

Effect of Inhibitor in Suppressing Spontaneous Heating of Coal

Alok Ranjan Mahananda, B. K. Pal

Abstract: Spontaneous combustion of coal is a natural phenomenon responsible for the burning of thousands of tonnes of coal every year. Normally, when Indian coal gets exposed to air, it catches fire within 9 to 12 months and the application of inhibitors helps in preserving the coal by enhancing its time period (Incubation period). They have the capacity of retarding the spontaneous heating of coal by forming a protective layer around it. This paper deals with four inhibitors and its retardation capacity to spontaneous heating is laid down by experimental investigation. Crossing Point Temperature (C.P.T) analysis and Flammability Temperature analysis (F.T) are the prime method in determining its retardation effect. Coal samples from Mahanadi Coalfield Limited (MCL) were prepared and used for experimentation. Proximate analysis is used to study the composition of coal. The prepared coal sample is treated with inhibitors at three different proportions of 5%, 10% and 15% by wt. Considering the economic and safety application for miner and mining industry, the maximum retardation capacity of an inhibitor at particular percentage is been shown in this paper.

Keywords: crossing point temperature, proximate analysis, retardation, spontaneous combustion

I. INTRODUCTION

Mine fire due to spontaneous heating of coal is one of the major hazards that cause an economic loss of coal reserve for the nation. It has an adverse effect on the environment and the economy. Considering these aspects, studies have been focused on spontaneous combustion of coal of different ranks. It is seen that coal of low-rank values are more liable to spontaneous heating if they are stored for a longer duration. The coal affected due to heating may be partially unsuitable to use. Therefore, steps should be taken to enhance the time period of storage of coal. The application of inhibitor is one of the methods of increasing this period and retarding the self-heating of coal.

Inhibitors are chemical or substance which when applied to other substance causes a slowdown of reaction. It may be due to the formation of layer/coating around the coal surface to obstruct the oxidation of coal. Many inhibitors are been trialed considering its inhibiting nature.

II. SAMPLE COLLECTION

Indian coals come under the parent organisation Coal India Limited. MCL is a subsidiary of CIL. The coal samples selected for experimentation are from different mines of Mahanadi Coalfield limited (MCL). The samples are grounded and prepared for different mesh sizes for different experimental investigation.

III. EXPERIMENTAL INVESTIGATION

The intrinsic properties of coal are studied through proximate analysis. Coal composition having moisture, ash, volatile matter and fixed carbon content are experimentally investigated. Table No.1 shows the composition of all coal samples.

Table No 1. Proximate analysis of 4 coal samples from MCL mines

S. No.	Sample	Moisture	Ash Matter	Volatile Matter	Fixed Carbon
1	S1	12.59	30.01	13.33	44.07
2	S2	07.81	22.35	26.42	43.42
3	S3	08.55	24.34	25.78	41.33
4	S4	06.96	23.52	28.67	40.85

The susceptibility of coal to spontaneous combustion is affected by numerous factors such as moisture rank, carbon content, particle size, temperature, oxidation rate etc. One of the most important factors is the oxidation rate. Spontaneous combustion occurs when the rate of heat generation from oxidation exceeds the rate of heat dissipation.

The susceptibility of the coal sample was conducted by determining the crossing point temperature of coal. Crossing point temperature is one of the practised methods of determining the spontaneous heating susceptibility of coal. The obtained results and its correspondence to liability index and risk rating towards spontaneous heating to catch fire is shown in Table no.2.

Table No 2. C.P.T and Risk Rating of coal samples

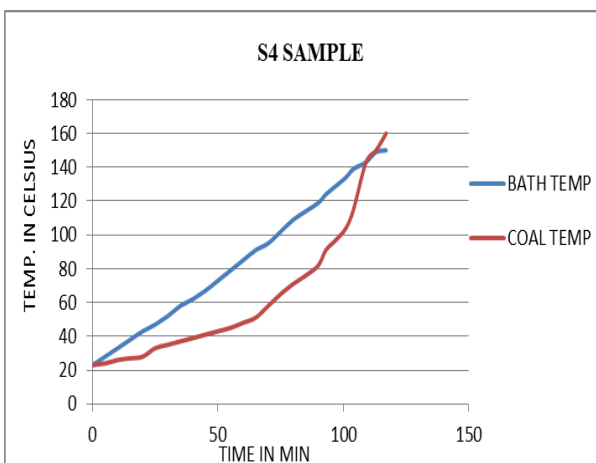
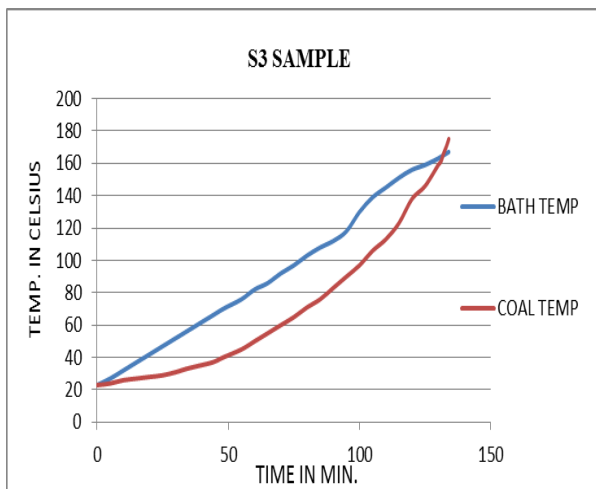
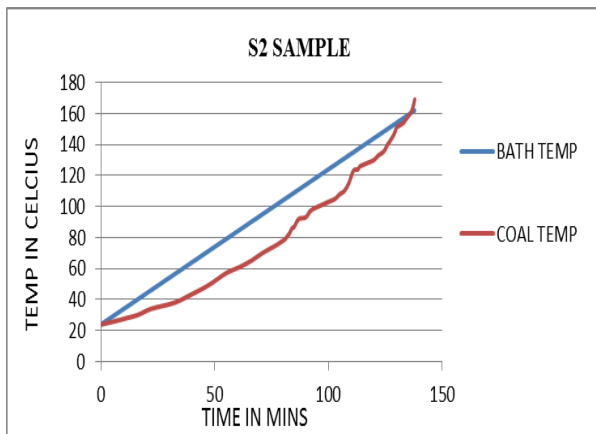
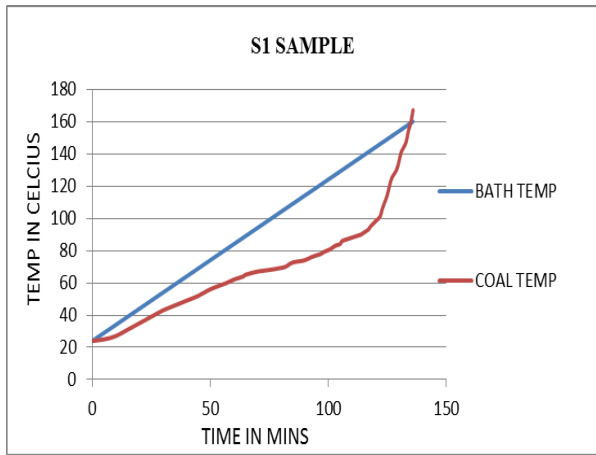
S No.	Sample	C.P.T (°C)	Risk Rating (susceptibility)
1.	S1	158	Moderately
2.	S2	161	Moderately
3.	S3	166	Poorly
4.	S4	142	Moderately

Revised Manuscript Received on January 15, 2020.

Mr. Alok Ranjan Mahananda, pursuing Ph.D, Mining Engineering, N.I.T, Rourkela, Odisha, India.

Dr. B. K. Pal, Senior Professor, Mining Engineering at N.I.T., Rourkela, Odisha, India.

Effect of Inhibitor in Suppressing Spontaneous Heating of Coal



Coal upon slow oxidation reaches to a point where the temperature rise occurs in a self-propellant manner. If it is able to inhibit the coal from reaching the temperature, the coal can be stored for a longer duration in silos and bunker. A large number of resources can be saved and can be used at the time of need. This minimum temperature at which coal catches fire is called is termed as flammability temperature. Flammability temperature of coal differs depending on the rank of coal and on the percentage of oxidation of coal. The flammability temperature of coal decreases with an increase in the oxidation of coal. This temperature difference between oxidation of coal prior to its oxidation is one of the parameters in determining the susceptibility of coal. The application of retardants delays the spontaneous heating of coal and a significant rise in the temperature at which coal catches fire.

Selection of Retardants

The selections of retardants are based on many properties like toxicity, solubility, cooling capacity, economic viability etc. The most important factor among them is the retarding capacity and its inert nature. Economic and safety are to be chosen after studying the inhibition capacity of retardants. On this basis four retardants were selected i.e. Sodium chloride, Sodium Nitrate, Fused calcium chloride, and Sodium dodecyl sulfate.

IV. RESULTS & DISCUSSION

The application of sodium chloride and sodium nitrate enhances the flammability temperature of coal samples by 50° C and 120° C. The rise is almost the same for all coal samples. Table no. 3 & 4 and the figure below it exhibits the analysis of all four coal samples on treating sodium chloride sodium nitrate at different percentages of 5%, 10%, and 15 %.

Table No. 3 Flammability temperature of the coal samples w.r.t sodium chloride

S No	Sample	F. T. (°C)	Sodium Chloride		
			5 %	10%	15%
1	S1	505	550	555	555
2	S2	530	575	580	580
3	S3	500	550	545	550
4	S4	560	600	610	615

Table No. 4 Flammability temperature of the coal samples w.r.t sodium nitrate

S No	Sample	F. T. (°C)	Sodium Nitrate		
			5%	10%	15%
1	S1	505	620	625	625
2	S2	530	650	650	655
3	S3	500	615	620	620
4	S4	560	675	680	680

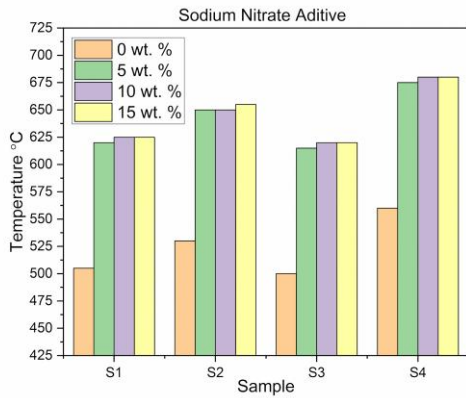


Fig. 1.F.T. of coal sample on application of sodium nitrate

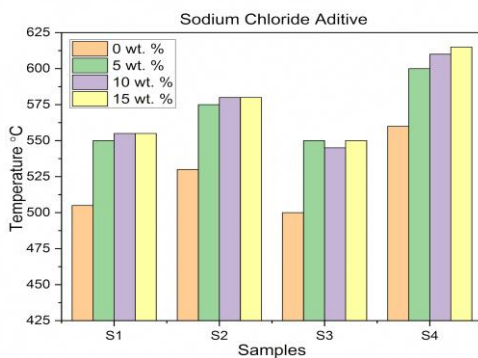


Fig. 2. F.T. of coal sample on application of sodium nitrate

Table No. 5 Flammability Temperature of the coal samples w.r.t fused calcium chloride

S No	Sample	F. T. (°C)	Fused Calcium Chloride		
			5 %	10%	15%
1	S1	505	540	540	545
2	S2	530	565	565	570
3	S3	500	535	535	540
4	S4	560	595	600	600

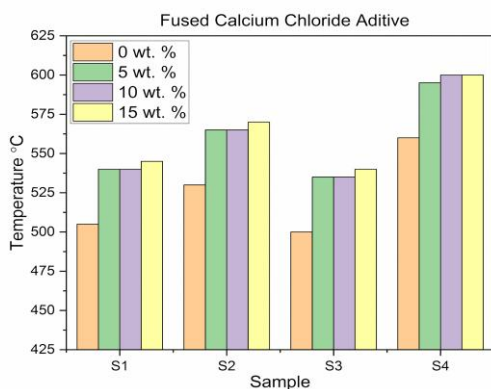


Fig. 3.F.T. of coal sample on application of fused calcium chloride

The rise in flammability temperature for fused calcium chloride and sodium dodecyl sulphate is found to be 40° C and 120° C as seen from Table no. 5 and 6. It is seen that the rise of temperature is uniform for all coal samples. It might be due to the formation of an inhibiting layer around the coal surface.

Table No. 4 Flammability Temperature of the coal samples w.r.t sodium dodecyl sulphate

S No	Sample	F. T. (°C)	Sodium Dodecyl Sulphate		
			5%	10%	15%
1	S1	505	625	625	630
2	S2	530	645	650	650
3	S3	500	615	620	615
4	S4	560	670	670	675

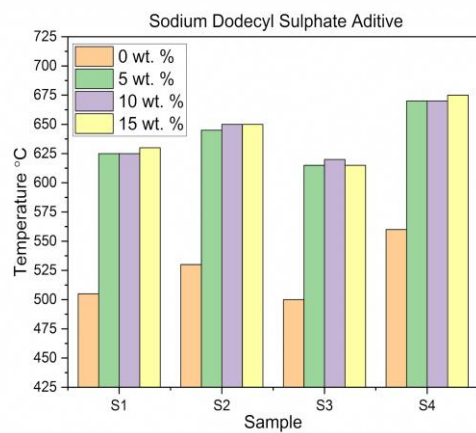


Fig. 4. F.T. of coal sample on application of sodium dodecyl sulphate

V. CONCLUSION

From the observations, it can be concluded that inhibition of spontaneous heating done with retardants is of different value at different percentages. Considering the difference in change in rising for different percentage inhibiting capacity is also noted. In some cases 10% is more efficient and in few 15 % serves as the best retardation. The sequence of retardation capacity is that sodium dodecyl sulphate has highest followed by sodium nitrate, sodium chloride and calcium chloride. Sodium dodecyl sulphate has the chances of causing irritability whereas the other three are eco-friendly in nature. The optimisation of retardation can be done by suitable mixing of three chemicals. There may be number of chemicals and its combination is to be studied to determine the best possible inhibitor. Suitable application of chemicals can save large amounts of coal from catching fire.

REFERENCES

1. N.K. Mohalik, V.K. Singh, R.V.K. Singh, Application of carbon dioxide (CO₂) for controlling subsurface fire area: Indian context, J. Min. Sci. 45 (2009) 390–397. doi:10.1007/s10913-009-0049-y.
2. W. Sujanti, D.K. Zhang, Laboratory study of spontaneous combustion of coal: the influence of inorganic matter and reactor size, Fuel.

Effect of Inhibitor in Suppressing Spontaneous Heating of Coal

- 78 (1999) 549–556. doi:10.1016/S0016-2361(98)00188-4.
3. B. Beamish, P. McLellan, M. Raab, Delaying spontaneous combustion of reactive coals through inhibition, (2013) 221–226.
 4. Y. liang Xu, D. ming Wang, L. yun Wang, X. xing Zhong, T. xiang Chu, Experimental research on inhibition performances of the sand-suspended colloid for coal spontaneous combustion, *Saf. Sci.* 50 (2012) 822–827. doi:10.1016/j.ssci.2011.08.026.
 5. W.S. Watanabe, D. ke Zhang, The effect of inherent and added inorganic matter on low-temperature oxidation reaction of coal, *Fuel Process. Technol.* 74 (2001) 145–160. doi:10.1016/S0378-3820(01)00237-5.
 6. A.C. Smith, Y. Miron, C.P. Lazzara, Inhibition of spontaneous combustion of coal, (1988) 21.
 7. V. Slovák, B. Taraba, Urea and CaCl_2 as inhibitors of coal low-temperature oxidation, *J. Therm. Anal. Calorim.* 110 (2012) 363–367. doi:10.1007/s10973-012-2482-4.
 8. J. Zhan, H.H. Wang, S.N. Song, Y. Hu, J. Li, Role of an additive in retarding coal oxidation at moderate temperatures, *Proc. Combust. Inst.* 33 (2011) 2515–2522. doi:10.1016/j.proci.2010.06.046.
 9. X. Dong, The Effect of DDS-Inhibitors on Suppressing the Spontaneous Ignition of Coal, (n.d.) 571–580.
 10. J. Zhu, N. He, D. Li, The relationship between oxygen consumption rate and temperature during coal spontaneous combustion, *Saf. Sci.* 50 (2012) 842–845. doi:10.1016/j.ssci.2011.08.023.
 11. X. Yong-liang, W. De-ming, Z. Xiao-xing, T. Zhao-jun, Q. Xu-yao, Study of inhibition characteristic of sand suspending thickener for spontaneous combustion prevention, *Procedia Earth Planet. Sci.* 1 (2009) 336–340. doi:10.1016/j.proeps.2009.09.053.
 12. S.K. Ray, R.P. Singh, Recent developments and practices to control fire in underground coal mines, *Fire Technol.* 43 (2007) 285–300. doi:10.1007/s10694-007-0024-6.
 13. Z. Wu, S. Hu, S. Jiang, X. He, H. Shao, K. Wang, D. Fan, W. Li, Journal of Loss Prevention in the Process Industries Experimental study on prevention and control of coal spontaneous combustion with heat control inhibitor, *J. Loss Prev. Process Ind.* 56 (2018) 272–277. doi:10.1016/j.jlp.2018.09.012.
 14. B. Taraba, R. Peter, V. Slovák, Calorimetric investigation of chemical additives affecting oxidation of coal at low temperatures, *Fuel Process. Technol.* 92 (2011) 712–715. doi:10.1016/j.fuproc.2010.12.003.
 15. X.H. Fan, J. Yi, Z.Q. Bao, Research on safety input research model for preventing coal gas explosion, *Procedia Eng.* 26 (2011) 2012–2017. doi:10.1016/j.proeng.2011.11.2398.
 16. B.Z. Dlugogorski, E.M. Kennedy, An Effective Method for Fast Determination of Susceptibility of Coal to Spontaneous Combustion, *Aofst* 3. (1988).

(NCA) of India. He is an active Honorary Member of Asia Pacific Accreditation and Certification Commission (APACC). In August 2005, he received the invitation to represent India in the Inter-Governmental Program organized by CPSC, held in Philippines also. He is the active Member at many International Symposiums viz. “Mine Planning and Equipment Selection” (MPES); “Safety in Mines Research (SMR)”; “Case Histories in Geotechnical Engineering”; “International Council on Environmental Research (ICER)”; “Tsunami Reconstruction with Geo-synthesis – Protection, Mitigation and Rehabilitation of Coastal and Waterway Erosion Control” (Gpmrce) held in different countries and also the SME Paper Meeting (USA). He is the Editorial Board Member of many important Journals like *Journal of Institution of Engineers (India)*; *International Institution of Engineers*; *International Journal of Mining Science & Technology*; *International Journal of Environmental Sciences and Mining Engineering* etc. His area of specialization is Environmental Management, Safety Risk Assessment and Management. Dr. Pal has extensively traveled to many countries, viz. Australia, Canada, Germany, Indonesia, Japan, Kingdom of Thailand, Malaysia, Philippines, Rep. of Korea, Singapore, UK and USA many times either for Project related works or attending Conferences where mostly he Chaired the Technical Session along with delivering the speech as an Invited Speaker.

AUTHORS PROFILE

Mr. Alok Ranjan Mahananda has completed his B.Tech and M.Tech in Mining Engineering from Government Engineering College (Keonjhar) and from N.I.T, Rourkela in 2011 and 2014. At present, he is pursuing Ph.D. in N.I.T, Rourkela. It is an enhancement of the work done in M.Tech and is in the final stage of completion (Objectives achieved). His area of work is on Coal, Mine Fire, Mine Safety and Mine Environment. Being a mining expert, he has taken classes of B.Tech, Dual Degree (B.Tech & M.Tech) and Ph.D. students on Mine Fire and spontaneous heating, Mining Methods and Metal Mining in N.I.T, Rourkela. He used to take a laboratory class on Special topics of Mining Engineering which involves all computational work. He has successfully published papers in National Journals and in International Conferences (06).



Dr. B. K. Pal (58) did his B.Tech, M.Tech. and Ph. D. in Mining Engineering from IEST (Sibpore) and IIT, Kharagpur. He was awarded the Chartered Engineer (India) in 1989 and presently the Fellow Member of Institution of Engineers (India) and also International Institution of Engineers. At present working as a Senior Professor in Mining Engineering at NIT, Rourkela.. He worked as Head; Dept. of Mining Engineering from 2003-2007 and as Dean from 2007-2010. Dr. Pal has published more than eighty research papers in referred to National/International Journals and Conferences. He has successfully supervised Ten Research Students and three more are on-roll for completion. He has completed more than Ten Scientific Research and Industrial Consultancy (SRIC) Projects and three more are on-going. He has attended Eighteen International Programs. In September 2004, he represented India in an Inter-Governmental Program organized by Colombo Plan Staff College, Manila which was held at Seoul, and Republic of Korea where he has been nominated as the National Coordinator for Accreditation