Research on comprehensive early-warning technology of Coal and gas outburst

Zhao Xusheng¹,², Hu Qianting², Ning Xiaoliang², a*

¹. Shandong University of Science & Technology, Shandong Province, Qingdao 266510, China;
². National Key Laboratory of Gas Disaster Detecting, Preventing and Emergency Controlling, Chongqing, 400037, China

Abstract

The paper proposed the principle and approach of comprehensive early warning of coal and gas outburst. Objectively existing outburst risk of working face, defects of outburst prevention measures and management are the main source of danger of coal and gas outburst. Based on the opinion, the integrated index system of outburst early warning is established. According to relevant regulations, standards, and actual mine condition, the rule base models of comprehensive early warning of outburst were established, and the warning degree system is divided into two major categories: the state and the trend. Implementation method of the warning system was studied, and the software, hardware architecture and computer systems were built. The onsite trials and applications indicate that the comprehensive early warning system of coal and gas outburst can realize the intelligent advance warning of hazards, improve the mine management level of outburst prevention, and secure the mine production safety.

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1. Introduction

Predicting coal and gas outburst danger of mining face and grasping variety of potential risks in outburst prevention work, are the premise of effective outburst prevention. However, due to coal and gas...
outburst complexity, the diversity of factors, the limitations of conventional forecasting techniques, incomprehensive safety information, analysis is not deep enough, safety management deficiencies and other reasons; it is very difficult to put an end to outburst disasters. Using information technology to timely grasp comprehensive information on mine safety and to analyze it, from variety of dynamic monitoring information to extract the indexes of outburst danger for advance warning, becomes necessary. This is also the outburst prevention trends by integrating management and technology to improve the prevention effect.

2. Principle of outburst early-warning technology

2.1 Basic thought of outburst early-warning

Comprehensive warning of coal and gas outburst, means that, guided by the accident theory, coal and gas outburst prevention theory (particularly, outburst development law and prediction theory), using mine safety monitoring system, computer network system of mine, mine safety management organization and personnel system to develop the coal and gas outburst early-warning software system. Based on the collection, sharing and integrated intelligence analysis of the various basic information related to outburst in mine and static and dynamic safety information, realize the online monitoring, intelligent analysis, comprehensive evaluation and prediction of the outburst danger state and trends of working faces in coal mine, and then with different colors or risk levels, through the mine computer networks, SMS etc. send the appropriate warning and alarm information in advance in order to remind managers timely to take prevention measures, strengthen the prevention management, and eliminate outburst potential.

Early warning of coal and gas outburst is the recognitions of varieties of risk factors in prevention process of working face. The factors influence outburst include not only the outburst risk of working face, but also the effectiveness of measures taken, outburst prevention management deficiencies etc. (especially potential hazard in assessment of outburst risk and prevention measures). Outburst comprehensive early-warning, based on dynamic tracking and monitoring of various indexes, through comprehensive analysis, realize the integrated early-warning management functions including gas geology early-warning, mining superimposed stress early-warning, abnormal gas emission early-warning, early-warning of abnormal working face indexes, outburst prevention measures deficiency early-warning, and management potential risk early-warning.

Coal and gas outburst early-warning technology integrates occurrence of coal seam, gas geology, deployment of mining tunnel, monitoring, prediction of outburst, warning information, prevention measures, and outburst prevention and management etc as a whole, with outburst law in mine, realizes the integration of static and dynamic safety information, the integration of technology and management, the integration of artificialness and intelligence, the integration of regularity and specificity, and at last realizes the advancement and timeliness of early-warning. It supplies the reminding and warning of the safety states and trends of working faces.

2.2 Approach method

Coal and gas outburst early-warning technology, based on the outburst hazard characteristics and laws and other basic information, guaranteed by the standard and specific management system, built on the monitoring system and local network, the computer system as the carrier, is a comprehensive technical system. Its realization (Fig. 1) includes: the digitalization of mine, coal mine safety monitoring system, the establishment of dynamic database of safety information, the establishment of outburst early-warning information process model and early-warning rule database, the processing of safety information by outburst early-warning software to get the safety states and trends of working faces, sending of early-warning information through LAN, phone, SMS, etc.
3. Establishment of early-warning index system and model

3.1 Recognition of outburst danger sources and potential hazard

According to the danger source theory, the coal or rock with outburst danger, as the outburst energy carrier, is the dangerous substance, belonging to the first class of danger source. Taking various outburst prevention measures and management is approach to identify, eliminate, control and restraint the first class danger source. Technical and management measure deficiencies lead to release of outburst energy belong to the in the second class danger source. Any one of outburst accidents is the result of both class of danger sources. The identification of the first and second class danger source is the purpose of comprehensive coal and gas outburst early warning, and is the foundation of selection of warning index and model.

Based on the accident tree analysis with coal and gas outbursts, the impact of the outburst accident event is divided into three categories:

1. The basic events which reflect the coal and gas outburst danger of mining face, including:
   ① Outburst danger zone: the working face in the danger zone. ② Gas geological anomalies zone: the working face in the geological structure affected zone or the mutant region of coal occurrence and structures. ③ Mining activities affect zone: the working face in the stress concentration area caused by mining activities, or in a special extraction process (such as roadway to expose coal, dig up the tunneling, etc.). ④ The daily predictors abnormal: the daily outburst prediction (efficiency check) indicator excessive or continuous rise and close to the threshold in the loop or last loop. ⑤ Gas emission unusual or outburst signs: the gas emission of the working face abnormal, or when the nozzle drilling and hinder drilling phenomenon occurs, or with frequent coal guns etc.

2. The basic events belong to outburst prevention measures have serious deficiencies, including: regional outburst prevention measures to test the effect of non-compliance, the control range not far enough, not enough time to implement measures, measures to control the range of memory in the blank with, superb over-exploitation and so on. These are measures taken to prevent sudden outburst failed to eliminate the typical technical defects.

The basic events belong to outburst safety risks, including: outburst management of risk prediction instruments (not regularly calibrated and checked), the forecasting operation is not standardized, false projections, anti-conflict measures not in accordance with the design and construction, drilling false parameters, no measures to prevent sudden acceptance of links and so on.

3.2 Establishment of outburst early-warning index system
The three basic classes of events caused outburst are danger classes, and the warning sources and omens of outburst early-warning monitoring. Therefore, coal and gas outburst early-warning index system should reflect fully the objective risk of the outburst face, deficiencies in prevention measures, and management deficiencies. Based on the danger source theory of coal and gas outburst, early-warning index system framework shown in Fig. 2 was established in principle of purpose, science, system, advance and feasibility. At specific mine, the establishing need combine with the coal mine gas geology, tunnel deployment, mining methods, outburst law, prevention measures to select the appropriate indexes.

Fig. 2 Structure of coal and gas outburst comprehensive early-warning index system

2.3 Establishment of early-warning model

Referring to the warning degree representation of early-warning systems of various realms in the world, the warning degree of outburst early-warning system is established according to the early-warning classification and the outburst controlling requirement of specific coal mine. The warning degree of early-warning system is classified into 2 categories: status early-warning and trend early-warning. The degree of status early-warning is divided into 4 levels: normal (no alarm), threatened, dangerous and cataclysm. The degree of trend early-warning is divided into 3 levels: green, orange and red. The warning-responding regulations are made corresponding to different warning degrees.

In consideration of the complexity of coal and gas outburst, the warning-signal analysis model of coal and gas outburst is established. The indexes and regulations of this model is variable corresponding to different warning degrees, and a regulation library is established further; therefore, this model is convenient for warning-responding, can perform early-warning even under incomplete indexes condition, and is adapted to various categories of working face. The values of early-warning indexes reflect the status of production factors. In the process of outburst early-warning, the early-warning results of index values and regulations can be obtained by consulting the early-warning index system and the regulation library; then the upper level early-warning results can be obtained according to the key index and by the maximum danger principle; finally, the comprehensive early-warning results can be obtained by the maximum danger principle with regard to multi aspects (Fig. 3).
4. Establishment of the comprehensive early-warning system of coal and gas outburst

It is necessary to establish the software and hardware early-warning platform of coal and gas outburst, so that the safety signal from underground and various functional departments can be collected timely, and the comprehensive analysis and early-warning can be achieved, thus the early-warning results can be published timely, and the warning-responding and emergency treatment can be achieved further. This early-warning platform includes the monitoring system of coal mine safety, the LAN of coal mine, early-warning analysis server, the users of functional departments and coal mine managers, the publishing devices, the professional analysis software and the comprehensive analysis platform (Fig. 4).

Fig. 4 The comprehensive early-warning platform of coal and gas outburst

The early-warning software is of component design. It is composed of multi professional field subsystems. Each subsystem can run independently, thus the specific professional field function is accomplished. In order to achieve the comprehensive manage and early-warning, multi subsystem can also run cooperatively. The subsystems mainly include the comprehensive database of outburst early-warning, the management system of geological survey, the analysis system of gas geology dynamic, the management and analysis system of outburst controlling dynamic, the analysis system of gas emission dynamic, the management system of mining process, the safety supervising system, and the
comprehensive management platform of outburst early-warning. The real-time outburst danger and its development tendency of every working face can be queried via the LAN of coal mine, the rationale of early-warning result and the target-exceeding information can also be queries.

5. Experiment and application

This comprehensive early-warning system has been experimented successively in 2 places: Songzao, Chongqing, and Huaibei, Anhui. The result shows that safety information sharing and centralized management can be achieved by this system. Thus the application of this system can promote the informatization, standardization and refinement of outburst controlling. This system following characteristics: stable, quick responding, realistic early-warning regulations, well foreseeability and accuracy. Currently, this system has been applied in many coal fields including Songzao, Huaibei, Jincheng, Shuicheng, Tonghua, Lu’an, Jiaozuo, Hebi, etc. The experiment and application results show that this system has a preferable accuracy for outburst early-warning. Some examples show it released warning information before real outburst.

Some typical early-warning examples (Fig. 5) have been analyzed, the results show that this early-warning system can achieve the online monitoring, pre-reminding, real-time prediction and trend mastering. The status early-warning agrees roughly with the actual outburst danger of working face, and reflects the current outburst dangerous status. The tendency early-warning can release the development tendency of outburst danger in advance. The early-warning system provides timely and reliable decision information, makes the decision making of outburst controlling more targeted, help save production and guarantee coal mine safety.

![Fig. 5 The early-warning signal at the rail lane, 7# coal seam, northern No 3 panel of a coal mine](image)

6. Conclusions

(1) The comprehensive early-warning thought and technical approach is proposed. Based on centrally managing the coal mine safety information by information measures, the comprehensive early-warning of coal and gas outburst through the multiple index tracking and monitoring is the development trend of
outburst prevention and early-warning management in the future via taking into account the various factors that affects coal and gas outburst.

(2) The comprehensive early-warning index system including the management and technology in one is established according to the dangerous source theory. It includes three aspects: the objective outburst danger of working face, the defects of outburst control technique and the safety risk of outburst control management. The model of early-warning rule base is established according to practical rule, adjustable rule, easy response rule and so on. It is proved by the practice that the model conforms to the reality of mine outburst control management.

(3) The comprehensive early-warning network platform of coal and gas outburst is studied and established. The early-warning hardware system consists of local area network, coal mine safety system for monitoring, early-warning server, terminal computer and so on. The early-warning software system of unit-construction can run independent and combined. The professional analysis, comprehensive management and early-warning come true.

(4) It is indicated by field application that the sharing the outburst control information, monitoring the danger source online, reminding the risk advanced, analyzing the dangerous information intelligently and timely early-warning can be realized by the comprehensive early-warning system of coal and gas outburst. It is a way which can improve effectively the management level of mine outburst control and efficiency of departments to protect mine safety production further.

References