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Methods to find out spontaneous heating susceptibility of Indian coals

The paper describes two methods to determine spontaneous heating susceptibility of Indian coals. Crossing point temperature (CPT), a thermal method, widely used in Indian coal industry is described. Further, a new electro-chemical method called wet oxidation potential (WOP) technique is introduced for determining the susceptibility of coal to spontaneous combustion. Altogether 78 coal samples collected from thirteen different mining companies spreading over most of the Indian coalfields have been used for this experimental investigation. Experiments have also been carried out for proximate and ultimate analyses of coals. Susceptibility indices obtained from CPT method and WOP method were correlated with important intrinsic parameters of coal by multivariate analysis. A comparison has been made between correlation coefficients obtained from CPT and WOP analysis. Results of WOP method are validated with CPT.

Keywords: Spontaneous heating, crossing point temperature, wet oxidation potential method, proximate and ultimate analyses, multivariate analysis.

1. Introduction

Spontaneous combustion is largely responsible for coal mine fire. Researchers around the world investigated self-heating potential of coal by using a number of methods, viz. crossing point temperature, ignition point temperature, Russian U index, Olpinski index, adiabatic calorimetry, WITS-EHAC liability index, FCC index, MR index [1-10]. Out of these crossing point temperature (CPT) is one of the most widely used methods in many countries of the world. It has been observed by earlier researcher [7] that in case of high moisture coals usually with high susceptibility, there is a shift of the crossing point temperature to a high value, because of release of moisture during heating, indicating that the coal is poorly susceptible, but in reality it is a highly reactive coal. Tarafdar and Guha [11, 1989] conducted electro-chemical method i.e. wet oxidation potential experiments only with seven coal samples. They observed that higher the potential difference more susceptible would be the coal towards spontaneous combustion. Panigrahi et al. [12, 2004] conducted experiments with 12 coal samples from Indian coalfields. They found that wet oxidation potential method was more accurate in comparison with CPT method.

In the wet oxidation potential method emphasis is given to change in potential difference during the oxidation process. It has been investigated that 0.2N $KMnO_4$ with 1N KOH solution is the optimum mixture to carry out wet oxidation potential method for obtaining best response to spontaneous heating of coal [13].

Seventy eight (78) coal samples covering fiery and non-fiery seams of thirteen mining companies of India were collected for this investigation [14]. The companies are Eastern Coalfields Ltd. (ECL), Bharat Coking Coal Ltd. (BCCL), Central Coalfields Ltd. (CCL), Mahanadi Coalfields Ltd. (MCL), South Eastern Coalfields Ltd. (SECL), Northern Coalfields Ltd. (NCL), Western Coalfields Ltd. (WCL), North Eastern Coalfields (NEC), Singareni Collieries Company Ltd. (SCCL), IISCO Steel Plant (ISP) SAIL, Monnet Ispat & Energy Ltd., Neyveli Lignite Corporation (NLC) and Tata Steel Ltd. The coal samples were collected from different mines following channel sampling procedure [15, 16] and brought to the laboratory in sealed condition for analysis. This paper addresses two methods to determine spontaneous susceptibility of 78 coal samples. Two methods, viz. crossing point temperature method, wet oxidation potential method are described in detail. Correlation of susceptibility indices with intrinsic parameters obtained from proximate and ultimate analyses of coal are also found out. Results of WOP method are validated with CPT.

2. Crossing point temperature method

Crossing point temperature is a standard method followed in India for finding out the susceptibility of coal to spontaneous combustion.

In this method oxygen is passed through a bed of coal powder immersed in a glycerine bath, which is heated at a constant rate. Initially the temperature of the bed will be less than that of the bath. Due to coal oxidation being an

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exothermic reaction, heat will be evolved thereby increasing the temperature of the coal bed, thus reducing the difference between coal and bath temperatures. As temperature of the bath increases, the oxidation rate is enhanced and a stage comes when coal bed temperature equals bath temperature and then exceeds it. The temperature at which both bath and bed temperatures indicate equality is referred to as crossing point temperature and expressed in ^oC. The higher the crossing point temperature value, the less will be susceptibility of coal to spontaneous heating.

The experimental set up for the determination of crossing point temperature of coal is illustrated in Fig.1. The set up mainly consists of (i) a glycerine bath, (ii) a combustion or reaction tube, and (iii) a source of steady supply of oxygen.

The bottom of the combustion tube was packed with glass wool. In these tests freshly mined coal samples collected under inert atmosphere were used to avoid weathering. Samples were ground and sieved to suitable size making necessary coning and quartering to reduce the sample size. 20 g of powdered coal sample (-212 micron) was poured in the combustion tube and tapped gently. The rubber bung with thermometer and gas outlet tube was tightly placed over the combustion tube. The reaction tube was then placed into the bath. The reaction tube was connected to the oxygen cylinder and oxygen flow rate to the reaction tube was 80 ml/min. Temperature of the glycerine bath was raised at the rate of 1^oC/min. To maintain uniform temperature all through the glycerine bath, an air motor was used for continuous stirring. Results of these experiments are given in Table 1.

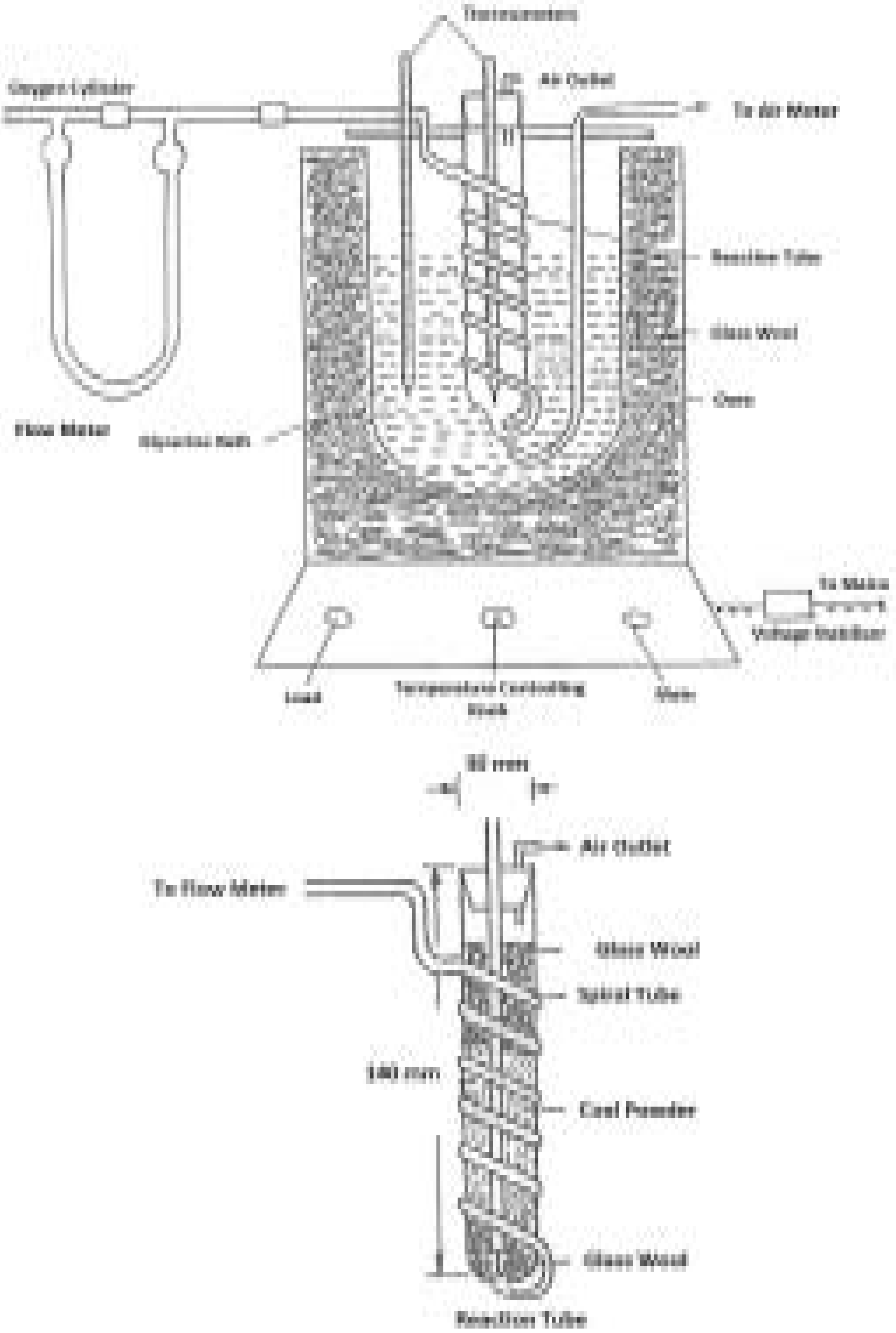

Fig.1 Experimental set up for determination of crossing point temperature of coal

3. Wet oxidation potential method

This method involves low temperature oxidation process. The schematic diagram of experimental set up for the wet oxidation process is presented in Fig.2. The experimental set up consists of a beaker, one saturated calomel electrode ($Hg/Hg_2Cl_2/KCl$) and one carbon electrode. The calomel and the carbon electrodes are connected to a milli-voltmeter to measure the potential difference during the oxidation process. The beaker along with electrodes and the chemical solution are placed over a magnetic stirrer and Teflon coated fish of the magnetic stirrer is placed inside the beaker. Temperature of the mixture is measured with a calibrated temperature recorder.

Wet oxidation potential (WOP) analysis was carried out with potassium permanganate ($KMnO_4$) as oxidizer in

Table 1: Results of crossing point temperature of coal

S.no.	Colliery and seam	CPT, ^{o}C	S.no.	Colliery and seam	CPT, ^{o}C
1	Central Kajora, RVIII	137	41	Haldibari, XB	133
2	Parascole East, RVII	134	42	Kamptee, VB	147
3	Shamsunderpur, RVII	135	43	Saoner Mine 1, IV(M)	142
4	Lakhimata, Metadih	140	44	Saoner Mine 3, V	133
5	Lakhimata, BII	150	45	Umrer, IV	142
6	Jhanjra, RVIIA	143	46	New Majri III, Majri	140
7	MIC unit Jhanjra, RVI	135	47	Ghuggus, Meyo (B)	143
8	Jhanjra, RVII	152	48	Ghuggus, Meyo (M)	140
9	Kottadih Project, RV	129	49	Naigaon, Meyo (B)	139
10	Kottadih, RIII/II	129	50	Naigaon, Meyo (M)	143
11	Khaskajora, RVIIIA	135	51	Jhingurda, Jhingurda	140
12	Khaskajora, RVIIIB	145	52	Jayant, Turra	143
13	Kumardhubi, Singhpur Top	146	53	Jayant, Purewa (B)	133
14	Bansdeopur, VIII	164	54	Jayant, Purewa (T)	137
15	Victoria West, Ramnagar	141	55	Amlohri, Purewa Merge	134
16	Sudamdih shaft, XI/XII	154	56	Amlohri, Turra	132
17	Bastacolla, 0	167	57	Tipong, 20'	145
18	Bastacolla, I	179	58	Tipong, 60'(B)	135
19	Bastacolla, II	160	59	Tipong, 60'(T)	137
20	Moonidih, XVI(T)	164	60	Tirap, 8' N Limb	132
21	Mudidih, IX	153	61	Tirap, 60'(T) N Limb	134
22	Kalyani, Karo (Major)	167	62	Tirap, 20'N Limb	139
23	Argada, I	129	63	Kakatiya LW, I	136
24	Argada, J	132	64	Kakatiya LW, IA	135
25	Hesagora, X (B)	133	65	Kakatiya LW, II	130
26	Churi, Lower Bachra	134	66	Kakatiya LW, III	135
27	KD Hessalong, Dakra	130	67	Adriyala Shaft, I	134
28	Kuju, VII	135	68	RK New Tech inc, 1A	130
29	Lilari, Lajkura Top	143	69	Sijua, XIII	161
30	Belpahar, IB	131	70	Sijua, XIV	164
31	Belpahar, Rampur (T)	143	71	6&7 Pits, IX	170
32	Belpahar, Rampur (B)	137	72	6&7 Pits, XI	169
33	Lakhanpur, Lajkura (T)	143	73	Milupara, II	137
34	Jagannath, III	125	74	Kondkel, III	129
35	Anjan Hill, III	136	75	Chasnalla, XII	144
36	NCPH , III	151	76	Western Quarry, XIII/XIV	130
37	Rajnagar RO, 8A2	125	77	Neyveli Mine 1A, Lignite	159
38	5&6 Incline, Index	140	78	Barsingsar, Lignite	160
39	Churcha West, V	134			
40	Churcha East, V	130			

S no. – sample no., S. no. 1-13: ECL, 14-21: BCCL, 22-28: CCL, 29-34: MCL, 35-41: SECL, 42-50: WCL, 51-56: NCL, 57-62: NEC, 63-68: SCCL, 69-72: Tata Steel Ltd., 73-74: Monnet Ispat & Energy Ltd., 75-76: ISP,SAIL, 77-78: NLC

potassium hydroxide (KOH) solution. Equivalence factor of $KMnO_4$ in this case was maintained as 158.04/3 = 52.68. 100 ml $KMnO_4$ solution of 0.2 N was prepared in 1N KOH solution. This mixture was taken in a beaker and a calomel reference electrode and a carbon electrode was immersed in it. The potential difference, i.e. EMF, in mV, was measured between these electrodes by using a milli-voltmeter after attaining a stable reading. 0.5 g of coal sample of -212 micron size was added in this mixture and was continuously stirred using a magnetic stirrer. The potential difference was recorded over a period of time till a nearly constant value was attained. Temperature of the mixture was measured with a calibrated temperature recorder. Potential difference and temperature were recorded at an interval of 1 min. Each experiment took

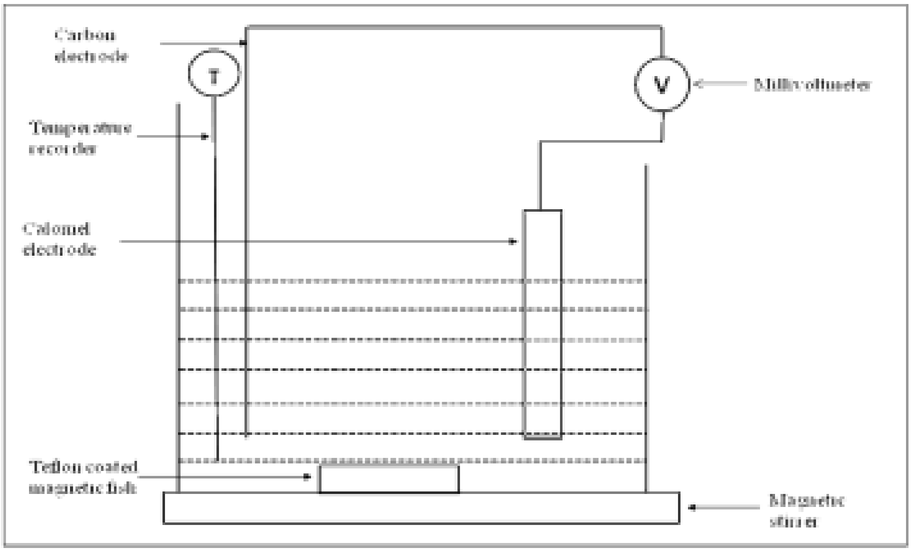

Fig.2 Experimental set up for wet oxidation potential method

TABLE 2: WET OXIDATION POTENTIAL ANALYSIS RESULTS

S. no.	PD, mV	S. no.	PD, mV	S. no.	PD, mV	S. no.	PD, mV
1	115	21	46	41	127	61	106
2	139	22	34	42	140	62	82
3	126	23	104	43	128	63	135
4	51	24	124	44	153	64	122
5	33	25	114	45	152	65	118
6	138	26	132	46	115	66	128
7	136	27	128	47	134	67	123
8	121	28	104	48	98	68	146
9	117	29	128	49	130	69	42
10	105	30	93	50	100	70	52
11	114	31	112	51	98	71	39
12	147	32	113	52	120	72	48
13	62	33	107	53	146	73	158
14	37	34	122	54	117	74	123
15	96	35	117	55	123	75	64
16	41	36	96	56	118	76	58
17	42	37	118	57	120	77	113
18	46	38	116	58	74	78	98
19	38	39	109	59	104		
20	40	40	110	60	136		

S no. – sample no.

about one and half hour and it poses no problem with high moisture coals. Experiments were carried out at 45°C. Wet oxidation provides a measure of ambient temperature reactivity that is relevant to the very initial stages of oxidation in self heating, but of course cannot fully capture the complexity of kinetics that might be relevant for taking the materials to full self-heating behaviour. In other words, the Arrhenius type temperature dependence should be given importance [17]. Earlier studies have shown that the rearrangement of peroxides on the surface can involve significant thermal effects [7], and that these occur only at slightly higher than ambient temperatures. That is the reason wet oxidation potential experiments have been carried out at 45°C, slightly more than ambient temperature avaiable in this part of the country. The difference between potential difference (PD) of the mixture before adding coal sample and after complete oxidization of coal sample was calculated for each sample and this parameter was considered as susceptibility index of coal towards spontaneous combustion and expressed in mV. WOP analysis results are given in Table 2.

4. Physico-chemical analysis

Samples were prepared for various analyses namely proximate (moisture, volatile matter yield, ash yield and fixed carbon), ultimate (carbon, hydrogen, nitrogen, sulphur and oxygen), following standard procedures i.e. IS, 1969 [18]; ASTM, 1993 [19].

The proximate analysis of coal is used widely as the basis for coal characterization. It was developed as a simple means of determining the distribution of products obtained when the coal sample is heated under specified conditions. While moisture, ash, volatile matter are determined experimentally fixed carbon is determined indirectly.

For ultimate analysis of coal Vario EL III CHNS analyser from Elementar Germany was used. Carbon, hydrogen, nitrogen and sulphur were determined from the analyser. Oxygen was calculated using the following relations:

$$O\% = 100 - (C\% + H\% + N\% + S\% + M\% + Ash\%).$$

The experimental procedure in brief is presented elsewhere [14, 19]. Table 3 depicts results of proximate and ultimate analysis of 78 coal samples. Volatile matter, carbon, hydrogen, nitrogen, sulphur and oxygen have been expressed in daf basis.

5. Analysis of results with statistical software

The correlation studies have been carried out between the susceptibility index, PD and the coal characteristics as obtained from proximate and ultimate analyses. Similar

Table 3: Results of Proximate and Ultimate analysis of coal

	M %	VM_{daf} %	FC %	A %	C_{daf} %	H_{daf} %	N_{daf} %	S_{daf} %	O_{daf} %
1.	5.66	40.08	48.46	13.47	80.81	5.43	1.88	1.04	10.84
2.	6.27	42.47	48.55	9.34	80.46	5.94	1.84	1.00	10.77
3.	9.74	39.11	50.26	7.72	78.70	5.56	1.96	0.91	12.87
4.	0.86	28.98	52.46	25.29	86.08	5.01	2.06	1.11	1.16
5.	1.15	29.68	59.01	14.93	85.72	5.12	1.97	0.80	6.39
6.	7.79	40.55	46.5	13.99	78.53	5.82	2.07	0.74	12.84
7.	8.85	39.15	46.79	14.26	78.36	5.81	2.05	0.72	13.06
8.	8.73	42.45	35.63	29.36	71.98	6.67	2.49	0.81	18.06
9.	4.82	40.66	34.59	36.89	76.24	6.26	2.35	0.55	14.60
10.	5.13	41.14	48.74	12.07	81.64	5.79	1.75	0.57	10.25
11.	4.80	42.76	44.60	17.28	79.76	5.97	2.13	0.87	11.27
12.	5.68	42.67	44.13	17.35	79.99	5.87	2.14	0.81	11.19
13.	1.27	30.40	52.28	23.61	85.46	5.43	1.98	1.03	6.11
14.	0.73	23.41	63.56	16.28	88.78	4.78	2.07	0.98	3.39
15.	1.40	31.04	55.51	18.10	85.84	5.14	2.00	1.01	6.01
16.	1.48	29.14	65.57	5.99	87.61	5.18	1.71	0.82	4.68
17.	0.45	20.44	70.28	11.21	89.27	5.04	1.45	0.63	3.61
18.	0.40	24.18	57.33	23.99	86.38	5.12	1.59	0.56	6.36
19.	0.43	21.17	52.54	32.92	87.44	4.73	1.85	0.68	5.31
20.	0.49	28.69	55.49	21.69	86.92	5.28	1.77	0.91	5.11
21.	0.82	22.80	59.86	21.64	88.25	4.81	1.84	0.86	4.23
22.	0.5	18.62	69.17	14.5	89.56	5.04	1.52	0.52	3.36
23.	2.38	34.90	47.61	24.49	79.94	6.02	1.64	0.46	11.94
24.	2.99	38.45	47.37	20.05	80.02	6.17	1.82	0.58	11.41
25.	2.05	41.53	45.23	20.59	80.93	6.93	2.37	0.94	8.83
26.	6.66	34.41	49.88	17.29	76.42	6.02	1.66	0.32	15.58
27.	5.18	44.23	42.9	17.9	73.79	6.29	1.40	0.85	17.67
28.	0.92	36.05	58.11	8.21	83.69	6.03	1.86	0.62	7.80
29.	10.98	46.53	33.89	25.64	77.82	7.81	1.72	1.09	11.57
30.	6.64	47.18	36.66	23.95	78.46	6.60	1.51	0.62	12.81
31.	7.91	48.25	31.56	31.11	77.35	6.84	1.44	0.64	13.73
32.	6.83	44.56	42.39	16.71	79.05	6.98	1.94	0.78	11.25
33.	7.88	47.93	27.94	38.46	71.73	6.90	1.40	0.86	19.12
34.	4.77	48.68	30.89	35.04	79.50	7.34	1.98	0.88	10.30
35.	6.06	40.10	49.15	11.89	79.87	6.53	2.24	0.77	10.59
36.	5.53	33.09	54.34	13.26	83.04	5.05	1.92	1.13	8.85
37.	5.61	38.92	50.25	12.12	81.37	5.51	2.02	0.91	10.20
38.	6.52	36.12	51.35	13.10	82.48	5.16	1.97	0.93	9.46
39.	2.00	36.62	57.82	6.77	76.37	8.25	1.58	1.18	12.62
40.	1.20	33.78	57.93	11.32	79.29	5.73	1.75	1.17	12.07
41.	5.04	36.14	49.4	17.6	79.68	6.51	1.59	1.85	10.37
42.	8.22	39.73	48.31	11.63	75.25	6.20	1.42	0.30	16.83
43.	8.76	42.42	43.2	16.21	77.97	7.30	1.71	0.60	12.42
44.	6.51	46.79	30.68	35.83	75.53	6.16	2.27	1.02	15.02
45.	9.44	46.35	45.44	5.87	73.07	7.18	1.39	0.43	17.94
46.	8.04	37.64	50.82	10.46	82.10	6.26	1.72	0.43	9.50
47.	12.45	44.45	41.7	12.48	81.51	7.34	2.14	0.37	8.63
48.	12.63	40.78	45.54	10.47	79.78	6.84	2.04	0.36	10.98
49.	10.21	41.07	47.6	9.01	77.93	6.55	1.57	0.78	13.17

Table 3 contd.

correlation studies have been carried out between CPT and coal characteristics. It has been observed by different researchers in the past that the susceptibility of coal to spontaneous combustion depends upon the different intrinsic characteristics of the coal. Synthesizing all the studies of the past, the independent variables have been chosen. The coal characteristics have already been studied by carrying out different experiments. From these experiments the following critical parameters affecting the susceptibility of coal to spontaneous combustion are chosen as independent variables for this correlation study:

Proximate analysis

(a) Moisture content, M (wt %), (b) Volatile matter on dry ash free (daf) basis, VM_{daf} (wt %)

Ultimate analysis

(a) Carbon content on dry ash free (daf) basis, C_{daf} (wt %), (b) Hydrogen content on dry ash free (daf) basis, H_{daf} (wt %), (c) Oxygen content on dry ash free (daf) basis, O_{daf} (wt %)

CPT as given in Table 1 and intrinsic parameters of coal like moisture (M), volatile matter (VM_{daf}), oxygen (O_{daf}), hydrogen (H_{daf}) and carbon (C_{daf}) obtained from Table 3 are correlated by statistical analysis. Potential difference (PD) obtained from WOP analysis as presented in Table 2 and intrinsic parameters of coal like M, VM_{daf}, O_{daf}, H_{daf} and carbon C_{daf} as given in Table 3 are correlated by statistical analysis. Design Expert 7.0.0 software is used for the statistical analysis of experimental results. Correlation coefficients (r) of each parameter obtained for different susceptibility indices are shown separately in Table 4. It may be mentioned here that nitrogen has no effect on the spontaneous heating tendency of coal. The total sulphur content of maximum number of samples is less than 1.90 wt% (except 3 coal samples where the values are 7.18 wt%, 5.04

	M %	VM_{daf} %	FC %	A %	C_{daf} %	H_{daf} %	N_{daf} %	S_{daf} %	O_{daf} %
50.	14.85	47.34	40.06	9.07	79.35	7.33	1.96	0.93	10.42
51.	13.36	43.74	38.84	17.60	78.98	6.89	1.46	0.56	12.09
52.	13.64	45.62	42.91	7.45	84.59	7.58	2.00	0.51	5.32
53.	7.62	40.93	43.80	18.23	80.46	6.81	1.25	0.46	11.02
54.	10.24	39.83	45.09	14.82	82.13	6.87	1.44	0.52	9.03
55.	9.88	46.93	38.34	17.87	75.83	6.73	1.54	0.64	15.27
56.	10.33	42.42	46.93	8.17	78.96	6.75	1.69	0.42	12.18
57.	1.70	45.34	53.00	1.34	70.02	6.92	1.06	7.18	14.82
58.	0.70	46.00	52.53	2.03	81.74	6.79	1.21	0.57	9.69
59.	1.03	48.52	48.89	4.01	76.25	6.77	1.16	3.69	12.13
60.	1.07	47.53	51.11	1.52	77.28	6.40	0.95	5.04	10.33
61.	1.02	42.22	56.68	0.88	80.10	6.61	1.33	1.40	10.57
62.	0.56	45.85	53.46	0.71	77.31	6.43	1.17	5.07	10.01
63.	6.69	42.27	43.22	18.45	79.84	5.38	2.26	0.81	11.70
64.	4.71	39.99	44.73	20.75	80.47	6.04	1.65	0.71	11.13
65.	3.00	46.02	38.12	26.38	81.38	6.63	1.64	0.69	9.66
66.	4.88	34.28	42.93	29.80	80.37	5.16	2.54	1.26	10.67
67.	3.90	47.96	41.64	16.08	75.54	6.84	1.54	1.09	15.00
68.	3.42	45.37	41.35	20.89	75.89	7.20	1.61	0.74	14.56
69.	0.75	24.13	68.48	8.99	87.72	5.09	1.50	0.88	4.82
70.	1.15	23.83	64.61	14.03	88.60	4.93	1.63	0.81	4.03
71.	0.49	23.40	51.48	32.30	86.56	5.03	1.65	0.61	6.14
72.	0.66	26.62	63.47	12.85	88.31	5.12	1.49	0.65	4.43
73.	4.82	34.34	53.47	13.74	82.99	5.28	1.89	1.08	8.75
74.	5.57	36.21	46.31	21.83	81.89	5.21	2.38	1.14	9.38
75.	1.29	34.32	54.09	16.35	83.50	5.28	1.64	0.67	8.91
76.	0.84	31.15	59.83	12.26	87.02	5.13	1.70	0.79	5.35
77.	15.71	55.22	36.4	2.98	74.42	6.37	1.69	0.85	16.68
78.	11.10	44.26	43.44	10.97	73.04	6.25	1.62	0.80	18.30

wt%, 5.07 wt%). Therefore, these parameters are not taken into consideration in these analyses. Further, multivariate analysis is carried out with the experimental data. In this analysis, two parameters, viz. M and VM_{daf}; O_{daf} and H_{daf}; and three parameters, viz. C_{daf}, H_{daf} and O_{daf} are considered together at a time to make correlation with PD as well as CPT.

The following points are noteworthy while critically analyzing Table 4:

- Overall improvement of correlation coefficients is noticed while analysis is done with PD.
- Maximum improvement in correlation coefficient is observed while making correlation with moisture. In case of PD it is 0.78 while in case of CPT it is 0.62.
- While carrying out correlation studies with C_{daf}, correlation coefficient r is found to be 0.77 in case of CPT analysis and PD analysis depicts its value 0.85.
- Improvement in correlation coefficient is also observed in case of H_{daf}. While correlation is done with hydrogen, CPT analysis shows r is 0.62 and PD analysis shows it is 0.69. Incidentally, while correlation is done with oxygen both the analyses, viz. CPT and PD show value of r as 0.74.
- Correlation coefficient r is also obtained combining M and VM_{daf} for both the analyses. CPT analysis depicts its value 0.85 and PD analysis gives its value 0.90.
- Considering O_{daf} and H_{daf} as two independent variables correlation analysis is made with CPT as well as PD. In case of CPT, r is found to be 0.75 and in case of PD, its value is 0.83.
- Considering C_{daf}, H_{daf} and O_{daf} as three independent variables correlation analysis is done with CPT as well as PD. In case of CPT, r is found to be 0.78 and in case of PD, its value is 0.86.
- Both the analysis results indicate that PD gives highest correlation coefficient in maximum number of cases.

Keeping the above detailed comparative analysis in view, it is recommended that susceptibility index PD in WOP method using 0.2N $KMnO_4$ solution with 1N KOH at 45°C should be used for determining the susceptibility of coal to spontaneous combustion.

TABLE 4: CORRELATION COEFFICIENTS OBTAINED FROM CPT AND PD ANALYSIS

	Intrinsic characteristics	Susceptibility indices	
		CPT	PD
1	M	0.62	0.78
2	VM	0.78	0.81
3	C	0.77	0.85
4	H	0.62	0.69
5	O	0.74	0.74
6	M & VM	0.85	0.90
7	O & H	0.75	0.83
8	C, H, O	0.78	0.86

VM, C, H, O are on daf bases

To verify the results of WOP method PD is correlated with CPT. It has been observed that as crossing point temperature increases potential difference (PD) decreases. Correlation coefficient between these two parameters is found to be 0.69 (Fig.3).

6. Conclusions

The following conclusions are emerged from the investigation:

- Since WOP method takes less time (about one and half hour) and it poses no problem with high moisture coals, it can be used for routine analysis by practicing engineers working in mines for ascertaining the susceptibility of coal to spontaneous combustion.
- While making correlation with critical intrinsic parameters like moisture (M), volatile matter (VM_{daf}), oxygen (O_{daf}), hydrogen (H_{daf}) and carbon (C_{daf}) it has been found that PD obtained from WOP method gives better correlation than the case with CPT (Table 4). Therefore, it may be concluded that WOP method is a better method than CPT.
- PD of all the coal samples have been correlated with crossing point temperature, a thermal analysis method, which is widely used in India. It has been observed that wet oxidation potential results are well corroborated with CPT (Fig.3).

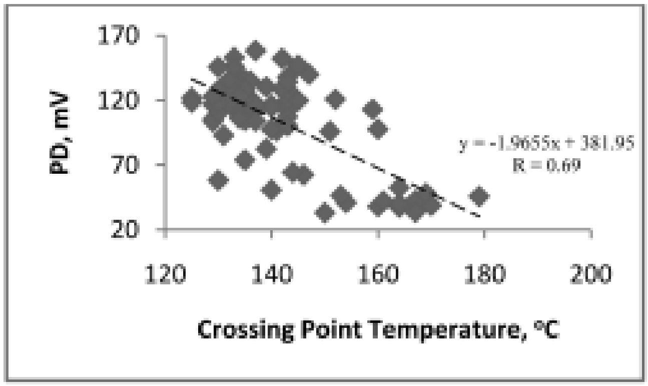

Fig.3 Correlation of PD with crossing point temperature

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