Research on Safety Management of Ventilation System Based on Regional Evaluation System

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Abstract. Large metal mines have many features of returning to the wind shaft and multi-level mining. The ventilation system is complex, and the ventilation conditions and external environment of each area are different. The general mine ventilation evaluation is for the entire mine system. It is not possible to accurately and specifically make specific evaluations and management recommendations for each part of the ventilation system. Taking the safety management research of the ventilation system of Huibaoling Iron Mine as an example, a regional evaluation method is proposed. An evaluation index system was established and evaluated for four different levels of regional ventilation systems in Huibaoling Iron Mine. The overall scores of each region and the scores of each indicator were used to provide a basis for specific safety management work. Field practice shows that regional ventilation management can solve ventilation management problems efficiently and in a targeted manner, and has good promotion and utilization value.

1. Introduction

The metal mine ventilation system is a complex, non-linear, dynamic system that changes with the development of production [1-3]. It is the basis for ensuring the safe production of mines and is also a field of frequent accidents. In the study of safety management in the field of mine ventilation systems in the field, the former Soviet Union has studied earlier in this area. The methods for assessing the reliability of mine ventilation systems are mainly structural methods, simulation model methods and statistical evaluation methods [4-6], but they are now safely managed. The evaluation method is for the entire mine ventilation system, and it is not possible to propose management recommendations in a targeted manner. Regional management is a management system model in which management entities divide and re-manage work requirements according to their own needs, and can achieve specific analysis of specific problems, which is conducive to management and development. Combined with the Huibaoling metal mine ventilation system project example, the ventilation area is divided into four parts for management.

2. Establishment of regional ventilation management evaluation index system

According to the 12 evaluation indicators in the indicator system, the four regional mine ventilation systems of Huibaoling Iron Mine were evaluated. The ventilation system index hierarchy structure is shown in Fig.1.
3. Ventilation Zone Division of Huibaoling Iron Mine

Huibaoling Iron Mine is located about 20km west of Cangshan County, Linyi City, Shandong Province, and 20km west of Zhaozhuang City. The administrative division is under the jurisdiction of Shangyan Town, Cangshan County. The geographical coordinates are: 117°49'30"~117°51'00" east longitude; 34°50'45"~34°50'45" north latitude. The area is about 4.23 km² and the design and production scale is 3 million t/a.

In order to solve the problem of ventilation management of complex system and realize the pertinence and high efficiency of safety management of ventilation system, the ventilation system of Baoling Iron Mine is divided into four areas according to vein condition and current mining technology (Fig.2). From the figure, we can see that the shallow resources are gradually decreasing, the production area is mainly concentrated to the west of -430 m level, the east of -430 m level is mainly exploited at present, and the deep -601 m level is mainly ore slipping and lifting system. The four wind regions are independent of each other, and are greatly affected by the large ventilation system. Specific criteria are as follows:

(1) Area 1: -60 m to -130m horizontal shallow area ventilation system;
(2) Area 2: Ventilation systems in main production areas west of main and auxiliary horizontal wells from -340 m to -430 m;

![Figure 2. Mine ventilation evaluation system area division.](image)
(3) Area 3: -340 m to -430 m horizontal main and auxiliary wells to the east to develop regional ventilation system;
(4) Area 4: Wind area of ore slipping and lifting system in deep -601 m level.

4. Establishment of Regional Fuzzy-Hierarchical Evaluation Model

According to the evaluation index system of mine ventilation system, the regional fuzzy-hierarchical comprehensive evaluation matrix is established, and the principle of fuzzy mathematics is used to evaluate things comprehensively from multi-level and multi-objective aspects. In order to accurately grasp the status of ventilation system in each region and serve ventilation management, this paper uses the analytic hierarchy process (AHP) to calculate the weight of the evaluation index.

4.1. Constructing Judgment Matrix

Analytic Hierarchy Process (AHP) obtains the relative importance between two factors of the same level in the same subsystem of hierarchical evaluation model by comparing and analyzing the importance between two factors of the same level in the same subsystem, and establishes a series of comparative judgment matrices. The principle of judgment matrices is 1-9 scale method, and the range of values is 1-9 (or 1-1/9). [7-8], according to experts’ judgments on the importance of each index, determine the weight of each index.

(1) Target layer

| Target level indicator weight | Area 1 | Area 2 | Area 3 | Area 4 |
|------------------------------|--------|--------|--------|--------|
| Regional ventilation network security A1 | 0.164  | 0.648  | 0.230  | 0.103  |
| Regional ventilation power and facilities A2 | 0.539  | 0.230  | 0.648  | 0.216  |
| Regional ventilation safety and supervision A3 | 0.297  | 0.122  | 0.122  | 0.681  |

(2) Criteria layer

| Criteria layer indicator weight | Area 1 | Area 2 | Area 3 | Area 4 |
|--------------------------------|--------|--------|--------|--------|
| Regional ventilation air supply and demand ratio B1 | 0.275  | 0.063  | 0.161  | 0.412  |
| Large system impact on regional ventilation B2 | 0.048  | 0.274  | 0.262  | 0.169  |
| Ventilation network complexity B3 | 0.100  | 0.108  | 0.099  | 0.072  |
| Regional ventilation air volume and wind resistance size B4 | 0.138  | 0.375  | 0.416  | 0.236  |
| Network tempering and dynamic change capability B5 | 0.439  | 0.180  | 0.062  | 0.111  |
| Multi-fan area ventilation stability energy B6 | 0.272  | 0.553  | 0.165  | 0.466  |
| Natural wind pressure on regional ventilation B7 | 0.482  | 0.062  | 0.558  | 0.096  |
| Regional ventilation air leakage rate B8 | 0.088  | 0.176  | 0.159  | 0.161  |
| Ventilation facilities in good condition B9 | 0.158  | 0.209  | 0.118  | 0.277  |
| Regional ventilation stability and disaster resistance B10 | 0.082  | 0.074  | 0.106  | 0.100  |
| Mine dust and smoke hazard B11 | 0.575  | 0.283  | 0.260  | 0.187  |
| Daily ventilation supervision and system implementation B12 | 0.343  | 0.643  | 0.633  | 0.713  |

4.2. Determination of Evaluation Level

According to the actual situation of ventilation in Huibaoling Iron Mine, five experts who are familiar with the ventilation condition of iron ore are selected to assign the ventilation status of each region, and the index parameters and grades of each region are calculated respectively, and finally the ventilation status of each region is judged. According to the actual safety situation of the ventilation system, the regional ventilation is evaluated by the evaluation system established above. The evaluation system is shown in Table 3.
Table 3. Regional ventilation evaluation index scores and grades.

| Area   | Target layer                                      | Score | total | %  | grade |
|--------|--------------------------------------------------|-------|-------|----|-------|
| Area 1 | Regional ventilation environment parameter A1     | 3.8   | 12.7  | 76 | medium|
|        | Ventilation power and facility reliability A2     | 4.4   |       | 88 | good  |
|        | Regional ventilation safety management A3         | 4.5   |       | 89 | good  |
| Area 2 | Regional ventilation environment parameter A1     | 3.7   | 11.6  | 74 | medium|
|        | Ventilation power and facilities are reliable A2  | 3.5   |       | 70 | medium|
|        | Regional ventilation safety management A3         | 4.4   |       | 88 | good  |
| Area 3 | Regional ventilation environment parameter A1     | 4.6   | 12.6  | 92 | excellent|
|        | Ventilation power and facility reliability A2     | 4.0   |       | 80 | good  |
|        | Regional ventilation safety management A3         | 4.0   |       | 80 | good  |
| Area 4 | Regional ventilation environment parameter A1     | 4.1   | 11.1  | 82 | good  |
|        | Ventilation power and facility reliability A2     | 3.9   |       | 78 | medium|
|        | Regional ventilation safety management A3         | 3.1   |       | 62 | Pass  |

As can be seen from Table 3, the comprehensive indexes of area 1 and 3 are 12.7 and 12.6 respectively, which indicate that the comprehensive evaluation scores of ventilation management in these two regions are close and the best; but for these two regions, the better parameter of area 1 index is A3, which indicates that the ventilation safety and ventilation safety supervision effect in this region are good. However, the complexity of ventilation network in area one is inferior to that in area three. The regional four general evaluation index is the lowest, among which the safety and supervision A3 evaluation value is the worst because of the complexity of the regional ventilation network and the location of the regional level in the deepest part of the mine. The management should be strengthened in the regional ventilation management, such as the establishment of a complete ventilation organization, the determination of effective ventilation rules and regulations, etc.

5. Suggestions on Ventilation Management of Huibaoling Iron Mine

Through the above evaluation results of regional ventilation management in Huibaoling Iron Mine, it can be seen that the comprehensive ventilation system in Huibaoling Iron Mine is mainly good and medium, which meets the requirements of mine production, but there are great differences in different evaluation indicators in different regions, so the emphasis of regional management will be different.

1) Area 1: The area has shallow burial depth, easy ventilation safety and supervision, short inlet and return air routes, abundant air supply, but relatively more places to use wind, and higher overall management level.

2) Area 2: This area is the main stope and Air-using place, with long air supply route, large air demand and serious air leakage. We should pay attention to strengthening ventilation management while increasing air allocation. The ventilation resistance of roadways and stopes or local ventilators can be properly utilized in the remote areas where the air is used to distribute and adjust the air volume in the section, and the ventilation network in the middle section can be formed [9-11].

3) Area 3: This area is an open-up area with simple ventilation network and small air demand, but with large depth, safety supervision should be strengthened appropriately.

4) Area 4: This area is mainly responsible for the transportation and upgrading of ore, with long air supply routes and relatively complex ventilation network. The regional level is located in the deepest part of the mine, with a large number of fans and sewage discharged from the main shaft. This requires that management be strengthened by regulating facilities, dust removal facilities and safety supervision.

Aiming at the problems of ventilation technology management in Huibaoling Iron Mine, the regional evaluation system of ventilation system proposed in this paper can adopt different management measures for different regions according to the evaluation results, which is convenient and effective for the management of complex ventilation system, and can greatly improve work efficiency.
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