Research on the Intelligent Early Warning System for Metal Mine Mining Safety

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Abstract. In order to reduce mine safety accidents and realize safe production, the mine safety early warning system was developed by studying the causes of accidents, using Python as the development language, using Web network technology and database technology. The paper uses the deployment of high-precision sensors and the development of a distributed management information system to realize the real-time collection and online monitoring of the monitoring index data of the metal mine; based on the accurately obtained key indicators such as the deformation displacement, the reservoir water level, and the depth of the infiltration line, it is safe for the metal mine Multi-level early warning and forecasting of risk conditions are implemented. The actual operation of the system shows that the integrated management system can provide decision-making basis for regional safety management.

Key words. Metal mine, intelligence, early warning system, safe production, real-time monitoring.

1. Introduction

Mine monitoring is the prerequisite and basis for ensuring that the mine is operating in a normal state. In traditional methods, the monitoring of surface subsidence, the deformation of underground roadways and empty areas are mostly realized by conventional means such as roof settlement gauges, convergence gauges, extensometers, level gauges, and theodolites. The main problems are: the monitoring range is small and the amount of observation data is small; it is impossible or difficult to monitor damaged roadways and unmanned areas; the monitoring efficiency is low, the labour intensity is high, and the empty area collapse cannot be quantitatively observed. The mining operation of metal mines is an important part of the mining of the whole mine, and it is also the operating environment for frequent accidents such as object strikes, roof falling and blasting [1]. For this reason, the paper adopts an informatized, real-time, and networked online monitoring system for metal mines, which can timely and intuitively grasp the data of ore body deformation, reservoir water level, infiltration line, etc., and carry out safety evaluation, early warning and forecast, for the safety of metal mines Provide strong support for monitoring and management decision-making.
2. Online monitoring system setting plan

2.1. System design method
This system uses access as the database, and stores some basic safety information such as personnel, environment, and equipment needed in safety evaluation or prediction, as well as the results of each safety evaluation and the reasons for hidden safety hazards. Comprehensively consider the mechanism of accidents in the mining operations of metal mines, as far as possible for daily safety management, refer to the actual situation of the mine and the corresponding safety regulations, and use safety evaluation methods such as accident trees and event trees to evaluate major hazards such as blasting and roof fall, analysis. The accident occurrence rules obtained from the analysis are programmed with VB high-level language, and the three safety states of the system, including danger, warning and safety, are represented by red, yellow and green flashing colours. For early warning or dangerous conditions, safety managers can click on the relevant button to inquire about the corresponding safety warning reasons or management measures. The specific process is shown in Figure 1.

![System design flow chart](image)

**Figure 1. System design flow chart**

2.2. System structure
The system is divided into early warning of human behaviour, early warning of the state of objects, and safety management programs. Human behaviour early warning is a judgment on the safety of employees. The early warning of the state of objects includes equipment evaluation and rock mass quality classification [2]. The safety management plan helps to achieve scientific management. The system function structure is shown in Figure 2.
2.3. Permission settings
The design of the system takes into account the two ways of ordinary user login and super user login: ordinary users can only enter data and query and save the pre-set interface content, and super users implement all functions as an administrator to perform system maintenance and Database management.

2.4. Functional design

2.4.1. Early warning of employee safety. The risk awareness and operational proficiency of employees are the prerequisites for accident prevention. The early warning of employee safety is divided into basic information management module, safety training management module and working environment monitoring module, which are the core of personnel evaluation. Basic information management includes educational background, type of work, marital status, past medical history and vision, hearing, vital capacity, biological rhythm, etc.; safety training management includes training type, training level, training hours, training content and training results; working environment monitoring includes continuous working hours, Noice, illumination, catarrh and air freshness at the work site. Enter the index factor data through the web page and click on the information query to call the respective module calculations. The calculation result of the basic information management module indicates the safety score of the employee, which is the most direct evaluation of the employee's safety degree; the calculation result of the safety training management module indicates the training performance of the employee, which indirectly reflects the safety degree of the employee; the calculation result of the work environment monitoring module indicates the employee Adaptability to the on-site environment [3].

2.4.2. Early warning of equipment status. Early warning of equipment status is the most important part of accident prevention, including ventilation system module, drainage system module, shaft hoisting system module, mining system module and mining operation system module. The evaluation parameters of the ventilation system module include the air volume of the main fan, the total air demand, the total effective air volume, and the number of wind speed qualified points; the evaluation parameters of the drainage system module include the waterproof door, the pump speed, the current size, the temperature condition, the pump lift and the pump flow, etc.; the shaft lift The evaluation parameters of the system module include wire rope inspection time, lubrication time, decoupling test time, safety dress level, emergency training, etc.; mining system module evaluation parameters include roof inspection, blind residual artillery treatment, pneumatic drill construction, ignition operation, and vertical slot treatment , Spraying operations, belt conveyor cutting, etc.; mining operation system
modules, evaluation parameters include roadway type, suspended roof treatment, wall pushing treatment, bayonet treatment, roof treatment and hazard signs.

2.4.3. This system adopts Q system. The rock is classified with the RMR system, by giving semantic qualitative indicators, and then converting the semantic indicators into data-based frequency indicators, and the obtained data is substituted into the calculation formula, the evaluation score of the rock can be obtained, and the corresponding evaluation and evaluation can be provided. Approach [4].

The evaluation indicators included in the Q system are rock quality index RQD, joint group number $J_n$, joint surface roughness $J_r$, joint surface alteration degree $J_a$, fracture water reduction coefficient $J_w$, and in-situ stress reduction coefficient SRF. The evaluation indicators included in the RMR system are uniaxial compressive strength, rock quality indicators, fracture spacing, fracture conditions, and groundwater conditions.

3. Design and calculation of early warning indicators

3.1. The influence of rock mass

The quality of the rock mass in the stope is one of the key factors affecting the stability of the stope. The geomechanically classification method is adopted to investigate the influence factors such as the uniaxial compressive strength of the rock, the rock quality index, the joint spacing, the joint condition and the groundwater state. Analyse, calculate its rock mass quality evaluation index, and then use the following formula to express the influence of rock mass quality on stope stability.

$$R_r = 1 - RQ$$

In the formula, RQ is the rock mass quality coefficient, and is defined as $RQ = \text{RMR}/100$; $R_r$ is the influence degree of rock mass quality.

3.2. The influence of the exposed surface of the stope

The finite element program is used to simulate and calculate the stress state and distribution law of the stope rock mass after excavation. According to the rock mass instability principle, the stress in the surrounding rock of the stope exceeds its limit value, and the instability phenomenon may occur, so its safety factor $F$ can be calculated by the following formula:

$$F = \begin{cases} \frac{\sigma_s}{\sigma_1} & (a) \\ \frac{\sigma_t}{\sigma_1} & (b) \end{cases}$$

In the formula, (a) is when the maximum principal stress is compressive stress; (b) is when the maximum principal stress is tensile stress; $\sigma_s$ is the compressive stress of the rock mass; $\sigma_t$ is the tensile stress of the rock mass; $\sigma_1$ is the tensile strength of the rock mass. For research needs, it is now stipulated that when the stope is in the critical failure state ($F_r = 1$), the influence degree of the stope exposed surface is 0.99; while in the dangerous state ($F_r < 1$), the influence degree of the stope exposed surface is 1. Therefore, the influence of stope exposure on stope stability can be expressed as follows:

$$S_r = \begin{cases} 1/F_r & F_r > 1 \\ 0.99 & F_r = 1 \\ 1 & F_r < 1 \end{cases}$$
3.3. Impact of blasting impact
In the process of mining and excavation, it is always accompanied by frequent blasting activities. Its instantaneous huge explosive force and impact force often cause the rock mass of the stope to rupture, or make the original fissures further expand, and greatly reduce the rock mass of the stope. Quality, weaken the stability of the stope, and even cause a large-scale fall in the stope. According to the blasting vibration test and sound wave detection observations, blasting activities are one of the key factors affecting the stability of the stope during the mining and excavation process [5]. Blasting effect Mainly manifested as damage to the quality of the rock mass. Using the calculation method of damage variables in damage mechanics, the following formula is used to calculate the degree of damage to the surrounding rock of the stope by blasting impact:

\[ B_r = 1 - \left( \frac{V_n}{V_0} \right)^2 \]  

In the formula, \( B_r \) is the quality damage variable of the blasting rock mass; \( V_n \) is the longitudinal sonic wave velocity in the stope rock mass during the mining process, m/s; \( V_0 \) is the sonic longitudinal wave velocity in the stope rock mass before mining, m/s. Blasting damage The variable \( B_r \) reflects the degree of influence of the blasting shock on the stability of the stope, so it can also be called the blasting shock influence index.

3.4. Stope stability evaluation and disaster warning
In order to comprehensively evaluate the influence of various factors, the comprehensive index method is used to construct the stope stability function, as shown below:

\[ D_i = \frac{\sum_{i=1}^{n} N_i U_i}{\sum_{i=1}^{n} N_i} \]  

In the formula, \( D_i \) is the comprehensive influence index of each factor; \( U_i \) is the influence degree of each factor; \( N_i \) is the weight of each influence factor. \( D_i \) represents the comprehensive influence degree of each factor on the stope. The larger the value, the more dangerous the stope is. The lower the degree of stability. And vice versa.

4. System Test
For the same mine, the geological conditions are basically the same, so the critical value of acoustic emission calculated from one stope can be used to predict another stope [6]. Assume that the number of acoustic emission events in the No. 1 stope of a mine is shown in Table 1, where the monitoring interval is 24h. And a roof fall occurred on the 7th day. Then the critical value \( R \) when roof fall occurs can be obtained from the data in Table 1. Through this critical value and the number of acoustic emission events in Stope 2 (see Table 2), the roof fall of Stope 2 can be predicted. The interface of the final information input, safety control and prediction result are shown in Figure 3.
Table 1. Number of Acoustic Emission Events Actually Monitored in Stope No. 1

| Serial number | time | Monitoring value | Serial number | time | Monitoring value |
|---------------|------|------------------|---------------|------|------------------|
| 1             | 12.2 | 1.33             | 5             | 12.6 | 9.35             |
| 2             | 12.3 | 3.65             | 6             | 12.7 |                  |
| 3             | 12.4 | 5.44             | 7             | 12.8 |                  |
| 4             | 12.5 | 8.22             |               |      |                  |

Table 2. Number of acoustic emission events actually monitored in Stope No. 2

| Serial number | time   | Monitoring value | Serial number | time   | Monitoring value |
|---------------|--------|------------------|---------------|--------|------------------|
| 1             | 12.1   | 1.63             | 5             | 12.14  | 9.46             |
| 2             | 12.11  | 2.98             | 6             | 12.15  |                  |
| 3             | 12.12  | 3.92             | 7             | 12.16  |                  |
| 4             | 12.13  | 5.62             |               |        |                  |

From the final safety evaluation and prediction results, it is not difficult to see that it is safe in terms of safety control, and the critical value of the acoustic emission event rate that occurred in stope 1 is 8.33266; based on this value, stope 2 is predicted, and it can be seen that the 8th day the incident rate of acoustic emission was 8.332660. From this, it can be inferred that there will be a roof fall accident in the No. 2 stope on December 17.

5. Conclusion

Arrange automatic monitoring instruments, power supply and communication facilities on metal mine reservoir areas and flood discharge structures, and realize automatic online monitoring, analysis and early warning of metal mine safety based on technologies and methods such as sensor automatic measurement, distributed networking and system development. A relatively complete metal mine risk management mechanism has been established to effectively guarantee the safety of the metal mine.
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