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A Research on the Spontaneous Combustion Tendency of Turkish Coals-Ilgin Lignite's Case

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Abstract: The phenomenon of spontaneous combustion in coal mines has been given a great attention by scientists and miners as it may cause serious problems both from safety aspect and on economic grounds if not prevented or controlled on time. In order to achieve an accomplishment at all collieries where spontaneous combustion occur, there is a substantial need for careful judgement in planning, constant alertness and prompt positive action. In this study, the results of the earlier research carried out to search the liability of Turkish coals to spontaneous heating are presented. Additionally, as the objective of the present study, the coal samples from Ilgin District in Turkey were investigated in terms of propensity of spontaneous combustion by utilising the crossing point method.

Key words: Spontaneous combustion, cross point method, Tukish Coals

Introduction

Although many works have been carried out on spontaneous combustion since the middle of last century, it is still accepted as an interesting research area. A great deal of useful information has been outlined and many practical recommendations have been made through these works. However, there is still much to do on the topic in concern.

The phenomenon of spontaneous heating is one of the most meaningful hazards encountered in underground coal mines, both from the safety aspect and on economic grounds. Every incident, however small, if not tackled effectively in the early stages can develop into open fire, or explosion of gas or coal dust.

Liability to Spontaneous Heating

The oxidation process of coal starting at low temperatures is controlled by many parameters with respect to mining, geology and environmental conditions (Mahadevan and Ramlu, 1985; Morris and Atkinson, 1986, 1988; Yildirim *et al*., 1994; Sensogut, 1997).

Suggested methods for the evaluation of spontaneous combustion liability of coals may be presented under two groups (Sensogut, 1997; Sensogut and Cinar, 2000).

Laboratory Techniques	Practical Methods
Static isothermal	Incubation period
Adiabatic oxidation	Olpinski
Chemical	Modified Bystron Dynamic and Urbanski
Differential temperature crossing point	
differential thermal analysis (DTA)	

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Laboratory techniques are based on the observation of the behaviour of the coal samples heated under a predetermined volumetric airflow. However, the practical methods pay attention to environmental conditions, experiences obtained during the previous work and frequency of spontaneous combustion events.

As yet there is no available method standardised for studying mine fires, nevertheless "crossing point" also known as "ignition point" method is a substantial candidate to become a standard technique due to its simplicity (Kaymakci and Didari, 1992).

Crossing Point Method

In this technique, the relative ignition temperature of coal is experimentally ascertained and delineated as the lowest temperature at which measurable spontaneous combustion takes place. This is also defined as the crossing point of temperature of coal. In order to obtain this temperature, the coal sample is heated in a reaction tube in a furnace or bath at constant or rising temperature (2°C/h) with oxygen or dry air passing through it at a predetermined rate of 40 mL min^{-1} until the coal temperature crosses the furnace or bath temperature. The temperature at which the temperature of the coal and the furnace/bath coincides is called the crossing point temperature (Feng *et al*., 1973; Mahadevan and Ramlu, 1985).

It is clear that a coal with high heating rate and low ignition temperature is more susceptible to self heating. Therefore, a Liability Index (LI) based on the average heating rate between 110-220°C was suggested by Feng *et al*. (1973). This is:

$$\text{LI: (average heating rate between 110-200}^{\circ}\text{C/crossing point) * 100} \quad (1)$$

The following classification was proposed to show the propensity of spontaneous combustion of coal according to the results obtained from Eq. 1 (Feng *et al*., 1973):

Liability Index (LI)	Comments
0-5	Low
5-10	Medium
>10	High

Spontaneous Heating Liability of Turkish Coals

The propensity of Turkish lignites and hardcoals to spontaneous heating has been searched since the beginning of 1980's and numerous experimental works have been carried out by using the crossing point method. The results of earlier research are summarised in Table 1 (Yilmaz and Atalay, 1990; Didari *et al*., 1993; Sarac, 1993; Kucuk *et al*., 1996; Kaymakci, 1998; Sensogut and Cinar, 2000).

According to the data as given in Table 1, the liability index of Turkish hardcoals varies between 4.00 and 7.24 min^{-1} (low to medium) while the same index for Turkish lignites differs from 3.68 to 19.57 min^{-1} (low to high).

Case Study

During the experimental works achieved for the present work, spontaneous combustion liability of the coal samples taken from Ilgin district were searched by the assistance of the crossing point.

Table 1: Results of previous study on the liability of spontaneous combustion of Turkish coals

District	Colliery/Seam	Crossing point (°C)	Heating rate (°C/min)	Liability index (LI) (min)	Risk group
Soma (lignite)	Darkale	127	1.17	9.21	Medium
	Merkez	125	1.22	9.76	Medium
	Eynez	110	1.19	10.82	High
Cayrhan (lignite)	Cayrhan	126	1.12	8.89	Medium
Tuncbilek (lignite)	Tuncbilek	142	1.77	12.46	High
	Omerler (upper)	141	2.76	19.57	High
	Omerler (lower)	142	1.29	9.08	Medium
Mugla-Milas (lignite)	Sekkoy	177	1.20	6.78	Medium
	Karaagac	161	1.92	11.93	High
Ermenek (lignite)	Turab	153	0.84	5.49	Medium
	Akpinar	156	0.85	5.45	Medium
	Polat	154	0.76	4.94	Low
Askale (lignite)	Askale	142	-	-	-
Zonguldak (hardcoal)	Sulu	190	0.70	3.68	Low
	Nasufoglu	170	1.03	6.06	Medium
	Domuzcu	171	1.06	6.19	Medium
	Piric	188	0.83	4.41	Low
	Hacimemis	183	0.82	4.48	Low
	Dibek	188	0.78	4.15	Low
	Buyuk	156	1.13	7.24	Medium
	Acilik	177	0.94	5.31	Medium
	Buyukdogu	195	0.78	4.00	Low
	Buyukbati	175	0.93	5.51	Medium

Table 2: Results of the proximate analysis

	Roof	Coal	Floor	Coal
	Original	Dried	Original	Dried
Moisture (%)	43.20	-	45.00	-
Ash content (%)	13.20	23.24	13.65	24.81
Volatile matter (%)	24.25	42.70	22.55	41.00
Fixed carbon (%)	19.35	34.06	18.80	34.19
Sulphur (%)	1.68	2.95	1.99	3.62
Lower cal. val. (kcal/kg)	2351.00	4595.00	2212.00	4513.00
Upper cal. val. (kcal/kg)	2739.00	4823.00	2605.00	4736.00

Seam Specifications

Ilgin lignite region taking place in the Middle Anatolia has a possible reserve of 152×10^6 t (Anac, 2003). The coal in this district with an overburden ratio of 5 to 1 is produced by Turkish Coal Enterprises by means of truck and shovel operation. The average seam thickness is about 5 m. Footwall of the coal seam is mainly made of blue-grey coloured clays while the hanging wall is formed by loosely cemented conglomerate, sandstone and clay strata.

Experimental Works

Approximately 25 kg of coal samples were taken from both roof and floor seams of Ilgin District and kept in hermetic containers at every stage of the work. Proximate analysis of these samples was conducted in the laboratory of GLI colliery. Results of the proximate analysis are given in Table 2.

For the study of self heating liability, the facilities in the spontaneous combustion laboratory of Zonguldak Industrial Support Centre (ZEDEM) were utilised. A total of 4 experiments were conducted. The coal sample of 30 g under 200 meshes is put into an oven inside a hermetic steel crucible for each trial. Dry compressed and preheated air is passed through a rota meter at a flow rate

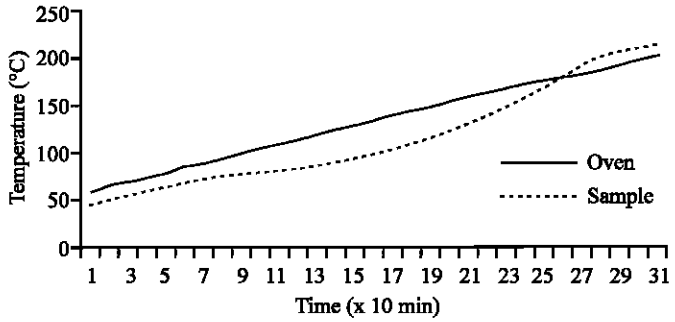

Fig. 1: Ignitability curve of coal sample for Experiment 1 (floor coal)

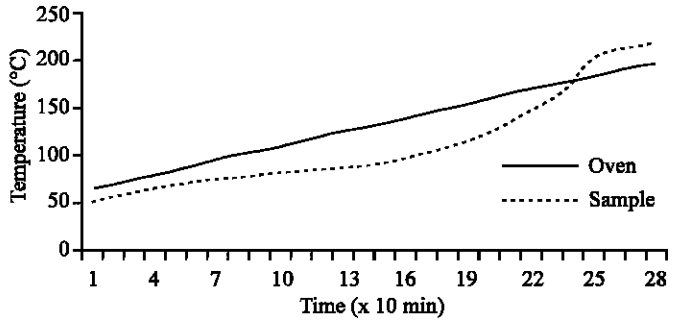

Fig. 2: Ignitability curve of coal sample for Experiment 2 (roof coal)

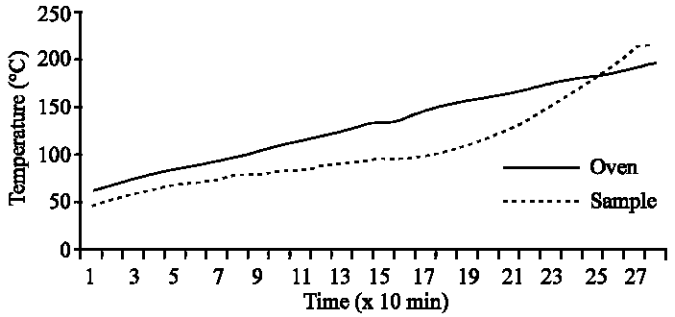

Fig. 3: Ignitability curve of coal sample for Experiment 3 (floor coal)

of 100 cc min^{1}. Initially, the oven is heated up to 50°C and kept at this temperature for 6 minutes. At the second stage, the temperature of the oven is increased by a linear escalation of 30°C/h up to 220°C at which the tests are ceased.

As a result of these experimental study, relative ignitability point, average heating rate and liability index of the samples were determined. These values for each experiment and ignitability curves are shown in Fig. 1 to 4.

Liability index and the risk classification of the samples evaluated in accordance with the crossing point are given in Table 3.

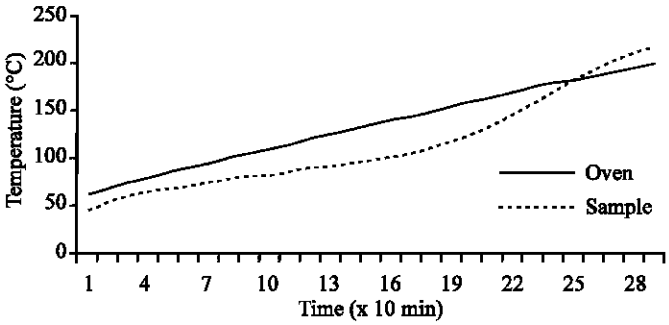

Fig. 4: Ignitability curve of coal sample for Experiment 4 (roof coal)

Table 3: Results of Turkish ceals on the liabilty of spontaneous combustion

Sample	Crossing point (°C)	Heating rate (°C/min)	Liability index (min)	Risk group
Floor coal	181	0.92	5.1	Medium
Roof coal	180	1.17	6.5	Medium
Floor coal	184	1.49	8.1	Medium
Roof coal	183	1.08	5.9	Medium

Conclusions

According to the results of the experimental work, the crossing point of the coals from Ilgin District varies between 180 and 184°C with no significant deviation. Additionally, the average heating rates are determined to range from 0.92 to 1.49°C/min. Therefore, the liability index lies between 5.1 and 8.1 min^{-1}. The liability of the coal samples of Ilgin District may be said to be in "medium" risk group according to the liability index.

Furthermore, It may also be concluded that the crossing point of the coals with high moisture content will artificially increase due to the effect of evaporation as in the case of Ilgin coals with 40% moisture content. The combustion events encountered frequently in the stockpiles of the district also support this conclusion.

Acknowledgements

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