ISSN: 2472-3703 DOI: 10.6911/WSRJ.202006_6(6).0018

Mathematical Analysis of Development Height of Water-Flowing Fracture Zoon in Huanglong Jurassic Coal Mine-Cui Jiagou Coal Mine

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Abstract

Due to the influence of overlying sandstone aquifer of Luohe formation, Zhiluo formation and Yan'an formation, the prediction of the height of the fracture zone of guiding water is very important to the prevention of roof water damage in Huanglong Jurassic Coal Mine-Cui Jiagou Coal Mine. In this paper, the correlation test and stepwise regression analysis method of spass software are used to analyze the factors affecting the development of the height of water-conductive fissure zone effectively, and the corresponding regression equation is obtained, which is of great significance to the subsequent geological work and practical production.

Keywords

Water-conductive fissure zone; spass software; stepwise regression analysis.

1. INTRODUCTION

Mathematical geology is a relatively new branch of geology, an inevitable result of the development of geology along the direction of quantification, and a product of the combination of qualitative and quantitative studies in geology [1]. The work of mathematics geology in China began in the early 1960s and gradually developed towards a higher level and a deeper new stage. At present, mathematical geology has opened up broad application fields and prospects in stratigraphy, petrology, tectonic geology, geochemistry, geophysical exploration, deposit reserve calculation and mineral resources evaluation, environmental hydrogeology and so on. In recent years, mathematical geology has made remarkable progress in fractal theory, dissipative structure theory, grey system theory and application of fuzzy mathematics in geology[2-3].Hou Enke et al[4],Based on Hongliulin coal mine in Shenfu mining area, four evaluation indexes of stratum age, thickness, weathering degree and lithologic assemblage of weathered bedrock are selected, and the Fisher discriminant analysis model of water-rich type of weathered bedrock aquifer is established, and the water-rich type of weathered bedrock without pumping test data is predicted. Zhai Guojing et al [5], Based on the relationship between groundwater dynamics and mining quantity, the grey differential equation, grey system equation and parameter identification of groundwater dynamics are studied. Cloulibaly et al [6], According to the relatively short groundwater level data and related hydrometeorological data, the delayed input neural network model and regression neural network model of groundwater level dynamics are established, and compared with the generalized radial basis function model and the probabilistic neural network model. Coppola et al[7-8],Mao et al[9], The neural network model of groundwater level and groundwater quality of multi-layer aquifer system with different time steps has been established and applied to groundwater management, which proves that

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202006_6(6).0018

artificial neural network can avoid the weakness sensitive to temporal and spatial variation of aquifer system in numerical simulation.

In the actual production process, because of the complexity of the problem and the influence of various errors in the test process, the function relation has some uncertainty, this kind of non-deterministic relation is the correlation relation, usually can only use the statistical method to find out the regression relation, carries on the regression analysis [10].And regression analysis can be divided into univariate and multivariate regression analysis according to the number of influencing factors. Multivariate linear regression analysis is an important branch of regression analysis to analyze the linear relationship between one dependent variable and multiple independent variables. When applying multivariate linear regression analysis to deal with practical problems, on the one hand, in order to obtain more comprehensive information, we hope that the model contains as many independent variables as possible, on the other hand, because of the overlap of roles between independent variables, if they are introduced into the model, not only increase the computational cost, but also adversely affect the parameter estimation of the model and the prediction effect of the model. The stepwise regression method can select the most appropriate independent variables and establish a reasonable and simple practical model[11-12].Therefore, In this paper, taking Cui Jiagou coal mine as an example, Based on the method of stepwise regression analysis[13-14], the influence factors are determined by fitting matrix scatter plot using spass software and the development height of water-conducting fissure zone is studied.

2. BASIC THEORY OF REGRESSION ANALYSIS

Regression analysis is used to study the interdependencies between multiple variables, while stepwise regression analysis is often used to establish an optimal or appropriate regression model study the dependencies between variables more deeply. Multivariate linear regression analysis, also called complex linear regression analysis, is a generalization of univariate linear regression analysis or simple linear regression analysis, which studies how a set of independent variables directly affect a dependent variable. The independent variable here refers to the independent free change variable, generally expressed in x, the dependent variable refers to the independent, affected by other variables, generally expressed in y.

Table 1. The height of water-conducting fissure zone and related factors

Drilling Number	4^{-2}Coal seam bottom depth	4^{-2}Coal seam floor elevation	4^{-2}thickness of coal seam	Water-conducting fissure zone height
C18	334.53	1045.14	0.8	
C22	398.08	1050.31	0.3	
C25	404.24	1022.38	4.18	83.6
C49	591.62	939.02	14.25	180
C5	736.03	896.17	23.46	180
C50	571.98	970.25	7.58	151.6
C54	520.64	1048.62	1.67	33.4
C8	672.25	925.32	14.34	180
B1	745.91	859.44	7.75	155
B2	654.25	916.61	24.42	180
B6	510.45	939.75	7.77	155.4
B7	459.4	1004.71	6.38	127.6
B8	426	968.91	8	160

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3. REGRESSION ANALYSIS PROCESS

3.1. Impact Factors and Measured Data

In the process of coal mining under near aquifer and surface water body, there are many factors that affect the development height of water-conducting fissure zone. According to the field measured data and combined with relevant research results, after comprehensive analysis, three impact factors, coal seam thickness, bottom depth and floor elevation are preliminarily selected as the key factors for the development height of water-conducting fissure zone.

The development height and influence factors of the water-conducting fissure zone measured by 13 boreholes in the study area are used as the original data for regression analysis, see Table 1.

3.2. Operational Results

Based on the measured data in Table 1.1, the correlation between the development height of the water-conducting fissure zone and the coal seam thickness, bottom depth and floor elevation is analyzed by using spass statistical software.

3.2.1.regression analysis significance test

Regression analysis model in practical application, usually use complex correlation relation number R to test the significance of trend surface model. i.e.

$$R=\sqrt{\frac{S_R}{S_R+S_E}} \tag{1}$$

In the middle: R—complex correlation coefficient;

S_R—regression square sum;

S_E—residual square sum.

From formula (1), we can see that the value range of complex correlation relation number is 0≤R≤1. the closer the R to 1 indicates that the smaller the SE, the better the regression model fits. the closer the same R2 to 1, the better the fitting degree of the regression model.

The scatter plot of the fitting matrix output from the spass software (Figure 1, Figure 2) shows that the linear relationship between the development height of the water-conducting fissure zone and the influencing factors is obvious, with R2 greater than 0.6 except the bottom depth, while the quadratic curve fitting degree is higher, and the R2 is above 0.96 except the bottom depth. It can be seen that among the three pre-selected factors only coal thickness and floor elevation have significant influence on the development height of water-conducting fissure zone.

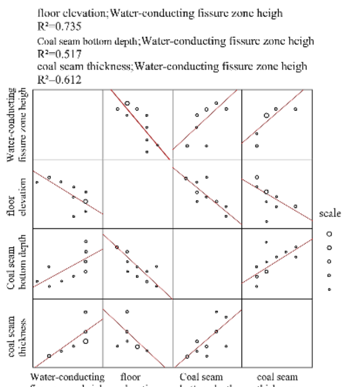

Fig 1. Scatter diagram of linear relation fitting matrix

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202006_6(6).0018

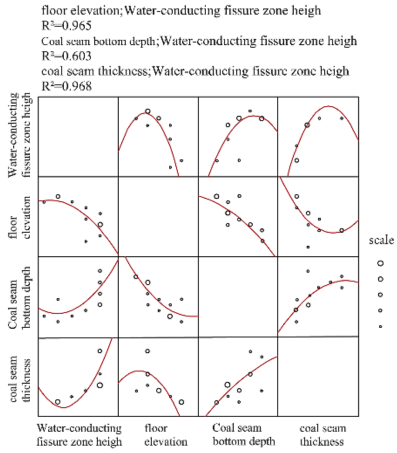

Fig 2. Diagram of matrix scatter of quadratic curves

3.2.2 Establishment of Regression Analysis Model

1. linear regression model

According to the results of the spass output, the coefficients of the univariate linear regression model can be obtained, as shown in Table 2.

Table 2. Parametric Estimation of Univariate Linear Regression Model

Model 1	R	R^2	Adjust R^2	Standard error of estimates		
	0.857	0.735	0.711	37.113		
	coefficient					
		Unstandardized coefficient		Standardized coefficient	t	Sig.
		B	standard error	Beta		
	X_1	-0.949	0.172	-0.857	-5.519	0.000
	constant	1040.903	166.809		6.240	0.000
Model2	R	R2	Adjust R2	Standard error of estimates		
	0.782	0.612	0.577	44.888		
	coefficient					
		Unstandardized coefficient		Standardized coefficient	t	Sig.
		B	standard error	Beta		
	X_2	6.897	1.656	0.782	4.164	0.002
	constant	57.908	19.804		2.924	0.014

Based on the non-standardized regression coefficients in Table 2, a linear model can be established:

$$y= -0.949x1+1040.903 \tag{2}$$

$$y= 6.897x2+57.908 \tag{3}$$

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202006_6(6).0018

In the middle: y—the height of the backwater fissure zone;

x1, x2—are floor elevation and coal seam thickness.

2.Quadratic Curve Model

According to the results of the spass output, the coefficients of the quadratic curve model can be obtained, as shown in Table 3.

Table 3. Parametric Estimation of Quadratic Curve Model

<table>
<tr><td rowspan="10">Model 1</td><td>R</td><td>R^2</td><td>Adjust R^2</td><td colspan="3">Standard error of estimates</td></tr>
<tr><td>0.982</td><td>0.965</td><td>0.958</td><td colspan="3">14.190</td></tr>
<tr><td colspan="6">coefficient</td></tr>
<tr><td rowspan="2"></td><td colspan="2">Unstandardized coefficient</td><td>Standardized coefficient</td><td rowspan="2">t</td><td rowspan="2">Sig.</td></tr>
<tr><td>B</td><td>standard error</td><td>Beta</td></tr>
<tr><td>X_1</td><td>17.525</td><td>2.288</td><td>15.828</td><td>7.660</td><td>0.000</td></tr>
<tr><td>X_1^2</td><td>-0.010</td><td>0.001</td><td>-16.692</td><td>-8.078</td><td>0.000</td></tr>
<tr><td>constant</td><td>-7849.373</td><td>1102.445</td><td></td><td>-7.120</td><td>.000</td></tr>
<tr><td rowspan="8">Model2</td><td>R</td><td>R^2</td><td>Adjust R^2</td><td colspan="3">Standard error of estimates</td></tr>
<tr><td>0.782</td><td>0.612</td><td>0.577</td><td colspan="3">44.888</td></tr>
<tr><td colspan="6">coefficient</td></tr>
<tr><td rowspan="2"></td><td colspan="2">Unstandardized coefficient</td><td>Standardized coefficient</td><td rowspan="2">t</td><td rowspan="2">Sig.</td></tr>
<tr><td>B</td><td>standard error</td><td>Beta</td></tr>
<tr><td>X_2</td><td>24.715</td><td>1.754</td><td>2.803</td><td>14.091</td><td>.000</td></tr>
<tr><td>X_2^2</td><td>-.717</td><td>.068</td><td>-2.107</td><td>-10.593</td><td>.000</td></tr>
<tr><td>constant</td><td>-5.227</td><td>8.416</td><td></td><td>-.621</td><td>.548</td></tr>
</table>

Based on the non-standardized regression coefficients in Table 3, a quadratic curve model can be established:

$$y= -0.01x12+17.525x1-7849.373 \tag{4}$$

$$y= -0.717x22+24.715x2-5.277 \tag{5}$$

In the middle: y—the height of the backwater fissure zone;

x1, x2—are floor elevation and coal seam thickness.

3. Binary Linear Regression Model

According to the results of the spass output, the coefficients of the quadratic curve model can be obtained, as shown in Table 4.

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Table 4. Parameter Estimation of Binary Linear Regression Model

Model	R	R^2	Adjust R^2	Standard error of estimates		
	0.884a	0.782	0.738	35.278944		
	coefficient					
		Unstandardized coefficient		Standardized coefficient	t	Sig.
		B	standard error	Beta		
	X_1	-0.682	0.244	-0.616	-2.794	0.019
	X_2	2.865	1.943	0.325	1.474	0.171
	constant	755.621	250.175		3.020	0.013

Based on the non-standardized regression coefficients in Table 4, a binary linear regression model can be established:

$$y= -0.682x1+2.865x2+755.621 \tag{6}$$

In the middle: y—the height of the backwater fissure zone;

x1, x2—are floor elevation and coal seam thickness.

3.2.3 Analysis of Predictive Effect of Regression Analysis Model

Table 5. Statistical table of the relative error between the predicted and measured values of the height of the water-conducting fissure zone

Drilling Number	Water-conducting fissure zone height	Formula (2) Predictive Elevation	Formula (3) Predictive Elevation	Formula (4) Predictive Elevation	Formula (5) Predictive Elevation	Formula (6) Predictive Elevation
C18	0	49.07	63.43	-456.47	14.03	45.13
C22	0	44.16	59.98	-474.20	2.07	40.17
C25	83.6	70.66	86.74	-384.77	85.50	70.33
C49	180	149.77	156.19	-210.63	201.32	156.04
C5	180	190.44	219.71	-175.20	179.92	211.65
C50	151.6	120.14	110.19	-259.59	140.87	115.63
C54	33.4	45.76	69.43	-468.35	34.00	45.25
C8	180	162.77	156.81	-195.31	201.70	165.64
B1	155	225.29	111.36	-174.06	143.20	191.69
B2	180	171.04	226.33	-187.52	170.69	200.46
B6	155.4	149.08	111.50	-211.55	143.47	136.97
B7	127.6	87.43	101.91	-336.25	123.22	88.69
B8	160	121.41	113.08	-257.09	146.56	117.74

According to the established trend surface prediction model, the measured data in Table 1 can be substituted into formulas (2) - (6), and the development height of the predicted water conduction fissure zone can be calculated. The concrete error results are shown in Table 5. From the error between the predicted value and the measured value calculated by this prediction model, it can be seen that the error between the predicted development height and the actual development height by applying equation (5) is not very large, between 2%~10%. Therefore, using the quadratic curve model with coal seam thickness as independent variable to predict the development height of water-conducting fissure zone in Cuijiagou coal mine has high precision and feasibility.

4. ENGINEERING APPLICATION

The established regression model prediction relationship was applied to the 2302 working face of cuijiagou coal mine to predict the height of the water-conducting fissure zone in the roof of coal seam. The coal seam thickness of this working face is 26 m, and it is substituted into formula (5). The predicted height of water-conducting fissure zone is 152.62 m, and the measured height is 150.84 m. It can be seen that the difference between the predicted value and the measured value is very small, and the relative error is 1%. The results show that the prediction model of water-conducting height regression analysis is more in line with reality and provides scientific basis for preventing water from coal seam roof.

5. CONCLUSION

By using spass software, it is concluded that there is a good correlation between the height of water-conducting fissure zone and the thickness of coal seam.

Compared with the empirical formula, the formula is more suitable for predicting the development height of water-conducting fissure zone in the study area.

More accurate prediction of the development height of water-conducting fissure zone provides favorable support for the prevention and control of mine water hazards.

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