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APPLICATION OF INFORMATION TECHNOLOGY FOR ASSESSMENT AND CONTROL OF COAL MINE FIRE

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कोयला खनन उद्योग के लिए खान की आग एक गंभीर समस्या है और उससे खान की सुरक्षा एवं मानवीय जीवन को जोखिम में पड़ने की प्रमुख आशंका रहेगी और इससे प्राकृतिक स्त्रोतों में कमी आएगी, खनन को कठिन या असंभव बनाएगी तथा जहरीली गैसों और धुएँ के निकलने से पर्यावरण हमेशा प्रदूषित होते रहने की आशंका रहेगी। वास्तविक खान की आग का पता लगाने, बचाव, नियंत्रण और कम्बेटिंग प्रौद्योगिकी के कारण भारतीय खनन उद्योग में काफी उछाल आएगा। जिससे उदारीकृत और प्रतियोगी वैश्विक अर्थव्यवस्था बनी रहेगी। विगत कुछ वर्षों में सूचना प्रौद्योगिकी के उपयोग से खनन उद्योग के अनेक भागों में विचारणीय सफलता मिली है। इसे खान की विभिन्न पहलुओं में (मामलों में) भी अपनाया जा रहा है। कुछ अनुसंधान कर्मियों द्वारा (रिसर्च वर्करों) पहले से ही खान की आग का पता लगाने, सुरक्षा और नियंत्रण के लिए सूचना प्रौद्योगिकी अपनाई जा चुकी है। इस आलेख में, वर्तमान में सूचना प्रौद्योगिकी के प्रयोग की स्थिति की और खान की आग का पता लगाने, सुरक्षा और नियंत्रण में सूचना प्रौद्योगिकी (आईटी) के भावी जरूरतों की संवीक्षा की गई है। सूचना प्रबंधन प्रणाली के विकास के लिए आधारभूत संरचना की जरूरत और प्रक्रिया का विवेचन किया गया है।

Introduction

Coal mining in India started dates back to 1774, when Sumenr & Heatly first discovered coal deposit Raniganj coalfield. Fire in coal mines are known to exist since inception of mining. Indian coal mines have a historical record of extensive fire activity for over 140 years back (Raniganj coalfield, 1865). The mine disasters in India revealed that fire and explosion contributed to about 41% of total fatalities. It presents a serious safety hazard to mine personnel as well as from economic point of view even a small incident of fire can take a heavy toll in terms of loss of production, machineries and fire fighting material, often requiring sealing a large section of mine or the entire mine. Besides, these mine fires also contribute to global problems such as loss of important coal reserve and environmental pollution etc. A tragic fire incident at New Kenda colliery of ECL (1994), where there 55 lives were lost, and demands were made for closure of the mine for more research on the assessment and control of mine fire.

The high risk associated with mine fire has brought about a number of innovations in the field of detection, prevention, control and combating the mine fires. The various laboratory methods and techniques dealing with mine fire are now well developed in monitoring, sealing, cavity filling, inertisation, ventilation and extraction. In the last few years, application of information technology has been developing rapidly and finding more successful applications in many parts of mining. It is largely been confined to those operations, which tend to build applications, which can aid decision-making, requiring empirical knowledge, subjective judgement, experience as well as certain information. The main problem, presently faced by mine management, is that how to acquire the in-real-time data; filter the relevant information from these data; take and, implement an appropriate decision within a desired period to optimise the mine productivity and safety. In the era of information technology, it is to consider transforming this knowledge into computer programmes, capable of analysing the mine fire problem and recommending control strategies to allow the safe extraction of coal.

Application of Information Technology for Mine Fire

From early 1970, many scholars have been working on the areas using digital computer to simulate underground fire.

Nordan *et al*, (1979) developed a one dimensional model including the complete differential for conservation

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of oxygen water, energy and for the reaction rate of oxygen with coal for mass transport both convection and diffusion where included for heat transport both convection and conduction. Although this model was the complete, the influence of moisture was not incorporated.

Stefanove *et al* (1984) formulated a computer programme (VENT-4) to solve the complex simulation of a mine ventilation network during a open fire. They have been used unsteady state conditions in the system to give the result from the following factors ie; temperature changes in the fire zone, gradual filling of ventilation network with combustion gases and it locate the heat transfer between these gases & the rock surfaces.

Deliac *et al* (1985) gave a module of PC fire, which works as an additional module of PC vent. It is based on the equations derived by Simode and Vielledent to calculate the effects of mine fire in a tunnel on the temperature, the mass flow and the pressure variation. In situations whereby evaporation can be neglected and the fans are not stopped, it has been found to converge in most cases the first results seems very permissive. The PC fire should be considered as a tool for training for prevention purposes rather than making decision when fighting against a fire.

Schmal (1987) developed TNO model, which was one dimensional convective and diffusive transport model including chemisorptions of oxygen to the coal, oxygen depletion in the pile, heat generation as a result of the chemisorptions, cooling and heating due to evaporation and condensation of water.

Husheng (1988) developed a computer programme for calculation of thermal pressure and solution of the ventilation network. He used the temperature distribution of smoke flow down casting the fire seat under fire circumstances.

Yihui *et al* (1988) formulated a mathematical model (UNIVAC-1100/10) on the characteristics difference method is used directly to solve fluid dynamic equations in the ventilation network during underground fire. The model works in the principles of diffusion dynamics, the distribution states of noxious gases in the mine have been analysed by the method of characteristics.

Dziurzynski *et al* (1988) derived a mathematical model to show the behaviour of the ventilation system caused by a fire make provisions for emergency plan. This model has been based upon the combustion of fuel in the airways, unsteady exchange of heat between the fire, airflow and surrounding rocks, i.e., the air flow in mine ventilation network and theory of heat flow in the rocks. The model facilitates a graphical presentation of the spread of the combustion products throughout network.

USBM developed MFIRE to calculate the flow rates for the airway with the fire source are used or input into the gravity current model (Greuer, 1977, 1987; Edward, 1981 and Chang *et al* (1990). Fire is modelled here as constant sources of heat with smoke and fumes being passive scalar contaminants. The model results for up-streams & down-streams heat flows and fume concentration gravity current breakdown are feed to MFIRE.

Chang *et al* (1990) simulated a computer simulation programme namely, MFIRE, which performs normal ventilation network planning calculation and dynamic transient state simulation of ventilation networks under a variety of conditions including fires.

John *et al* (1985) and Jones (1991) developed a 3-D finite volume code namely, FLOW-3D for simulating turbulent flow and heat transfer by the UK atomic energy authority. The model is based on non orthogonal body fitted grid which is arranged in a structured blocks allowing complex geometrical features to modelled and solves the governing equations for mass, momentum and energy conservation along with modelled turbulence equation.

Zhu *et al* (1991) formulated a mathematical model for air flows and self-heating to goaf is in its early stages.

Denby *et al* (1992) developed a knowledge based expert system namely EESH for the risk control of spontaneous combustion in underground coal mining. The system is capable of combining the certainty factors to provide a quantitative assessment of self-heating risk of coal in a specific mining situation. It is also able to identify the measure factors contributing the heating potential strategies against the possible risk are recommended using specialist knowledge based on the information integrated from the user and a relational database.

Lea (1994) developed a computational Fluid Dynamics (CFD) modelling to demonstrate potential for simulating the near fire low CFD techniques by the large number of grid cells necessary to describe the roadway geometry to simulating the phenomena closed to a fire.

Smith *et al* (1995) developed SPONCOM to aid in the assessment in the spontaneous combustion risk of an underground mining operation. A prior knowledge of the spontaneous combustion risk of coal and factors that increase risk can be useful in the planning and development of proactive monitoring ventilation and prevention plans for the mining operation. It determines the coal relative spontaneous combustion potential based on the coals proximate, ultimate analysis and heating value. Then it evaluates the impact and coal properties, geological & mining condition and mining practices on the spontaneous combustion risk of mining operation.

Saghafi *et al* (1995) derived a mathematical model of air, water and heat flow in a porous medium was developed and applied to an underground longwall goaf for predicting self heating behaviour of underground mines.

Panigrahi *et al* (1996) developed the software VENTSYS to combat heat and humidity problems in India. This software is very useful tool for ventilation network analysis and planning of underground environment.

Prakash *et al* (1996) has been used remote sensing

GIS techniques for estimating temperatures of ground surface above the subsurface coal fire.

Tripathi *et al* (1996) formulated an algorithm based on some recent fire indices, which provides some significant information relating to fire hazards within a coal mine including extent of a fire burning within a sealed environment.

Saghafi (1997) simulated a new mathematical model of spontaneous combustion applied to longwall mining. It simulates the process of heat generation and heat transport within a goaf. The heat is generated by low temperature oxidation of carbonaceous material as well as adsorption of water vapour solid material in the goaf. The model was applied to predict the temperature rise in longwall goaf where a particular ventilation layout was adopted to control both gaseous emission and spontaneous combustion hazards.

Roy *et al* (1997) formulated computer program CLIMA-S for prediction of transient climatic conditions in underground airway is developed using well-established psychometric and thermodynamic relations.

Zoltane *et al* (1999) developed a PC based information system namely, COALMAN in a framework of Dutch-Chinese project for one of the most important coal mining areas in Hu Ningxia Hui Autominous Region to integrate data and models in to management tool. It will be better tools for monitoring the fires, managing the fire fighting and to work out proper fire fighting and prevention plan.

Fierro *et al* (2001) modified the TNO one-dimensional model to predict the spontaneous heating of stock piled coals. The model is based on conservation of mass oxygen, heat flow and gives as result time and site profiles oxygen concentration in air, adsorbed oxygen concentration and calorific loss. It includes the influences of parameters such as free convection due to temperature rise of the pile and additional forced convection (wind speed direction). The model generally predicts very well, the order of magnitude of time and the site of spontaneous combustion. The model supports the calculation of calorific losses when the hot spots are developed. The co-efficient of heat losses also calculated.

Akgun *et al* (2001) developed a theoretical two-dimensional unsteady model to predict the existence of hot spots of a stockpiles. It is capable of predicting the realistic ignition times of the order of a month, at realistic pile heights of 2 or 3 m.

Shay *et al* (2002) developed a computer program EXPLO based on Ellicott's extensions of Coward's diagram for quick and accurate assessment of explosibility of air mixture build up in case of control of active fire. The advantage of this software is the first and reliable analysis of data and reduction in risk of misinterpretation of graphical information.

Need of Information Technology for Indian Mining Industry

In the era of information technology, the world is experiencing a major technological revolution, centered on information and communication techniques. Today business excellence, economy and safety are governed by accurate and efficient decision making. Under the present knowledge and technology explosion scenario, information technology is the strong arms to such an environment. It works on the principle i.e. a set of tools that can help providing the right people with the right information at right time. It enables expeditious and efficient data capturing, assimilating the same data, analyzing and decision making in fraction of seconds by networking keeping away time and distance. Hierarchy of information, from data to actions, is shown in Fig. 1.

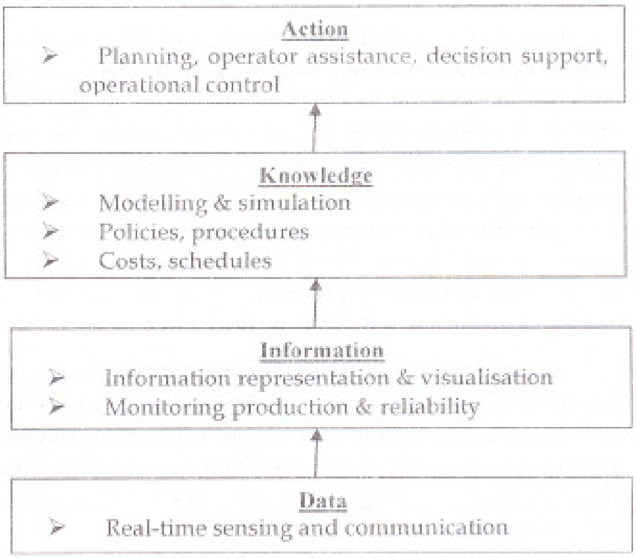

Fig. 1 : Hierarchy of information - from data to actions

More direct objectives are to maximise productivity, minimise unit cost of production (including maintenance), maintain safe and reliable operation, comply with safety and environmental standards, and ensure a long-term future by strategic planning. Timely and accurate information is critical to support planning and control functions.

Sometimes innovative technology to improve efficiencies and reduce costs is available to the industry. However, the infrastructure needed for integration of these technologies and handling the data have lagged the actual development of the technology. In the present era of computerisation, mining methodologies and processes are being modified through the introduction and use of new technologies. So the solution in the age of application of information technologies is to consider transferring this knowledge into computer programmes capable of analysing a mines spontaneous heating problem and recommending control strategies to allow the safe extraction of coal. A knowledge-based expert system is an important practical aspect of artificial intelligence (AI) can meet this demand.

The Indian mining industry will survive by innovating and optimising the operations with the help of the rapidly emerging technological opportunities and realise the economic benefit of improved efficiencies throughout the organisation. The development of virtual mine fire detection, prevention, control and combating technology will give a quantum jump for Indian mining industry to survive in this liberalised and competitive global economy. Considering the coal will remain prime source of energy for future generation, the concept of this technology and suitable R&D investment in this area may give more economical and safe extraction of coal, loss of natural resources and cut off global environmental pollution.

The most of Indian coal mines are very old, which was worked earlier unscientifically and there is no record of its. In the national level no researcher has tried to develop an expert system according to Indian scenario. The expert systems, which are developed earlier by different countries, are not suitable to our coal mines and still remains at an elementary level of design and further modification & refinement are required. In this system the status of fire in any working or abandoned coal mining area is not involved. This may useful for the mine during planning and design stages. These models are not considering the mines, which are now in productive phase or abandoned stage. With the above discussion the development of a new expert system in Indian scenario will provide an effective approach to the minimisation of spontaneous combustion incidents. This expert system will uses available information from the mine officials to make decision based on a series of rules provided by a programme, which will be interactive, user friendly and inexpensive method of conveying expert advice.

Need of Infrastructure

IT investments by mining companies have made often failed to provide the promised benefits due to haphazard way of investment. So careful planning, more methodical information of risks, quantification of risk and mitigation of those risk along the same lines that are applied to other investments in the mining industry would pay dividends for mining companies.

The basic use of an efficient IT system is to enable real time access to data from all mining and its coordinating & supporting processes. The data are integrated into a central data repository, to be assessed from anywhere in the organisation. Accuracy and timeliness of data are improved and full integration of mine management information system becomes possible.

The infrastructure needs of an efficient IT system of a mining organisation include:

- On-board machine monitoring, control and positioning systems.
- An open architecture object-oriented mine modeling and GIS (Geographical Information System).
    - An integrated database system that permits ready access by operations, maintenance or management groups using flexible, application-specific software.
    - A comprehensive mine planning system utilising the information and control capabilities of the mining system.
    - A bi-directional mobile communications system with adequate bandwidth (Peck et. al. & Zoltan, 2001).

Scope for Application of Information Technology on Mine Fire

The first step in implementing the next generation of mine planning and operational control systems is to specify overall information system architecture, one that is open, flexible, and scalable. The key should be to develop such a system, which allows interactions between applications to foster integration. System design should be both top-down and bottom-up.

Now-a-days some software are available in the market for different aspects of mine fire. Among which SPONCOM, COALMAN and TNO modified model is better as compared to other. SPONCOM software is very much useful for mine planning and design according to spontaneous combustion risk but for Indian context it needs some change in its structure, so that it will help for our mining industry. COALMAN will be better tools for monitoring the fires, managing the fire fighting and to work out proper fire fighting and prevention plan. TNO modified model is very suitable for determination of spontaneous combustion risk in coal stockpile. This model will not efficiently work in different climatic condition, so further modification is required in this field. In the present world there is no single software, which will be useful for different aspects of mine fire. So different modules of software are required for detection, prevention, control & combating aspects and integration of these modules of mine fire to make comprehensive package.

It is widely recognised that the internet is a world-wide network of computer networks using a family of agreed-upon technologies and protocols, an intricate and extensive web of communication that links millions of people across the world and should be viewed as the domain for 21st century. It is a tool that can be used to share and distribute information to anyone in the world at any time and at very little cost. This may be an enabling technology, providing a forum where people from industry integrating the external and distant expertise of this field can meet electronically to take decision about the different critical situations in remote mining locations and would solve the problems when industry people need. Mining industry requires skilled IT manpower to upgrade knowledge of correspondence courses, attending seminar & conference and discussing about different matters through E-mail communications, chat rooms or web conferencing. So an environment is required for mining industry people to use this technology in future. Intranets, with restricted access, reside behind company firewalls, supporting and enabling intra-company processes. Intranet can also displace the traditional practice of paper based information distribution, increasing the efficient use of emergency plan in case of mine fire. Extranets, secure hybrids of internet and intranet technologies with restricted access to the community membership, support and enable inter-company processes and extend the enterprises beyond its traditional boundaries.

Conclusion

The intent of this framework is to highlight the importance of application of information technology in mine fire and goal to drive the technology to implementation. The pace of technological revolution has been so rapid that there is no doubt that the adoption of new technology such as artificial intelligence, internet, intranet in today's mine monitoring and control system will dramatically help the elimination of underground fire hazards. With the above discussion the development of a new expert system will uses available information from the mine officials to make decision based on a series of rules provided by a programme, which will be interactive, user friendly and inexpensive method of conveying expert advice to the minimisation of spontaneous combustion incidents.

Expertise of mining and IT consultants may have to be taken in the process to meet the safety of mining industry to maximise the product output and minimise the unit overall cost of production and maintenance. So there are lot of challenges and opportunity ahead for researchers, software developers, software & hardware vendors and enterprises for detection, prevention, control and combating the mine fire.

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