeable in all the major coalfields like Raniganj, Jharia, Karanpura, Bokaro, Ib-valley, Talcher, Chirimiri, etc. [3].

Pattanaik et al. [3] investigated intrinsic properties and a few susceptibility indices to characterize the Chirimiri coals of the SECL coalfields. Singh et al. [4] devised some fire indices to be used for assessing the spontaneous heating susceptibility. Karmakar and Banerjee [5] worked on sixteen coal samples using comparative experimental techniques to measure the susceptibility of coal to spontaneous combustion. Several experimental studies have been performed on coal spontaneous combustion such as proximate, ultimate, petrographic analysis, crossing point temperature, Olpinski index, flammability temperature, wet oxidation potential analysis, differential thermal analysis, etc. by researchers, academicians and coal companies in the world to predict the susceptibility of coal in advance. Crossing point temperature method has been adopted in India and few other countries like Australia [6], New Zealand [7], Turkey [8], U.K. [9], Canada [10], China [11], and the Czech Republic [12]. Olpinski index plays a vital role and provides quick results as compare to crossing point temperature to determine the tendency of coal to spontaneous heating and has been used by researchers in India, Czech Republic, and Poland [5,12,13]. Flammability temperature [17,19], wet oxidation potential analysis [15,16], and differential thermal analysis techniques [17,18] are often used to ascertain the fire risk of coal mines in India. In this paper, an attempt has been made to characterize the Indian coals covering several major coalfields of India for

* Corresponding author. Tel.: +91 9437943121.
E-mail address: dsnimaje@nitrkl.ac.in (D.S. Nimaje).

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assessing their susceptibility to spontaneous combustion by investigating their intrinsic properties and susceptibility indices using statistical analysis.

2. Site location

Sample collection sites were selected with practically no dirt bands in order to maintain uniformity, covering more or less the same area. The channel sampling method was used to collect forty-nine non-coking and coking in-situ coal samples from various sites covering major coalfields of India viz., Western Coalfields Limited (WCL), Mahanadi Coalfields Limited (MCL), South Eastern Coalfields Limited (SECL), Singareni Collieries Company Limited (SCCL), North Eastern Coalfields Limited (NEC), Northern Coalfields Limited (NCL), Indian Iron and Steel Company (IISCO), Bharat Coking Coal Limited (BCCL), and Tata Iron and Steel Company Limited (TISCO) as per Indian Standard IS: 436(Part-I/Section I)–1964 [21]. The collected coal samples were crushed and sieved as per the experimental requirements following IS: 436(Part-I/Section I)–1964.

3. Experimental investigations

To assess the liability of coals to spontaneous combustion, it is important to investigate the intrinsic properties by proximate analysis, ultimate analysis, and petrographic analysis as well as to determine susceptibility indices viz.: Crossing point temperature (CPT), Olpinski index (Sza), wet oxidation potential analysis, flammability temperature (FT), and differential thermal analysis (DTA).

3.1. Proximate analysis

Proximate analysis involves the determination of parameters namely, moisture (M), volatile matter (VM), ash (A), and fixed carbon (FC) for the collected coal samples following Indian Standard IS: 1350 (Part-I) – 1984 [22] and the results are summarized in Table 3.

3.2. Ultimate analysis

An elemental composition such as carbon, hydrogen, sulphur, and oxygen for the collected coals were determined using CHNS elemental analyzer following the standard procedure [20] and the results are listed in Table 3.

3.3. Petrographic study

Coal is a rock composed of number of distinct organic entities called macerals and lesser known amounts of an inorganic substance called as minerals. Each maceral has a different set of property, and it influences the behavior of coal. The macerals such as vitrinite (V), liptinite (L), inertinite (I), and visible mineral matter can be identified using a Leitz Orthoplan-Pol Microscope. Petrographic analyses of coal samples were carried as per the procedure laid down by the International Committee on Coal and Organic Petrography [25,26] and IS: 9127(Part-I & II) – 1979 Indian Standards [23,24] under oil, using reflected light microscope. The maceral analysis was carried out on polished particulate mounts in white incident light using a Leitz Orthoplan-Pol Microscope equipped with 50-X oil immersion objective and a 10-X ocular. The modal analysis was performed with the help of a mechanical stage and point counters, and the spacing between the counts was maintained at 0.4 mm. Six hundred (600) counts were taken on each sample and the amount of macerals viz., vitrinite, liptinite, and inertinite were found out using a microscope and the results are depicted in Table 3. From the previous research investigations on Indian coals, it was observed that petrographically, coking coals (higher-rank coals) have vitrinite reflectance, Ro(max) values between 0.80% and 1.40% with vitrinite >50% while non-coking coals have Ro(max) values 0.4–0.79% [34].

3.4. Crossing point temperature method

The Crossing point temperature is lowest temperature at which the coal temperature coincides with that of the furnace/bath (Fig. 1). Four g coal of −100 + 200 mesh was heated in a reaction tube in the tubular furnace at 1 °C/min linear heating rate; with oxygen purging at 80 ml/min until the coal temperature crossed the furnace or bath temperature. The heating rate was controlled by furnace/bath controller, and the readings were noted [14]. The curve between bath and coal temperature with respect to time and the CPT was found to indicate the liability of coal to spontaneous heating, and the results are shown in Table 4. The fire risk of the coal samples can be ascertained using Table 1.

3.5. Wet oxidation potential analysis

Coal oxidation leading to an immediate formation of surface oxides, followed by the formation of colloidal humic acids and finally to small aromatic and aliphatic acids in an alkaline medium is a stepwise process. It has been found that alkaline permanganate oxidation of different coals produces carbonic, acetic, oxalic, and many benzene carboxylic acids [16,29].

It is a quick method of categorization using wet oxidation apparatus (Fig. 2). 0.5 g of coal of −72 mesh was mixed with 50 ml of 0.1-N $KMnO_4$, and 50 ml of 1-N KOH solution and the coal oxidant suspension was continuously stirred by using a magnetic stirrer. The Millivolt meter records the EMF (wet oxidation potential difference, ΔE) between saturated calomel and carbon electrodes at an interval of 1 min until potential difference attains a constant

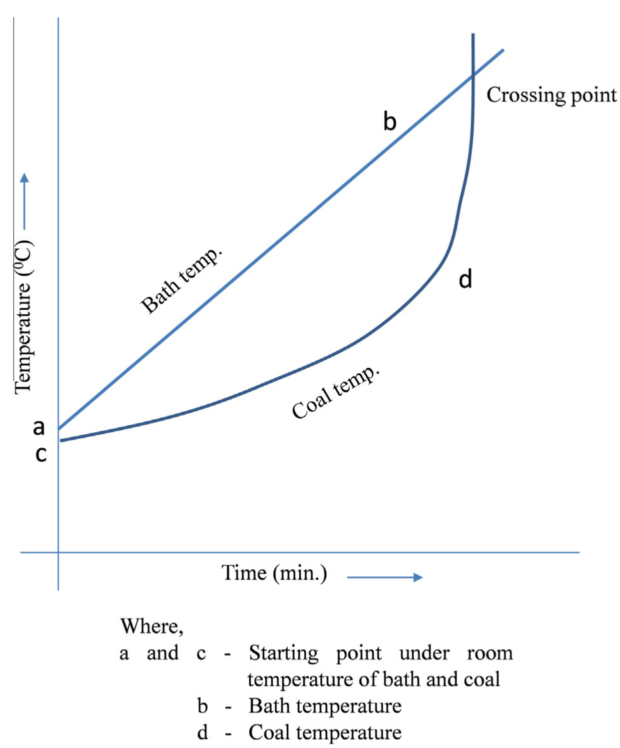

Fig. 1. CPT curve under linear heating rate [28].