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Determination of Spontaneous Heating Susceptibility of Indian Coals by Wet Oxidation Potential Method

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Abstract—*Spontaneous heating of coal leading to fire is one of the major problems that are been faced in coal mining industries all over the world. Many researchers have determined the spontaneous heating temperature through different methods. This research paper describes the same through wet oxidation potential (WOP), an electrochemical method that can be used for the determination of susceptibility of coal towards spontaneous heating. It involves less computational time and high accuracy. The method involves the rate of decrease in voltage with respect to time which corresponds to the susceptibility of coal. About 6 coalsamples from different mines were used for experimental investigations. The results thus obtained by Wet Oxidation Potential Method were cross-checked with crossing point temperature (CPT) of coal.*

Keywords: *WOP, Voltage, Susceptibility, CPT.*

1. Introduction

Coal fire in mines is a major threat tothe mining industry all over the world. Majority of fires existing today in Indian coalfields are due to spontaneous combustion of coal. The auto-oxidation of coal ultimately leads to spontaneous heating which is the root cause for the disastrous in coal mine. Many studies and researches have given prime importance on the susceptibility of coal. The assessment of susceptibility is carried through thermal analysis. The most widely used method in many countries is Crossing Point Temperature (CPT) method. The CPT method classifies the susceptibility of coal into low, moderate and high. Lower CPT coals are less susceptible than that of High CPT Values. Wet Oxidation Potential is also one of the phenomenon's of determining the susceptibility of coal. This paper deals with the report of Wet Oxidation Potential and Crossing Point Temperature. Coal study is done on the basis of two parameters i.e intrinsic and extrinsic. The intrinsic parameter is studied through proximate and ultimate analysis of coal whereas the extrinsic properties depend on the environmental and geological conditions. The experimental results of intrinsic properties of coal are correlated for verification with the results of CPT analysis. It was found that Wet oxidation potential method provides similar data within a short period of time.

The results of proximate and ultimate analyses are depicted in Table 1. The crossing point temperature of coal samples was determined following the procedure and experimental set-up described by Panigrahi et al. (1999). The results of these experiments are also shown in Figure2. Earlier, Tarafdar and Guha (1989) conducted wet oxidation experiments with seven coal samples. They observed that the higher the potential difference the more susceptible would be the coal towards spontaneous combustion. Panigrahi et al. (2004) conducted experiments with 12 coal samples from Indian Coalfields. They found thatthe wet oxidation potential method was more accurate in comparison to the CPT method.

2. Geological Details

The Gondwana Coal of India comprises 98 percent of the total coal reserves and nearly 99 percent of the production of coal in India. The carbon content in Gondwana coal is of metallurgical grade as well as superior in quality. Both coking as well as non-coking and bituminous as well as sub-bituminous coal are obtained from Gondwana coal fields.The volatile compounds and ash (usually 13 – 30 percent) and doesn't allow carbon percentage to rise above 55 to 65per cent. The moisture content is low, but it contains sulphur and phosphorous. They are found in basins of rivers. They are the Damodar (Jharkhand-West Bengal); the Mahanadi (Chhattisgarh-Odisha); the Son (Madhya Pradesh Jharkhand); the Godavari and the Wardha (Maharashtra-Andhra Pradesh); the Indravati, the Narmada, the Koel, the Panch, the Kanhan and etc. The coal samples were collected from different mines following channel sampling procedure and brought to the laboratory in sealed condition for analysis. Samples were prepared for proximate (moisture, ash matter, volatile matter and fixedcarbon) and the result obtained are laid in table 1. It is seen that BCCL has very less percentage of moisture content and the MCL coals have higher. Ash percentage is more in-case of NECL coals and less for BCCL coals; Volatile matter is minimum in NECL coals and highest in BCCL coals and the fixed carbon comes to be maximum for NECl coals.

Table 1: Proximate analysis of coal sample of different mines

Sl. No.	Sample	Moisture	Ash Matter	Volatile Matter	Fixed Carbon
1	MCL1	13.50	31.01	10.30	45.11
2	NECL	04.41	38.21	02.00	55.37
3	SECL1	10.62	22.72	23.42	40.86
4	WCL	11.32	32.56	11.92	44.21
5	SCCL	07.20	28.23	24.21	40.36
6	BCCL	01.33	18.29	25.92	54.46

3. Wet Oxidation Potential Analysis

Wet Oxidation Method is one of the thermal analysis method used for determining the susceptibility of coal. This method involves the measurement of differential temperature at a different base temperature at a constant heating rate. In this method, two electrodes i.e. saturated calomel electrode taken as a reference electrode and a carbon electrode is immersed in coal oxidant mixture which is connected to the battery terminal. Alkaline Permanganate Solution is taken as oxidant and the time taken for the coal sample to get oxidized along with the Potential difference (mV) provides sufficient information about the susceptibility of coal.

Principle

An alkaline potassium permanganate ($KMnO_4$) solution is prepared and used for the wet oxidation potential experiment. The reduction of permanganate ion to magnate ion is represented as follows:

$$MnO4^{-} + e^{-} \rightarrow MnO4^{2-}$$

MnO_4^{-} + e- MnO_4^{2-}

The standard electrode potential (E^0) for the redox reaction of the permanganate ion is 0.56V. The electrode potential can be calculated by the following equation:

$E = E^0 – (RT/F) \ln ([MnO_4^{2-}] / [MnO_4^{-}])$

$$E = E^0 - (RT|F) \ln\langle[MnO4^{2-}|[MnO4^{-}]\rangle$$

Where, R = Universal gas constant

T = Temperature

F = Faraday's constant

The addition of coal leads to oxidation of coal sample while the permanganate ion is reduced to magnate ion which results in the change in EMF and the change in potential occurs till the whole oxidation is completely over. The change in potential of the carbon electrode is measured for taking the results. The electrode is represented as carbon/ MnO_2-.

Procedure

At first, 100ml of a decinormal solution of potassium permanganate ($KMnO_4$) in 1N potassium hydroxide (KOH) solution is prepared in a glass beaker, and then it is placed on the magnetic stirrer machine along with the Teflon coated fish of the magnetic stirrer. After that the carbon electrode is fixed as the cathode and the calomel as an anode. The magnetic stirrer uniforms the mixture all around when the wet oxidation apparatus is switched on. Then about 0.5 gm of coal sample of (-212µ) size is weighed and mixed into the alkaline solution. The magnetic stirrer ensures homogeneity in the mixture because of its rotation which could be controlled accordingly. The readings are noted down from a voltmeter at an interval of 1 minute till the potential difference tends to become constant. The graphs are plotted between Time and Potential differences obtained for all the coal samples and have been presented in figure2. It could be seen from the graphs that the potential difference becomes constant for all the coal samples after 30 minutes. Thus, 30 minutes was selected as the time interval for the comparison of the potential difference values. The results of the experiment analysis are shown in Table 1, a schematic diagram of the WOP in figure 1 and CPT curve in figure 3.

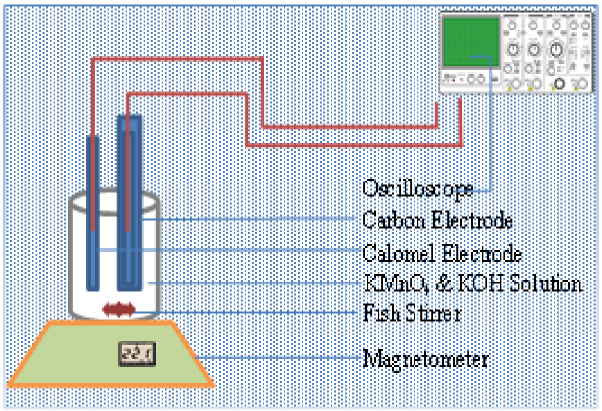
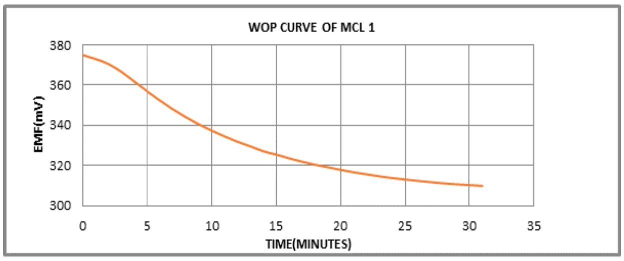
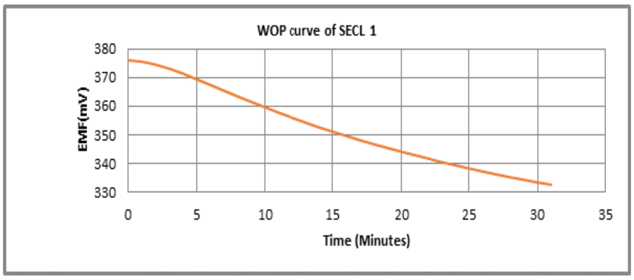
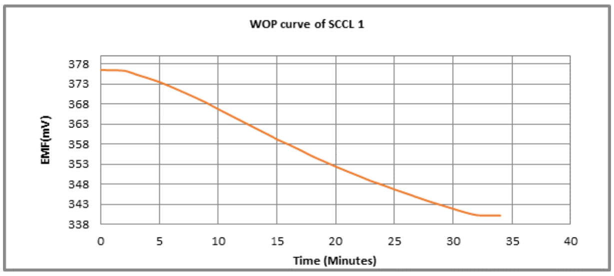


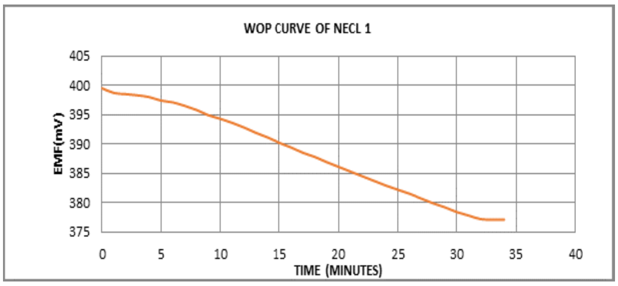
Figure 1: Schematic diagram of the WOP apparatus

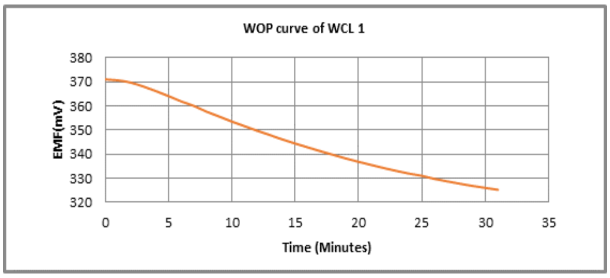
Analysis of Result











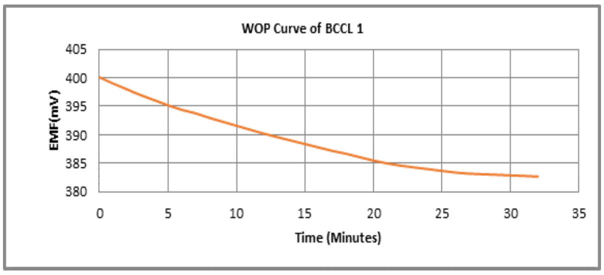
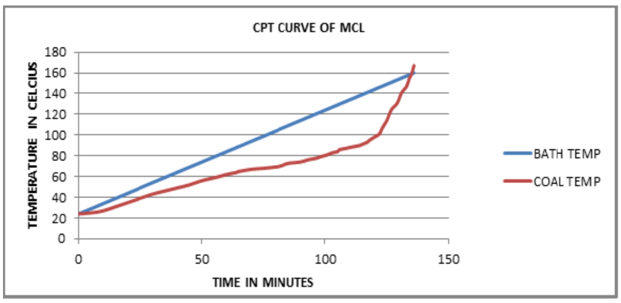
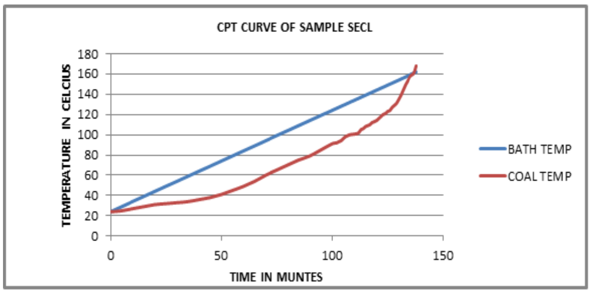
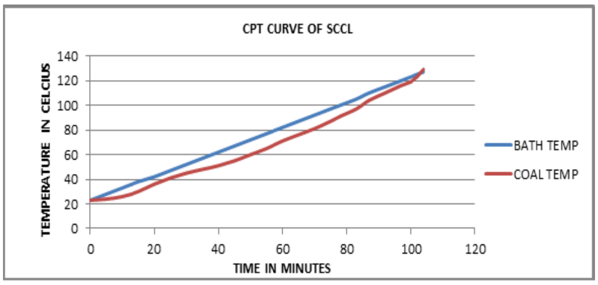
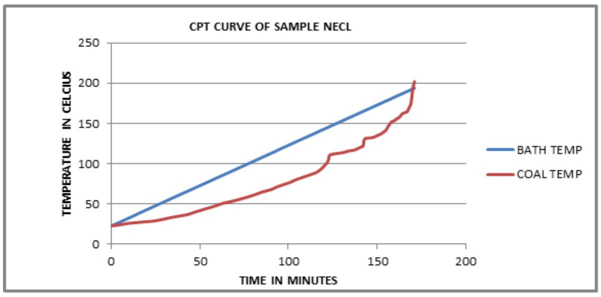


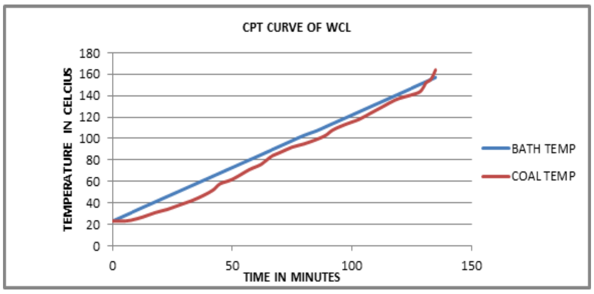
Figure 2. W.O.P curve of coal sample from different mines











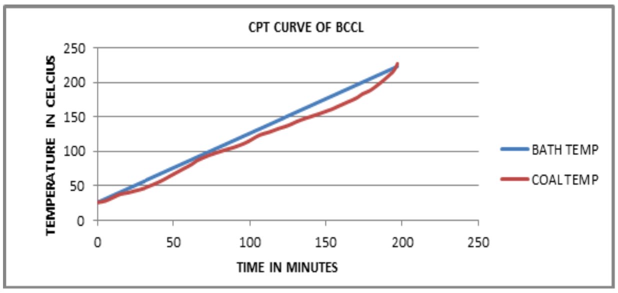


Figure 3. CPT curve of coal sample from different mines

The results of WOP are measured by measuring the differential temperature at different base rate temperature. The electrodes taken for WOP have saturated calomel electrode and carbon electrode. At a constant heating rate when coal – oxidant mixture is mixed, there is the change in the electromotive force. These measurements were made on six coal samples of known crossing point temperatures (CPT). The crossing point ranged from 120-225°C. One sample, considered to be highly susceptible to spontaneous heating, had CPT in the range 120–130 °C, and four considered poorly susceptible to spontaneous heating, had values in the range 160–220 °C, and four moderately susceptible to spontaneous heating(140°C -160°C). Highly Susceptible Coal is from SCCL whereas moderately belongs to WCL, four Coal samples of MCL and coals of NECL, BCCL, SECL are poorly susceptible. The Experiment was carried for nearly 2 hours for each sample with a cooling effect of 4-5 hours for a furnace to come to normal temperature.

The Wet Oxidation Temperature Analysis was carried out from 350°C to 400°C and time duration of 30 minutes was taken for analysis. Each sample analysis nearly took forty minutes and a gap of one hour was maintained for proper maintain-ace of electrodes and for the necessity of carrying out for the next experiment. The observation showed highest Wet Oxidation Potential Difference in case of MCL.It reflects that it is highly prone to rapid oxidation and is highly susceptible to spontaneous heating problems. Lower values of Wet Oxidation Potential difference were seen in case of BCCL, NECL claims that these seams are less susceptible to spontaneous heating. An averagely high value of Wet Oxidation Potential Difference in case of MCL and WCL suggests that these respective coal seams are moderately susceptible to spontaneous heating. Observations should a correlation between CPT and the potential difference changes. It can be said thatwet oxidation potential of coal may be used as alternative techniques for the assessment of tendency to spontaneous heating.

Conclusion

In India, generally crossing point method is used for assessment of spontaneous heating susceptibility of coal. However, this method has certain drawbacks. The results are dependent upon packing density, rate of heating and oxygen flow rate etc., and sometimes the results are not reproducible. Moreover it takes more than three hours to complete the experiment. In the present study, wet oxidation potential difference method was attempted for the evaluation of spontaneous heating of coal. In comparison to crossing point temperature, the wet oxidation experiments only take about 30 minutes for completion, hence it is less time-consuming. The wet oxidation potential difference method gives excellent repeatability of the experimental results for the same sample, but in case of crossing point temperature; the repeatability of the experimental results is not as good as wet oxidation method. The correlation analysis between potential difference and intrinsic properties was found to be fairly accurate, which indicates that this method may be adopted as a measure of spontaneous heating susceptibility. Moreover, the wet oxidation method is very handy and easy to perform compared to CPT. Thus, wet oxidation potential difference method may be a useful method for the assessment of liability of coal to spontaneous heating. From the above discussion, it may be concluded that the coal samples from MCL, SCCL and SECL had extreme values in the WOPD experiments which indicates that it is highly susceptible to spontaneous heating. Among other samples, CCL andNCL are also highly susceptible to spontaneous heating.

References

[1] Beamish B.B. and Arisoy A., "Effect of intrinsic coal properties on self-heating rates", 12thU.S./North American Mine Ventilation Symposium 2008 – Wallace (ed), pp. 149-153,2008

[2] Kaymakci, E., Didari, V. (2002), Relations between coal properties and spontaneouscombustion parameters, Turkish Journal of Engineering & Environmental Sciences, 26,Pp. 59-64.

[3] Pal, B. K., Mukunda, P.G. and Mahadevan, V. (1998): Thermal Analyses of Washed, Micro-wave treated and Magnetically Separated Coals of South-Eastern Coalfields, India, Journal of Thermal Analysis and Calorimetry, Vol. 51, No. 1, pp 321-326.

[4] Panigrahi, D. C., Sahu, H. B., Udayabhanu, G. and Saxena V. K., Wet oxidation method forpredicting the spontaneous heating susceptibility of Indian coals", IICM, (June-Aug),2004, pp. 13-21

[5] Ray S.K., Panigrahi D.C. and Varma A.K., "An electrochemical method for determining thesusceptibility of Indian coals to spontaneous heating", 2014 Elsevier B.V., InternationalJournal of Coal Geology, No. 128–129, pp. 68–80, 2014

[6] Ray S.K., Panigrahi D.C., Udayabhanu G. and Saxena V.K., "Assessment of spontaneousheating susceptibility of Indian coals-A new approach", Energy sources, part a:recovery, utilization, and environmental effects, vol. 38, no. 1, pp. 59–68, 2016.

[7] Singh R.V., "Spontaneous heating and fire in coal mines", The 9th Asia-Oceania Symposiumon Fire Science and Technology, Elsevier, Procedia Engineering, No. 62, pp. 78 – 90,2013

[8] Sahu, H. B., Panigrahi, D. C. and Mishra, N. M., "Assessment of spontaneous heatingsusceptibility of coal seams by differential scanning calorimetry", Journal of Mines,Metals and Fuels.Vol. 52, Nos. 7&8, July-August, 2004. pp. 117-121.

[9] Tarafadar M. N. and Guha D. (1989), Application of wet oxidation processes for theassessment of the spontaneous heating of coal, Fuel, Vol. 68, pp. 315 – 317.