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Analysis of Influencing Factors of Gas Concentration in Fully Mechanized Coal Face Based on GPA

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Abstract. There are many factors that affect the gas concentration in the fully mechanized coal mining face, and only by making clear the internal relations among various factors can we better predict the underground safety production situation. In view of the characteristics that GRA can be used for statistical analysis between multiple dependent variables and multiple independent variables, based on the basic principle of gray correlation analysis, a group sequence gray correlation analysis method suitable for the statistical analysis of gas concentration in fully mechanized coal mining faces is established. First, analyze and select the influencing factors of the gas concentration in the fully mechanized mining face, and then use the gray correlation analysis method to verify the influencing factors. Finally, select the gas concentration in the inlet air flow, the gas concentration in the upper corner, the gas concentration in the return air flow, the gas emission, the wind speed, the coal cutting speed of the shearer, and the atmospheric pressure to form the gas concentration influencing factor system.

1 Introduction

In real life, many influencing factors depend on or restrict each other. The relationship between some variables can be expressed by function expression, while the relationship between some variables cannot be expressed by function expression. The influencing factors of gas concentration are one of them. Some of them have strong effects on gas concentration, while others have weak effects on gas concentration.

In previous studies, correlation and regression methods were often used for multivariate statistical analysis. In the process of multiple regressions, the sample size should be large enough, and the typical distribution should be presented. The calculation is heavy and the process is complex. And because regression analysis is mainly the operation of data power, sum, product sum, etc., errors in the calculation process can lead to serious errors, distorting the essential relationship between factors1.

With the continuous development of research, many studies have adopted dynamic means in recent years. For the dynamic relationship between factors, the classical method is to use its centralized trend, namely, the mean $(\overline{X})$ for analysis. In the predetermined

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observation stage, the error of indicators with small variability is still small, but for indicators with large fluctuations and variability, it is obvious that there will be a large error to take $(\overline{X})$. And $(\overline{X})$ can only reflect the centralized trend, ignoring the dynamic instantaneous relationship, losing a lot of information and dynamic meaning. REN2 investigated the causality relationships between CO_2 emissions intensity and its influencing factors in China during the period 1980 - 2010. Chen3 used polynomial logit model to analyze and found that 174 countries had different characteristics in the causal relationship between GDP and energy consumption. Zhao4 thinks that if it is a general analysis of the evaluation object, principal component analysis is more appropriate; If the measurability analysis of the evaluation object is conducted, the gray correlation method is more reasonable.

Grey relational analysis (GPA) is a multi-factor statistical analysis method in statistics. Specifically, in a system containing multiple factors, in order to study the relationship between one of the factors and other influencing factors, the gray correlation degree can be used to calculate the correlation degree of all influencing factors and target factors. If the correlation degree is high, it proves that the target factors and their influencing factors have a large correlation, that is, the relative relationship is strong. If the correlation degree is low, it proves that the target factors and their influencing factors have a small correlation, that is, the relative relationship is weak. This paper uses this method to analyze and determine the degree of influence between each influencing factor and the target factor, taking the gas concentration of the working face as the parent sequence and other influencing factors as the sub sequence, and finally ranking all influencing factors to obtain the degree of correlation.

Therefore, in order to accurately verify the influencing factors of gas concentration selected above, the grey correlation degree method is used to verify the influencing factors of gas concentration, and the influencing factors are sorted according to the correlation degree. On the one hand, it can reduce the impact of low accuracy of the prediction model caused by too many input factors, and on the other hand, it can improve the training speed of the prediction model in the training process [73].

2 Selection of influencing factors of gas concentration

As the main place of coal mine production, the change of gas concentration in the fully mechanized working face will seriously affect the safe production of the coal mine. Once the gas exceeds the limit, the consequences will be unimaginable. Therefore, effective prevention of gas concentration exceeding the limit is of great significance to the prevention and control of mine gas disasters.

There are many factors affecting the gas concentration in the fully mechanized mining face, including the geological conditions of the coal seam, the gas concentration of the air flow, the gas emission factors, the production factors, the drainage flow factors and other factors. Obviously, there is a complex nonlinear relationship between the above factors. It is one-sided to only study the influence of a single factor on gas concentration. Multiple factors affecting gas concentration should be considered comprehensively to predict the gas concentration of multiple factors.

The "U" type ventilation system is usually used in the coal mining face. With the continuous increase of the mining volume, the gas emission is increasing, which is easy to cause gas accumulation in the upper corner.

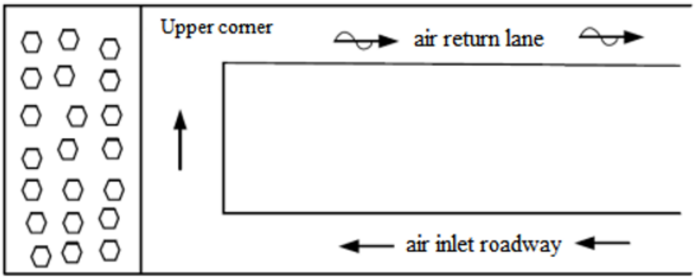

Fig. 1. Air flow direction diagram of U-type ventilation system

It can be seen from the above figure that the gas concentration in the fully mechanized mining face is closely related to the gas concentration in the inlet air flow, the gas concentration in the upper corner and the gas concentration in the return air flow. In addition, the gas concentration in the fully mechanized mining face is also affected by the following factors:

2.1 Gas emission

The amount of gas emission is one of the main factors that directly affect the change of gas concentration in the working face. During the mining process, the coal wall and scattered coal blocks will release a large amount of gas due to pressure and flow to the working face. The amount of gas emission is closely related to the gas content in the coal seam. If the gas content in the coal seam is high, the gas emission is large; otherwise, the gas emission is small.

2.2 Wind speed

The wind speed of the working face will directly affect the change of gas concentration. According to the coal mine regulations, the wind speed is within 0.25~4.0m/s. If the wind speed is too high, it will cause the mine dust to fly, which is easy to cause the coal dust explosion; When the wind speed is too low, the air flow is slow, which is easy to form gas accumulation, thus causing gas explosion.

2.3 Cutting speed of shearer

The cutting speed of the shearer will affect the change of gas concentration in the fully mechanized face. Within the limit cutting speed of the shearer, the gas concentration will gradually increase with the increase of the cutting speed. Therefore, effective control of the cutting speed of the shearer during the production of the shearer can control the gas concentration in the working face.

2.4 Atmospheric pressure

The change of atmospheric pressure will also lead to the change of gas concentration in the working face. During the alternation of spring, summer, autumn and winter, the atmospheric pressure will change, which will lead to the change of the pressure difference inside and outside the goaf, thus causing the abnormal gas emission, and increasing the gas concentration of the return air flow in the working face.

To sum up, the main factors affecting the gas concentration of the fully mechanized mining face are the gas concentration of the inlet air flow, the gas concentration of the upper corner, the gas concentration of the return air flow, the gas emission, the wind speed, the coal cutting speed of the shearer and the atmospheric pressure.

3 Verification of factors affecting gas concentration

The calculation formula of grey correlation method is as follows:

3.1 Define data columns

If the reference sequence is x_0, then $x_0(1)$ represents the value at the first time, $x_0(2)$ represents the value at the second time, and $x_0(\mathrm{k})$.

Then it represents the value at time k. Therefore, the reference sequence $x_0$is denoted as $x_0 = \big((x_0(1), (x_0(2), \dots (x_0(n)\big)$, similarly, the reference sequence can be expressed as $x_1 = \big((x_1(1), (x_1(2), \dots (x_1(n)\big), x_k = \big((x_k(1), (x_k(2), \dots (x_k(n)\big)$.

3.2 Correlation coefficient expression

For reference sequence x_0, other sequences are represented as $x_{0,} x_1, \dots, x_n$, and Eq. (1) is used to represent the difference between each comparison curve and reference curve at each point.

$$\xi_i(k) = \frac{\min_i(\Delta_i(\min)) + \xi \max_i(\Delta_i(\max))}{|\,|x_0(k) - x_i(k)| + \xi \max_i(\Delta_i(\max)) |} \tag{1}$$

In the formula, $\xi_i(k)$ represents the difference between the reference curve x_0 and the comparison curve x_i at time *k*, and it is called the correlation coefficient of x_i to x_0 at time *k*. Where ξ is the resolution coefficient, 1> ξ >0, ξ is taken according to different background requirements, in this paper, ξ is taken as 0.5.

$$\min_i(\Delta_i(\min)) = \min_i(\min_k |x_0(k) - x_k(k)|) \tag{2}$$

$$\max_i(\Delta_i(\max)) = \max_i(\max_k |x_0(k) - x_k(k)|) \tag{3}$$

3.3 Calculate the grey correlation degree

The multivariate single series statistical analysis formula is as follows:

$$\gamma_i = \frac{1}{\mathrm{N}} \sum_{k=1}^{N} \xi_i(k) \tag{4}$$

When analyzing the influencing factors of gas concentration in the fully mechanized mining face, the gas concentration in the working face is set as the parameter sequence x_0, and other influencing factors are taken as the comparison sequence x_i, which are respectively the gas concentration in the air inlet flow x_1, the gas concentration in the upper corner x_2, the gas concentration in the return air flow x_3, the gas emission x_4, the wind speed in the working face x_5, the coal cutting speed of the shearer x_6, and the atmospheric pressure x_7. Standardize the above influencing factors to unify the units between different dimensions, and substitute the processed data into the above formula to obtain the correlation degree between various influencing factors and gas concentration in the working face. Some original data sets are shown in Table 1, and the correlation degree of various factors of gas concentration is shown in Table 2.

Table 1. Original data statistics of gas concentration and influencing factors in fully mechanized mining face

No.	Gas concentration of working face %	Gas concentration of air inlet %	Gas concentration at upper corner %	Gas concentration of return air flow %	Gas emission /($m^3 \cdot min^{-1}$)	Wind speed of working face/($m \cdot s^{-1}$)	Mining speed($m \cdot min^{-1}$)	Atmospheric pressure /kpa
1	0.61	0.56	0.71	0.62	0.67	1.02	6.5	101.24
2	0.67	0.57	0.70	0.60	0.65	1.00	6.7	101.23
3	0.62	0.55	0.69	0.56	0.79	1.02	6.5	101.25
4	0.60	0.56	0.70	0.55	0.85	1.08	6.4	101.23
5	0.67	0.47	0.68	0.57	0.89	0.98	6.7	101.21
6	0.65	0.54	0.67	0.58	0.91	1.01	6.6	101.19
7	0.61	0.49	0.64	0.55	0.86	1.02	6.5	101.21
8	0.59	0.52	0.68	0.64	0.92	1.11	6.3	101.20
9	0.59	0.55	0.65	0.68	1.06	1.12	6.3	101.18
10	0.58	0.57	0.62	0.63	1.13	1.09	6.1	101.16
…	…	…	…	…	…	…	…	…
2000	0.68	0.59	0.65	0.57	0.84	0.95	6.6	101.18

Table 2. Correlation between gas concentration and influencing factors

Influence factor	Relevancy
Gas concentration of air inlet	0.7665
Gas concentration of return air flow	0.7862
Gas emission	0.8661
Atmospheric pressure	0.7169
Gas concentration at upper corner	0.8103
Mining speed	0.8207
Wind speed of working face	0.8542

3.4 Sort by the grey correlation degree

According to Table 2, the correlation degree between all factors affecting gas concentration and gas concentration in the working face is above 0.7, which indicates that the selected influencing factors have a strong correlation with gas concentration in the working face, which proves that the seven factors selected in this paper are correct, And ranking the influencing factors according to the degree of correlation, it can be concluded that: gas emission > face wind speed > coal cutting speed of shearer > gas concentration in upper corner > gas concentration in return air flow > gas concentration in inlet air flow >

atmospheric pressure.

4 Conclusion

Gas disaster is a major safety problem in coal mine field. With the continuous improvement of the intelligent level of coal mine, the gas concentration prediction and early warning technology plays a vital role in the prevention and control of coal mine disasters. Making full use of a large number of gas data in coal mines to predict and early warn gas concentration can effectively improve the early warning ability of gas disasters. Therefore, accurate and reliable gas concentration prediction and early warning is of great significance to coal mine safety production.

In view of a large number of coal mine data, various factors affecting gas concentration are analyzed by using data mining technology, and the impact of geological factors and environmental factors on gas disasters in the production process is analyzed, the influencing factors system of gas concentration is composed of gas concentration in the inlet air flow, gas concentration in the upper corner, gas concentration in the return air flow, gas emission, wind speed, coal cutting speed of the shearer and atmospheric pressure. The composition of influencing factors of gas concentration is shown in Fig 2.

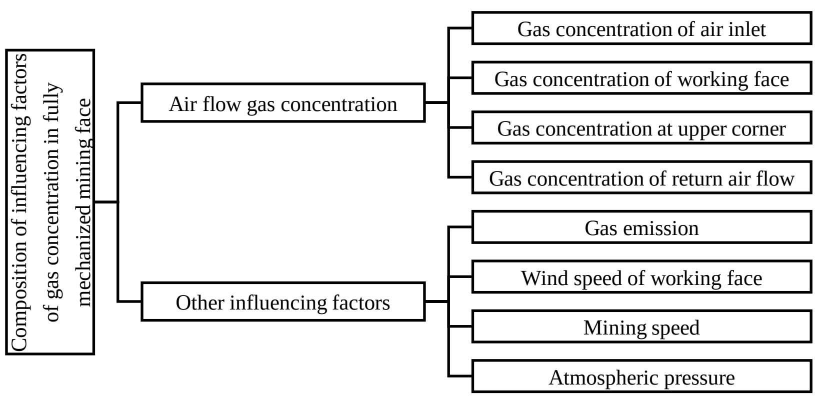

Fig. 2. Influencing factors of gas concentration in fully mechanized mining face

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