Permeability Coefficient Optimization Research Based on Structure Fractal

Xu Hui1,2, Mu Yi1,2, Qiu Hao1,2

1Mine Safety Technology Branch of China Coal Research Institute, Beijing,100013;
2State Key Laboratory of Coal Resource Efficient Mining and Clean Utilization(China Coal Research Institute),Beijing,100013;

*Corresponding author's e-mail: 550544407@qq.com

Abstract. Based on fractal theory, the capacity dimension in the fractal dimension is taken as the basic feature quantity. The grid covering method was used to quantitatively evaluate the structural complexity of Donghuantuo Mine. Based on this method, the positive relationship was found between the structural complexity and permeability coefficient with using the fractal theory. And the value of permeability coefficient is optimized for empirical formula to be closer to the real situation. Thus, the prediction accuracy of water inflow is improved.

1. Introduction
The complexity of the geological structure has a significant effect on coal mining conditions, water inrush and gas outburst and so on. In the mine water prevention, there is also a direct relationship between geological structure and water inflow. Due to the constraints of tectonic stress field, the distribution of faults and folds in the zone is zonal. The degree of structural development has a controlling effect on the permeability of the rock, which affects the accuracy of the prediction of water inflow. Therefore, it is very important to quantify the complexity of geological conditions and understand the permeability of rock in specific areas (mining, roadway, working face, etc.) in mathematical language.

It is difficult to quantitatively reflect the complexity of the geological structure of the mining area by using conventional mathematical statistical methods. This paper the introduction to fractal theory in the capacity dimension, access to more accurate than conventional statistical methods of measurement. In recent years, some experts and scholars at home and abroad have shown that the fractal dimension in fractal theory can comprehensively reflect the fault extension length, scale and distribution of faults in the evaluation of fault network complexity in geological blocks. The fractal dimension can be used to quantitatively evaluate the complexity of the fracture network compared with the conventional mathematical statistical method.

2. Fractal theory

2.1 Fractal definition
Fractal is the word, 1973 B.B.Mandelbrot[1] from the Latin “Frangere” created from the word. Its original meaning is irregular, fragmented meaning, fractal geometry is a geometric shape with irregular geometry as the object of study. Because irregularity is common in nature, fractal geometry is also called...
geometrical description of nature. However, there is no definite definition of fractal. Fractal is a general term for shapes and structures without self-similarity in length.

2.2 Fractal determination method

At present, there is no definite method to judge fractal and non-fractal. The methods used by some experts and scholars are as follows: (1) artificial determination; (2) correlation coefficient test method; (3) strengthening coefficient method; (4) fitting error method; (5) the fractal dimension error method; (6) the overall fitting method and so on.

2.3 Definition of fractal dimension

Fractal dimension is an important parameter to describe the fractal, which can reflect the basic characteristics of fractal, but there are many kinds of definition and calculation method because of the difference of the focal plane. There are similar dimension, Hausdorff dimension, capacity dimension, box-counting dimension and so on. They have different applications. In this paper, only the capacity dimension is involved.

Capacity dimension is the use of the same size of the shape of the ball or cube covered geometric objects defined dimension, by the famous Soviet mathematician Kolmogorov proposed. Suppose a geometric object S, if the diameter of the ball with a standard to cover S, the minimum required for the small ball N (ε), then the capacity of S dimension:

\[ D_c = \min_{\varepsilon \to 0} \frac{\log N(\varepsilon)}{\log(\varepsilon)} \]

3. Evaluation of structural complexity

This paper takes Donghuantuo Mine as an example to introduce the method of fractal theory to evaluate the structure complexity of mining area.

3.1 Introduction to coal mine

Donghuantuo Mine located in Tangshan City, Hebei Province Fengrun District, located in the Chezhoushan syncline. The syncline is a long, asymmetric syncline. The synclinal axis is tilted toward the northwest, and the hinge is tilted to the southwest, extending in a "tongue" shape on the plane. The strata of synclinal wings vary greatly, the southeastern wing is gentle and the northwest limestone is steep. In the syncline, the fault structure is more developed and the strike direction is more consistent with the synclinal axis. The main aquifer of the mine have quaternary bottom pebble aquifer, A~A0 aquifer, 5#coal roof aquifer, 12~14# aquifer, 14~K3 aquifer, Ordovician limestone aquifer, each aquifer has a hydraulic connection.

3.2 Fractal calculation

Based on the tectonic data in the mining plan of Donghuantuo Mine, the fractal dimension (volume dimension) of each unit area is calculated by using grid cover method to mine structure.

The capacity dimension of the fault grid is calculated as follows: The grid is divided into four levels of 1000m × 1000m, 500m × 500m, 250m × 250m, 125m × 125m in order to form a square grid with exponential increase in grid density (Figure 1). The number of grids containing fault traces in different units is counted in turn, and the specific method is referred to the fractal dimension tomography (Figure 2).
3.3 Calculation results and evaluation

Table 1 statistics Donghuantuo unit structural unit of the fault volume dimension data. The fractal dimension values represent the values of the center points of the partitioned units. As a result, the complexity of the fault network within the Donghuantuo Mine is quantified.

| Numbering | Area   | Regression equation           | Fractal dimension | Correlation coefficient |
|-----------|--------|-------------------------------|-------------------|-------------------------|
| 1         | Whole mine | $y = -0.3312x + 2.8732$     | 0.3312            | 0.9973                  |
| 2         | I      | $y = -0.3497x + 2.4464$     | 0.3497            | 0.9943                  |
Based on the double logarithmic linear regression analysis, the capacity dimension of Donghuantuo mine is 0.3312 (Figure 3), and most of the correlation coefficients of each unit are more than 0.95, which indicates that the distribution of fault network is Donghuantuo mine area. The correlation of unit data is good. The coordinate values and capacity dimension values of the center points of the partitioned units are input to the computer, and the contour map of the fault network capacity of Donghuantuo mine is drawn (Figure 4).

The analysis shows that the capacity dimension value of the area I is 0.3497. The regional boundary is east of the 16 section line to the southeast of the synclinal axis, which is a tectonic block section. The block section has little change in strike and trending, and is simple monoclinic structure. 58 faults were found, and the fault density was 1.38/km. Most faults concentrated in the northeast region (Capacity Dimensions: 0.36) development is more complex.
The capacity dimension of the area II is 0.3581. The area boundary is 16 section line to the southeastern wing of the F35 fault. The block section is characterized by high angle inclination or oblique normal fault, the fault is more developed and the drop is larger. There are 17 faults (F22-F37) in the area, 16 of them are normal faults, and the faults greater than 50 m are: F22, F27, F31, F32 and F35. The gap between the fault 30-49m have F23, F26 and F30. The faults less than 30m have six. Most faults concentrated in the southeast region II (Capacity Dimensions: 0.5) development is more complex.

The fractures in the above two block sections are more developed than those in other block sections, and the values of the capacity dimensions are significantly higher than those of the weak faults. The capacity dimensions value of the whole area is 0.3312, which shows that the structure is simple in the field, but the heterogeneity of the structure in the area.

4. Optimization and application of permeability coefficient

The degree of structural development has a controlling effect on the permeability of the rock, and are there any links between the two? With this question, the authors find out the fractal dimension of the location of the pumping hole and the permeability coefficient measured by the hole. They find a positive correlation between the fault capacity dimension and the permeability coefficient (Figure 5). The authors use this relationship to optimize the permeability coefficient\(^{[4-5]}\), and obtain the optimization formula.

\[
K^* = 44.7653 - 102.0408D
\]

\(K^*\): The optimized value of permeability coefficient K.

This optimization formula is applied to the prediction of water inflow in the working face of Donghuantuo Mine.

Method of prediction: “big well method”

Calculation formula:

\[
Q = 1.366K^*\frac{(2H - M^*)M^*}{\lg R_0 - \lg r_0}
\]

The results are shown in Table 2.

| Value error | Value  |
|-------------|--------|
| Measured value | 2.3m³/min |
| Predictive value | Conventional 3.4m³/min 47.83% |
| Predictive value | Optimization 2.35m³/min 2.2% |
5. conclusion
The capacity dimension of fractal theory is introduced into the evaluation of the complexity of coal mine structure. Taking Donghuantuo Mine as an example, this paper describes the evaluation method of the complexity of coal mine structure, and realizes the quantitative evaluation of the structure complexity. The method provides a certain analysis method for mine water inrush and gas outburst during mining, which also has significance to guide mine water prevention correctly.

The authors found a positive correlation between the fault capacity dimension and the permeability coefficient. This relationship to optimize the permeability coefficient is used and the optimization formula is obtained. This optimization formula is applied to the prediction of water inflow in the working face of Donghuantuo Mine, and the result shows that the prediction error is improved greatly compared with the original prediction error.

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