iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 8 **Issue:** I **Month of publication:** January 2020

DOI: http://doi.org/10.22214/ijraset.2020.1011

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.177
Volume 8 Issue I, Jan 2020- Available at www.ijraset.com

Review on Mine Accidents Due to Coal Mine Fires Causes and Prevention in Indian Coal Fields Scenario

Dr. R. Giri Prasad[1], Dr. P. Brahmajirao[2], E. Nandish Goud[3]
[1, 3]Associate Professor, Dept. of Petroleum, Aditya Engineering College (A)
[2]Professor, Dept. of Environmental Science, Acharya Nagarjuna University

Abstract: Coal absorbs oxygen even at lower temperatures than the ambient temperature and they start heating up. This heating without any external source of supply of heat generally leads to due to auto-oxidation, also called spontaneous heating of coal. There are numerous reasons for which generally this occurs and they are broadly classified as mining, seam and geological factors. The sub-classification of these factors is so intimately associated that exact reason is still unknown. However, this phenomenon is the cause of a numerous accidents and disasters in mining industry, not only in India but is the problems all over the world. Due to auto-oxidation, we are faced with many dangerous problems. Therefore the assessment of this problem has become necessary and hence we are trying to calculate and predict how susceptible or prone any coal might be towards spontaneous heating before its use in any industry.

India is having a huge amount of coal resources spread all over the country and most of the coals are liable to auto-oxidation. As a Mining Engineer some steps towards the prevention were noted from the observations of earlier investigators and some suggestions are made from our findings which may reduce the possibilities of tendencies towards auto-oxidation and also to find some suitable way to minimize the threat caused due to this spontaneous heating.

I. INTRODUCTION

Carbonaceous Organic Aromatic Lump which generally known as COAL is a formation due to the decaying of vegetable matters (Drift or Allochthonous theory) or submerging forest due to tectonic movements (In-situ or autochthonous theory) with carbon percentage in a wide range. The classification according to their carbon percentage would be Graphite (100%), Anthracite (91%), Bituminous (78.5%), Semi-bituminous (69.5%), Sub-bituminous (64.5%), Lignite (61.8%) and Peat (50.9%).

Spontaneous heating is auto-oxidation at coal sometimes leads to fire restricts the mining operation. This phenomenon was first observed by plot in 1686.

II. DEFINITION OF SPONTANEOUS HEATING

Coal absorbs oxygen even at lower temperatures than the ambient temperature and they start heating up. First, the heating causes the water or moisture to evaporate and release from the coal, after which the rate of oxidation increases. But, every heating doesn‟t lead to ignition because of dissipation of heat during this process, when the dissipation of heat is greater than the accumulation then it cannot reach to "critical temperature of oxidation" and is generally called as weathering. But, when accumulation is greater than the oxidation it leads to fire or ignition.

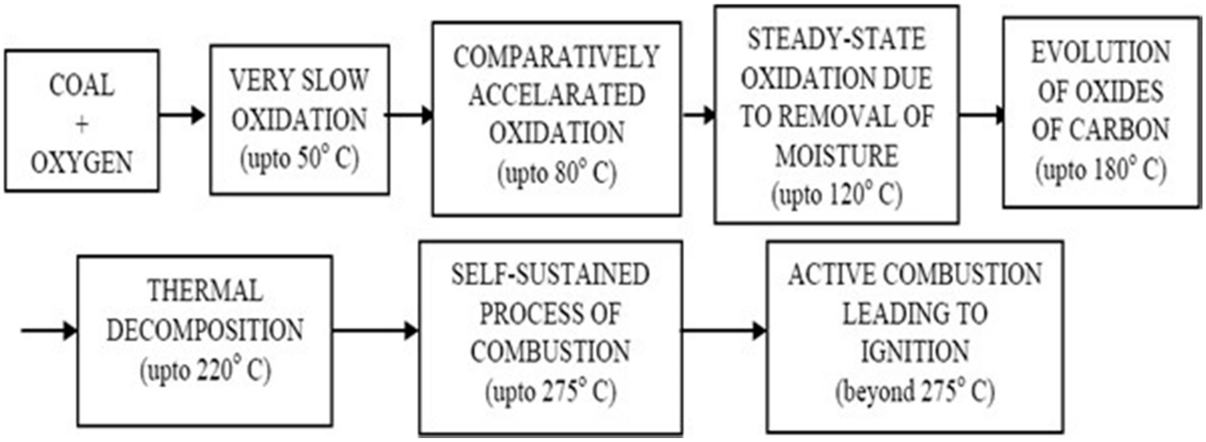
The critical temperature of oxidation depends upon the mineral content, temperature, pressure, geographic location etc., few examples would be:

Indian coals -70-85^{o}c French coals – 80-85^{o}c US/Russian coals – 60-70^{o}c

In Indian coal mines, 80% of the mine fires occur due to spontaneous combustion. The main aspect of a start of fire in India is because the coal seams are thicker and there is a tendency of spontaneous heating during the depillaring operation. The problem of extraction of thick seam and coal standing in pillars becomes a serious threat when coal is of high moisture, high volatile matter and low ash content which is more liable to spontaneous combustion.

It is impractical to be able to extract all the coal by caving method. Pillars standing for long time are liable to deteriorate and spilling may occur. If coal is heated to about 93°C and O2 in the air is available, the oxidation will take place at an accelerated rate and if the heat of dissipation is less than the heat of accumulation then coal bed temperature increases, ultimately leading to fire.

Fig 1.1 Stages of Spontaneous Combustion (Pal B. K., 2012)



III. MECHANISM OF SPONTANEOUS HEATING

The main mechanism of spontaneous heating is absorbing the oxygen from atmosphere and decomposing into various carbon and oxygen complexes. This process generally liberates heat. As coal is very diverse in its chemical composition, mineral matter etc. the procedure of decomposition becomes very complex during the oxidation. There will be so many concurrent and overlapping reactions taking place that it would be very difficult to separate out the reactions.

Coal first adsorbs the gaseous or liquid so as to oxidize which is otherwise known as sorption. When the accumulation of other solution restricts further penetration into the body, it is only known as adsorption. But, when the solution can enter the bulk it is called absorption.

Coal when absorbs oxygen it heats up because oxidation of coal in presence of air is exothermic. Up to 50^{o}c the oxidation is very slow, when it reaches up to 80 ^{o}c the oxidation rate is increased and when reaches near 120 ^{o}c, the water evaporates and moisture of the coal gets released. Here the oxidation is faster and steady. The evolution of oxidation of carbon starts when the temperature is from 120 to 180 ^{o}c. At this temperature up to 220 ^{o}c, thermal decomposition of coal starts. When the temperature increases from 220 ^{o}c to 275 ^{o}c coal starts self-sustained process of combustion. When the temperature rises from 275 ^{o}c, coal starts active combustion which sometimes can lead to ignition.

IV. THEORIES IN SPONTANEOUS HEATING

There are various theories of spontaneous heating because of the complex reaction occurring due to the diverse properties of coal.

A. *Pyrite Theory*

When there is pyrite content in coal and heating of coal starts then, the pyrite forms a complex acid solution of greater volume, this causes cracks and fissure development, although the effect is negligible when pyrite content is less than 5%. It follows the reactions written under in general:

$2FeS_2 + 7O_2 + 16H_2O = 2H_2SO_4 + 2FeSO_4 + 2FeSO_4.7H_2O + 31Kcal$ $FeS_2 + 15/4O_2 + 5/2H_2O = FeO.OH + 2H_2SO_4$

B. *Bacterium Theory*

Potter observed that there was a slight increase in heat build-up when bacteria were introduced.

Graham observed that the heat build-up in sterilized and unsterilized coal both were at the same rate. Therefore there is no certain proof of this theory being true.

C. *Humidity Theory*

Stott saw that the atmospheric oxidation of coal liberated less heat than the required heat for evaporating moisture from coal. Therefore the temperature of heating can be decreased by inducing evaporation of water.

Mukherjee and Lahiri observed that the source of CO and CO_2 could be resulted due to the following at low temperatures.

$H_2O + (H)(OH) = (H_2)(O) = (H_2) + (O)$

$C + O = (CO) = CO$

$(CO) + O = (CO_2) = CO_2$

D. Prevention and Control

A number of methods and techniques have been developed throughout the world to extinguish coal fires and prevent their (re-)ignition. Though some of these are very efficient in dealing with the problem, they only apply to specific geo-mining conditions. Their performance rate also varies from case to case. The methods currently available may be summarized as follows:

Trench cutting and filling	Hydro-pneumatic/fly-ash stowing
Blanketing	Digging out
Sealing through isolation stopping	Application of sealant/surface coating material
Hard foam for isolation of fire area	Injection of cement/hydrogel in coal mass

Application of water mist	Dynamic pressure balancing
Chamber ventilation	Multi-zonal ventilation systems
	Application of fire-fighting chemicals
Inertisation processes: Liquid/gaseous nitrogen, High-pressure high-stability foam, Carbon dioxide halons, steam flue gas	

E. Inertisation

Inert gases were used to fight mine fires during latter half of the nineteenth century. Subsequently, flue gases, carbon dioxide and nitrogen were used for combating mine fire with varied degree of successful attempts. Probably, the earliest report to extinguish mine fires using inert gases was in the year 1850, at the Clackmannan Mine, Scotland (Adamus, 2001, Amartin 2001). In India carbon dioxide was used for the first time in the year 1977 to smoother an underground fire at Sudamdih Shaft Mine, BCCL and first trial of nitrogen was done to control an old fire in Laikdih Deep Colliery, BCCL in March 1981 (Tripathi and Singh, 2002; Mohalik et. al. 2006)

F. Different Inertisation Methods

Application of inert gases in cutting of the source of oxygen and taking away heat from the reaction interfaces has gained importance in combating coal fires recently. The technology, efficacy and economics of operations, however, determine the applicability of the method in large scale fire combating practices. Application of suitable inert gases permits rapid sealing of fire zones and significantly reduces the hazard of gas explosion. However, the practice is generally less effective and more costly than conventional direct fire fighting methods. The technology of inert infusion for fire combat activities in underground mines may be divided broadly in four categories as follows:

Replacement of air with inert gas in goaf vulnerable to heating leading to prevention of gas explosions by modifying the atmosphere; Replacement of air before sealing a district where heating has been detected by reducing the intensity or spread of secondary combustion and to cool the area surrounding the fire zone;

Control and extinction of fire in sealed off area by inert gas infusion with pressure chambers for safety and recovery;

Protecting shaft pillars and ribs adjoining main and haulage road from advancing fire by putting up an inert gas plug.

The main difficulty with gas injection methods has been the limited availability of plant to provide large volumes of gas on site at short notice. Moreover such methods are costly. Inert gases which have been employed with varied degrees of success are halons, steam, CO_2, N_2 and flue gas.

I. Composition Of Coal Mine Gases

Coalification under high pressure and temperature transforms vegetation materials to coal. In this process many organic gaseous hydrocarbons and carbon dioxide is produced.

Gas emissions are calculated by measuring gas emission rate in return airway. The gas emission rate can be determined by:

$Q = (C \times 60 \times 24 \times q) / T \times K$

Where: Q - methane emission rate (m^3/t)
q - Air flow rate in return airway (m^3/min)
c – Concentration of methane in return airway (indecimal) T – Coal production (t/d)
K = (max. conc. Of methane on any day in a week) / (avg. conc. Methane over the week)

Indian coal seams are classified as degree of Gassiness I, II or III when methane rate emissions are <1, 1-10 or >10 m^3/t output respectively.

Gases Explosibility:

Generally methane burns when comes in contact with ignition in presence of air. But, under favorable conditions it can explode when firedamp in air is present. The general combustion takes place in the following equation:

$CH_4 + 2(O_2 + 4N_2) = CO_2 + 2H_2O + 8N_2$

Therefore, one unit volume of methane requires two unit volumes of oxygen. Firedamp is most violent when the percentage is in 9.5% and it is explosive in nature within 5.4 to 14.5%.

Table 1.1 Flammable Limits of Combustible Gases

Gases	Lower flammable limit	Upper flammable limit
CH_4	5.0	14.0
CO	13.0	72.0
H_2	4.0	72.0
C_2H_2	2.5	80.0
C_2H_4	3.1	32.0
C_2H_6	3.2	12.5
H_2S	4.3	46.0

The lower flammable limit of firedamp even reduces to lower percentage when there is any presence of other combustible gases like C_2H_2, CO, etc. Le-Chatlier gave a relationship considering this properly as following:

$100/L = P_1/l_1 + P_2/l_2 + P_3/l_3 + \ldots$

Where „P‟ is the percentage of corresponding gases and „l‟ is lower flammable limits of those respective gases.

V. CONCLUSION

There is a high possibility of mine fire as higher percentage of combustible gases will be present in the air too.The different technologies mentioned above are not suitable for controlling and combating all types of underground/surface fires. Every fire problems are different in nature. Under the circumstances, before tackling any fire problem one should carefully examine the status of fire and to decide the appropriate technology before application for controlling the fire. It is not possible to eliminate fires completely, but it is possible to bring the situation under control. The main attention should be given for detection, assessment, prevention and control of mine fire of Indian coalfields to deal with the existing fires and to avoid future occurrences of fire in Indian coal mines. The incidence of mine fire is mostly attributable to spontaneous heating in Indian coal mines. It is not possible to eliminate fires completely, as the very process of mining which introduces factors contributable to spontaneous heating of coal. Suitable techniques should be used for prevention and control of fire as per fire situation

REFERENCES

[1] Pal B. K. and Mahadevan V. (1988): Seam Factors and Spontaneous Heating of Coal, Mining Science and Technology, Vol-7, pp 149-159.
[2] Mahadevan, V., Ramlu, M. A., 1985. Fire Risk Rating of Coal Mines due to Spontaneous Heating, Journal of Mines, Metals and Fuels 33, p. 357.
[3] Morris R. and Atkinson T. (1986): Geological and Mining Science and Technology, Vol- 3, pp 217-231.
[4] Banarjee S. C. (1985): Spontaneous Combustion of Coal and Mine Fires, Oxford & IBH Publications Co.
[5] Nimaje D. S. and Tripathy D. P. (2010), Thermal Analysis on Spontaneous Heating of Coal, The Indian Mining and Engineering Journal, April pp 10-21.
[6] Tripathy D. P. and Pal B. K.: Spontaneous Heating Susceptibility of Coals Evaluation Based on Experimental Techniques, Journal of Mines, Metals and Fuels, Vol-49, pp 236- 243.
[7] Morris R. and Atkinson T. (1988): Seam Factors and Spontaneous Heating of Coal, Mining Science and Technology, Vol-7, pp 149-159.
[8] Ramlu M. A. (2007): Mine Disasters and Mine Rescue, University press
[9] Banarjee S. C. (2000): Prevention and Combating Mine Fires, Special Edition, New Delhi, Oxford and IBH Publication Co. Pvt. Ltd., pp 68-77.
[10] Mohanik N. K., V. K. Singh, R. V. K. Singh, J. Pandey; "The Application of CO_2 for Controlling Substance Fire Area: Indian Context", Journal of Mining Science, Vol.45, No.4, 2009, pp 390-397
[11] Mohanik N. K., V. K. Singh, R. V. K. Singh, J. Pandey; " The Application of Nitrogen as Preventive and Controlling Sub-surface Fires- Indian Context", Journal of Scientific and Industrial Research, Vol.64, April 2005, pp 273-280.