An Investigation of Spontaneous Heating and Control of Fires in a Under Ground Coal Mine Segmented Area

D. Kotaiah(✉), Chitti Ravi Kiran, and Gangadari Tharun

Department of Mining Engineering, UCE (KU), Kothagudem, India
kotesh19@gmail.com

Abstract. The major issue of spontaneous heating that ultimately results in coal mine fires has long been a source of worry for the mining sector. Industry and researchers are both interested in learning what causes it and figuring out which coal seams are susceptible to spontaneous heating. The spontaneous combustion of coal is the main cause of the majority of coal mine fires that occur in various coal fields. Mine fires typically start off relatively small but eventually grow to a vast scale, destroying all of the natural resources, polluting the land, water, and air, and incurring enormous financial losses to the organization in question. Different coals' susceptibilities to spontaneous heating varied widely; therefore it's critical to gauge how susceptible they are. The spontaneous heating susceptibility of coal needs to be thoroughly assessed, despite the fact that there has been a lot of research on the subject, so that mine operators can be alerted well in advance and schedule the job effectively. To organize the production activities and maximize coal mine production during the incubation phase, it is crucial to determine the coals' susceptibility to spontaneous heating and classify them. The impact of gases in underground mines is discussed in this paper, determination of coal's susceptibility to spontaneous heating and its fluctuation in characteristics.

Keywords: Spontaneous Heating · Gases · Incubation Period · Rank of the Coal · Method of working

1 Introduction

With carbon contents ranging from 95% in anthracite to 60% in the lignite stage (new coal), with bituminous and sub-bituminous in between, coal is a layered organic heterogeneous rock. An intricate physiochemical process called automatic oxidation involves the absorption of oxygen, the development of a coal oxygen complex, and the subsequent breakdown of the complex to release heat [1, 2]. The above procedure is incredibly difficult because to the vast variety of mineral stuff that makes up coal. The oxidation of the heterogeneous coal mass does involve several overlapping simultaneous processes. In general, the rate of coal oxidation at ambient temperature determines how susceptible coal is to auto oxidation. Because there are so many different oxidation states of carbon, a variety of strong carbon–oxygen bonds are formed as a result of the structural changes made to the coal mass during this low temperature aerial oxidation.

© The Author(s) 2023
B. Raj et al. (Eds.): ICETE 2023, AER 223, pp. 1377–1383, 2023.
https://doi.org/10.2991/978-94-6463-252-1_137

The visible structural and compositional changes provide evidence that the process described above is a dynamic, time-dependent activity.

- Due to the presence of the two phases solid and gas intrinsically
- Extrinsically—as a result of various structural modifications

In general, coal heats up when it takes in oxygen, and the process of decomposition can be described as follows: The rate of oxidation is very slow below 50 °C and speeds up beyond 50 °C, however after it exceeds 80 °C, a stable state is reached for a brief period of time, perhaps as a result of moisture removal [3, 4]. At 120 °C beyond that, the elimination of carbon oxides starts. Up to 180 °C, the pace of oxygen's interaction with coal accelerates, and between 120 °C and 180 °C, decomposition begins. Finally, the self-sustaining combustion process starts between 220 °C and 275 °C, rising erratically until the ignition threshold is reached.

1.1 Coal Seams

Within the mine's borders, there are three usable seams. The seams' thickness and parting are as follows: Strata section at borehole A/324 (Fig. 1).

1.2 Mine Ventilation

Due to the size of the mine and its lengthy air circuits. Due to collapses in the return air channels, the water gauges on two fans are higher. Prof. D. C. Panigrahi conducted a ventilation pressure quantity survey and computer simulation. According to the proposals, it is suggested that the significant ventilation reorganization work be finished in two stages.

First phase,

- By closing 4 Inclines and 1 Air shaft of the Incline Section, the entire Bottom seam and King Seam above 59L are closed.
- Changing the winder's position from the old 5 shaft to the new shaft.
- Transforming the current 5 shaft into an up-cast shaft.

Second Phase,

- Closing all interseam tunnels between the top and king seams, as well as two incline structures and one air shaft, completes the closing of the top seam.
- New tunnel excavation from the surface to the king seam. There will only be three entries—two shafts and one incline—after Phase II operations are finished.

1.3 Type, Capacity of Main Mechanical Ventilator

(See Table 1).

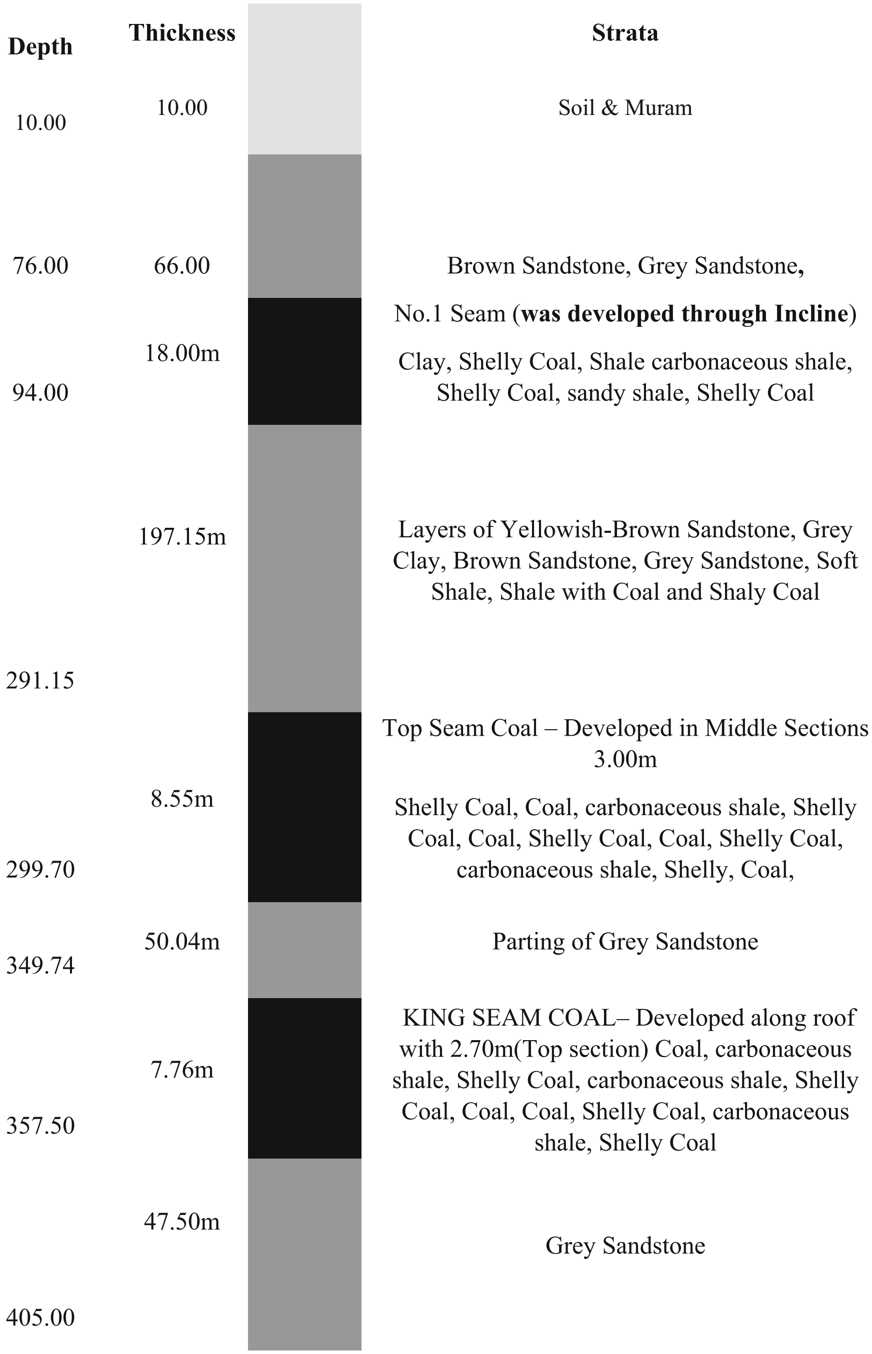

Fig. 1 Section of Strata at Borehole No. A/324

Table 1 Details of ventilators

Sl. No	Type Pf fan/Make	Capacity Cu. M/Min	Water gauge	Motor KW	Remarks
1	VOLTAS	3 Lakh	89–90 mm	300 HP	Running
2	ANDREWYULE	3 Lakh	60 mm	300 HP	Stand bye
3	JOY	2 Lakh	40–41 mm	200 HP	Running
4	JOY	1 Lakh	19 mm	90 HP	Stand bye

2 Control of Fire in Sectionalized Area in King Seam at South Indian Underground Coal Mine

Occurrence of fire in sectionalized area in king seam at 16 D. The fire was of progressing nature [5, 6]. The intensity of fire can be judged from the fact that the Graham's Ratio reached to a level of 30 against the index value of 11 indicating formation of water gas around the fire area and also indicating the fire is in active stage. Considering the apprehension of water gas explosion, the competent authority has stopped the underground deployment totally resulting in suspension of production @ 1000 tonnes of coal per day.

Accordingly, three boreholes have been drilled from surface to the fire affected sectionalized area for injection of CO_2 as well as monitoring of status of environment in term s of explosibility. It is worthwhile to mention here that in case of CO_2 injection from external source most of the fire indices, viz. Graham's ratio, young's ratio, Oxides of carbon ratio, Jones-Trickett ratio etc., generally considered for assessment of status of fire are masked by excess CO_2. In this case attempts have been made to suppress the explosive mixtures present in the sectionalized area and shifting of the nose limit of coward's diagram to origin to reduce the area of the explosive range. The environment inside the sectionalized panel is lean fuel non-explosive. Hence, this can be maintained or shift to non-combustible non-explosive by injection of CO_2 at slow rate [7, 8].

2.1 Details of Boreholes

I.1st Bore Hole (89L/14D) Depth = 256 m, Diameter 80 mm Outer dia. & 60 mm Inner dia.

II.2nd Bore Hole (89L/12D) Depth = 262 m, Diameter DTH drill 190.5 mm.

III.3rd Bore Hole (87L/12D) Depth = 246 m, Diameter 80 mm Outer dia. & 60 mm Inner dia.

2.2 Injection of CO_2

CO_2 injection was started through borehole n-1 located at (89L/14D) in rise side of the fire affected 6A panel. The Quantity of CO_2 injection during the period as under:

CO_2 Flushing through 1st Bore Hole started:

1 = 4.2 Tonnes
2 = 7.6 Tonnes
3 = 6.4 Tonnes
4 = 7.8 Tonnes

Total = 26 Tonnes

3 Monitoring of Status of Environment of the Sectionalized Panel

Air samples are collected through borehole no 3 close to the expected seat of fire by using suction pump and connected with the pipe lowered up to the roof of the gallery. A bubbler is connected between the pump and the pipe for unidirectional flow in the pipe. The samples were analyzed in chemical laboratory using Gas Chromatograph [9–11]. Explosibility of the atmosphere has been assessed sample wise by software EXPLO based on Ellicott's extension of Coward's diagram and the results are graphically represented (Fig. 2 and Table 2).

Results of air sample analysis collected through BH-NO-3 revealed that:

1. Environment inside the fire affected 11D sectionalized panel is still lean-fuel non-explosive. Hence, this environment is required to be maintained or improved by injection of CO_2 through borehole.
2. Results also indicated that more oxygen-consuming period for the fire is between 8:00 PM to 6:00 AM. Hence, injection of CO_2 through borehole should be done during 8:00 PM to 6:00 AM.

Table 2. Gas Chromatograph

S.NO	TIME	CO_2	O_2	CH_4	CO	H_2	N_2
1.	3:26 AM	10.37	5.18	0.6155	3.9158	3.247	76.2651
2.	3:15 PM	8.883	8	0.4245	3.6463	2.884	76.143
3.	5.20 AM	28.499	5.798	1.7	1.118	0.114	62.17
4.	5.00AM	29.748	4.4933	1.18	1.514	1.303	61.762
5.	5.20AM	27.1191	5.8862	1.071	1.395	1.125	63.405
6.	2.25PM	30.313	6.3726	0.722	0.994	0.741	60.858
7.	8.30AM	25.849	7.1244	0.5442	0.9856	0.622	64.874
10	12:05 PM	23.89	7.39	0.543	0.977	0.599	66.594
11	4:10 PM	23.32	7.21	0.564	1.002	0.62	67.278
12	12:05 AM	34.511	6.008	0.964	0.715	0.694	57.108
13	12.30 AM	35.283	6.261	0.971	0.788	0.712	55.985
14	4:15 AM	37.616	6.36	0.964	0.784	0.708	53.568

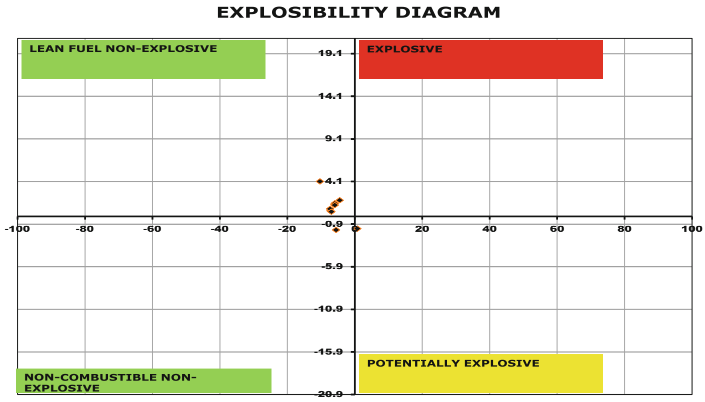

Fig. 2. Ellicott's extension of Coward's diagram

4 Observations

Some of the important observations during mine visit are as follows:

i. Pressure of the stopping at 11D of 87L was indicated 1.0 mm wg positive and presence of CO was observed outside the stopping.
ii. Pressure of the stopping at 10D of 87L was negative when door at 10D was between 87 and 86 level was closed.
iii. Pressure drop across the door was measured to be 0.8 mm wg.
iv. Cracks and fissures around the stopping's was also observed.
v. Inrush of water in to the fire affected sectionalized area.

In view of the above, it may be concluded that the quality of sealing of the fire affected sectionalized panel is not in good conditioned and required to be improved.

5 Conclusions

The results of investigation, observation and the air ample analysis results revealed that.

1. The quality of sealing of the sectionalized panel is required to be improved.
2. The environment inside the sectionalized panel is lean fuel non-explosive. Hence, it is required to be maintained or shift to non-combustible non-explosive by injection of CO_2 at slow rate through borehole until completion of sealing work.
3. Results also indicated that more oxygen-consuming period for the fire is between 8:00 PM to 6:00 AM. Hence, injection of CO_2 through borehole should be done during 8:00 PM to 6:00 AM.
4. Collection of air sample through boreholes should be carried out between 8:00 PM to 6:00 AM at the interval of four hours.
5. Record of diurnal change in barometric pressure is required to be maintained at the surface to correlate with the air sampling results.
6. Ventilation control to reduce leakage may be applied after the study of diurnal change in barometric pressure.

7. Entry of water into the sealed off area required to be avoided.

References

1. Beamish, B. B., Barakat, M. A., and St George, J. D. (2000). Adiabatic testing procedures for determining the self-heating propensity of coal and sample ageing effects. Thermochemical Acta. 362 (1–2), 79–87.
2. Bhat, S., and Agarwal, P. K. (1996). The effect of moisture condensation on the spontaneous combustibility of coal. Fuel, 75(13), 1523–1532.
3. Chen, X. D. (1991). The effect of moisture content on spontaneous ignition process: A review. Proceedings Symposium of 4th Coal Research Conference, Wellington, New Zealand, 2, 327–337.
4. Cudmore, J. F. (1969) Spontaneous combustion of coal: development of laboratory methods of assessment. Australian Coal Industry Research Laboratories Ltd. Report No. P. R. 69–5.
5. Essenhigh, R. H. (1981) „Fundamentals of coal combustion" In: Chemistry of Coal Utilization. Ed: M. A. Elliott, John Wiley & Sons, Inc., USA, pp. 1153–1312.
6. Monazam, E. R., Shadle, L. J., & Shamsi, A. (1998). Spontaneous combustion of char stockpiles. Energy & Fuel, 12, 1305–1312.
7. Nordon, P. A. (1979). A model for the spontaneous heating reaction of coal and char. Fuel, 58, 456–464.
8. Rosema, A., Guan, H., & Veld, H. (2001). Simulation of spontaneous combustion, to study the causes of coal fires in the Rujigou Basin. Fuel, 80, 7–16.
9. Saghafi, A., & Carras, J. N. (1997). Modeling of spontaneous combustion in underground coal mines: application to a gassy longwall panel. In Proceedings of the 27th International Conference of Safety in Mines Research Institute (pp. 573–579).
10. Kumari, K., Dey, P., Kumar, C., Pandit, D., Mishra, S.S., Kisku, V., Chaulya, S.K., Ray, S.K. and Prasad, G.M., 2021. UMAP and LSTM based fire status and explosibility prediction for sealed-off area in underground coal mine. *Process Safety and Environmental Protection*, *146*, pp. 837–852.
11. Tang, Y. and Xue, S., 2015. Laboratory study on the spontaneous combustion propensity of lignite undergone heating treatment at low temperature in inert and low-oxygen environments. *Energy & Fuels*, *29*(8), pp. 4683–4689.

Open Access This chapter is licensed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (http://creativecommons.org/licenses/by-nc/4.0/), which permits any noncommercial use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.