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Matematičko modeliranje i primena kompjutera pri izvedbi površinskog kopa

The mathematical modelling and computer application for the open pit performance

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Sažetak: *Stvaranje modela diskretne interpolacije ili modifikovanog modela konačnih razlika kao preduslov za homogenizaciju rude opalske breče za potrebe cementne industrije, baziraju se na principu postojanja diskrecije tj. simulacije ležišta kao jednog postojećeg fenomena preko sistema mini blokova. Pomoću ovog fizički reprezentativnog modela, može se matematički opisati matričnom formom simbola ili figura, koji predstavljaju blok segmente površinskog kopa. Kurs stvaranja modela ležišta se izvodi kroz nekoliko faza.*

KLJUČNE REČI: DISKRETNA INTERPOLACIJA, KONACNE RAZLIKE, MODEL MINI BLOK

Abstract: *The formation of the discreet mathematical model or the finite differences - modified model as the precondition of the ore homogenization by opal breccia for the cement industry demands are based on the principle of the discretion extant, i.e. the deposit simulation as an extant phenomenon over the mini blocks system. By means of that physical represented model, it may be described mathematically by matrix form symbols or figures whichever representing the block segment of the open pit. The model formation course of the deposit is run across the few phases.*

KEYWORDS: DISCREET INTERPOLATION, FINITE DIFFERENCES, MODEL, MINI BLOCK

Introduction

The formation of the discreet mathematical model as the precondition of the ore homogenization by opal breccia for the cement industry demands is based on the principle of the discretion extant, i.e. the deposit simulation as an axtant phenomenon over the mini blocks system. The whole or the encircled part of the deposit by interpolation together with the working environment is divided over the prismes - mini blocks, so every prism, as a part of the whole is bearing some information about the located part of the extant. By means of that physical represented model, it may be described mathematically by matrix form symbols or figures whichever representing the block. In such away the extant model directly may be represented as a threedimensional matrix or indirectly by twodimensional matrix set in the horizontal or vertical sections.

The method of finite differences is based on shift of partial derivates with answering differences of relation by answering independent variables.

The method of finite differences for approximate determination of partial differential equations is based on the following:

- Boundary district, in which is looking for determination, is covered with approximate net composed of equal elementary surfaces.
- The partial equation which is given, is shifting in the knots of the net with answering equations in the shape of finite differences.
- On the base of boundary conditions is approving the value of the determinations of boundary knots.
- The system of approximate equations is determining, which present algebraic system with great number of unknowns.
- The determinations of the system of approximate equations is taking as a near determinations of partial differential equations.

The application of the discreet interpolation

If the purpose is to form the discreet model of both deposit or ore body with the surrounding follower rocks, the deposit extant have to be derived in mini blocks. According to the obtained in formation by the investigated tests have to define mining-geology signs of every block, i.e. the useful component assay, the both assays tailings and injurious components, the digging residence etc. which will contribute for the studying of the possibility of composite material production which will be used in the cement industry. The idea of the extant discreet interpolation is based on the definition from the influence of every point bearing the investigated information from the influenced group of the investigated mini block.(Fig. 1.)

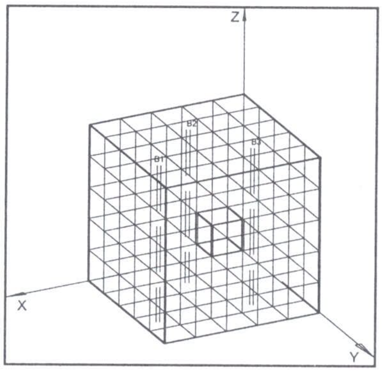

Figure 1. Scheme of the mini block

The influence of the all known points - holes from the influenced group, to the observed unknown point - mini block is estimated according to the equation:

$$U_n = \frac{\sum_{p=1}^{p=m} U_p \cdot L_{p,n}^{-l}}{\sum_{p=1}^{p=m} L_{p,n}^{-l}}$$

where are:

U_n - unknown point;

U_p - known point;

$L_{p,n}$-distance between influenced known and unknown point;

l - degree of influenced activity of the distance.

From the theoretical view point, defining the characteristics of every unknown point - the mini block by means of discreet interpolation, the influenced activity has had all information points as a bearers of the mining-geology information about the unique extant whole - deposit, having:

$U_{min} < U_n < U_{max}$

The application of the finite differences

In physical sense, the method of finite differences is based on treatment of discretion of continue surface U=U(x,y), it means her approximate presentation through approximate system of points arranged about regular net.
The idea of surface U=U(x,y) about interpretation by geologic-mining aspect and modeling of deposits can be connected with traits from different quantitative and quality nature, as change of strength of layer, change of contents of useful minerals, etc.
With approximate presentation on surface U=U(x,y) with method of finite differences, which means forming the model of deposit, it is starting of known contour conditions, which can be defined with research holes (boundary knots) or with underground research works (boundary lines).
The principle of discretion is giving opportunity for define the values of searching parameters for each point of the net.
This means that when it is forming a discrete model of the deposit, the size and the shape of the base of the mini block needed to coincide with the size and the shape of elementary surface ($\Delta x\ \Delta y$), it is necessary the knots of the net to coincide with gravity (center of gravity, points aim) points of mini blocks.
If this condition is satisfying, than value for $U_{i,j} = U(x_i, y_i)$, can be given on answering mini block with coordinates (x_i, y_i).

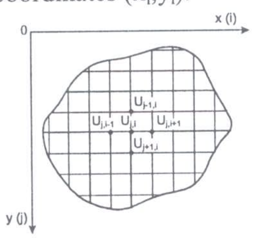

Figure 2. Scheme of geometry interpretation for covering of the boundary district

Laplace's equation for definition of the value of dependent variable U=U(x,y) in each point of boundary district has the shape:

$$u_{i,j} = \frac{1}{4}(u_{j,i-1} + u_{j,i+1} + u_{j-1,i} + u_{j+1,i})$$

Experimental investigation of discreet interpolation and finite differences

The practical experiments and reviewing of the discreet interpolation and finite differences applicable for the deposit model formation, are carried out by means of experimental investigation from the opal breccia deposit "Spancevo"-Cisinovo-R. Macedonia, according to the set theoretical principles, simultaneously, using the graphic presentation with SURFER computer programme.

The disposition of the investigated holes, SiO_2 and Al_2O_3 assays

Table 1.

Hole N°	Samp. N°	Type of material	Chemical analysis results	
			SiO_2	Al_2O_3
1	1/1	Opal breccia	74.06	12.81
2	2/1	Opal breccia	79.92	7.54
3	3/1	Opal breccia	87.50	2.15
4	4/1	Opal breccia	85.49	2.92
5	5/1	Opal breccia	80.70	10.06
6	6/1	Opal breccia with and. incl.	53.46	20.13
7	7/1	Opal breccia	79.92	7.54
8	8/1	Opal breccia	84.50	5.15
9	9/1	Opal and tuf breccia	74.95	12.60
10	10/1	Andenzite, vulcanic tuf	51.80	4.50
11	11/1	Opal breccia with and. incl.	52.70	16.05
12	12/1	Opal breccia with and. incl.	57.10	22.32
13	13/1	Opal breccia	70.36	14.80
14	14/1	Opal breccia	81.70	9.06
15	15/1	Opal breccia	78.92	6.50
16	16/1	Opal breccia	88.40	2.25
17	17/1	Opal breccia	83.17	4.52
18	18/1	Opal breccia	80.94	6.03
19	19/1	Opal breccia with and. incl.	56.40	15.73
20	20/1	Opal breccia	87.30	2.82
21	21/1	Opal and tuf breccia	78.40	6.35
22	22/1	Opal and tuf breccia	73.95	1.60
23	23/1	Opal and tuf breccia	79.70	9.06
24	24/1	Opal breccia	89.40	1.92
25	25/1	Opal breccia	80.93	8.90
26	26/1	Opal and tuf breccia	68.60	10.00
27	27/1	Opal and tuf breccia	69.50	9.10
28	28/1	Opal breccia	86.40	2.25
29	29/1	Opal and tuf breccia	69.60	2.92
30	30/1	Opal breccia	78.82	7.50
31	31/1	Opal and tuf breccia	74.40	6.40
32	32/1	Opal and tuf breccia	73.95	2.65
33	33/1	Opal and tuf breccia	74.82	5.77
34	34/1	Opal breccia	76.60	4.00
35	35/1	Opal and tuf breccia	71.36	13.80
36	36/1	Opal and tuf breccia	78.30	7.25

The opal breccia open mine determination is determined by means of computer programmes for discreet interpolation and finite differences.

It was encircled the deposit investigation field represented by blocks matrix with following dimension: Dx = 50 m and Dy = 50 m with carried in disposition of the investigated holes (the number of 36) with following characteristics (Table_1.)

Matrix obtained from discreet interpolation method (SiO_2) Table 2.1.

82.13	68.02	62.15	**57.10**
84.50	70.55	64.34	58.79
82.50	73.28	68.01	63.88
77.78	75.85	72.36	69.12
75.14	78.60	75.27	71.96
74.74	**79.92**	76.04	73.61
76.81	78.90	77.05	75.07
79.60	78.33	76.83	74.65
80.70	78.41	76.88	**74.06**

Matrix obtained from finite differences method (SiO_2) Table 2.2.

77.17	68.62	65.33	**57.10**
84.50	70.47	67.30	63.82
78.18	72.20	69.44	67.34
75.75	73.97	71.47	69.71
74.82	76.19	73.31	71.51
74.82	**79.92**	74.83	72.91
75.67	78.24	75.75	73.92
77.40	78.14	76.44	74.74
80.70	78.64	77.20	**74.06**

Matrix obtained from discreet interpolation method (SiO_2) Table 3.1.

74.82	77.33	77.93	**78.82**
75.34	77.92	78.02	78.35
76.33	78.95	78.36	77.66
76.99	80.21	78.31	76.82
77.90	**80.93**	78.29	75.98
79.54	80.18	77.40	74.98
82.70	78.97	75.99	72.74
87.06	78.17	74.19	70.00
89.40	77.62	73.41	**68.60**

Matrix obtained from finite differences method (SiO_2) Table 3.2.

74.82	76.81	77.20	**78.82**
75.45	77.22	77.28	77.41
76.07	77.81	77.32	76.72
76.78	78.80	77.34	76.21
77.63	**80.93**	77.24	75.67
78.76	79.07	76.73	74.96
80.40	78.32	76.06	73.94
83.20	77.93	75.37	72.25
89.40	77.63	74.88	**68.60**

Matrix obtained from discreet interpolation method (SiO_2) Table 4.1.

87.30	78.71	80.68	**83.17**
85.17	79.42	80.79	82.96
81.43	79.94	80.79	82.13
78.70	80.55	80.67	81.87
7(.41	**80.94**	80.40	81.53
72.92	80.26	80.08	80.96
67.24	78.63	79.84	80.32
59.71	77.44	79.42	79.26
56.40	77.11	79.34	**78.92**

Matrix obtained from finite differences method (SiO_2) Table 4.2.

87.30	78.70	79.44	**83.17**
82.16	79.31	79.98	81.68
79.72	79.62	80.24	81.35
77.97	79.95	80.32	81.29
76.23	**80.94**	80.23	81.20
74.12	78.85	79.82	80.94
71.21	77.64	79.35	80.53
66.49	76.94	79.00	79.95
56.40	76.82	78.94	**78.92**

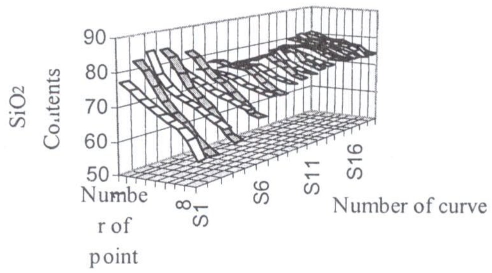

Figure 3. Comparation graphic (table 2.1 & table 2.2)

Discussion

It's forced the question: "How much the obtained mathematic model does response on the real system which is studied ?"

We will make the comparison of the values from the matrix members obtained by the discreet interpolation method and from the matrix members obtained by the finite differences method.

In order to perceive the differences between values obtained by both methods, are separated parts - matrix with sizes 9x9, with fixed points.

The biggest part of the obtained results show that there aren't differences and deviation by using of these two methods.

The differences are moved in the limits from 1.0% to 1.01%.
The graphic presentation confirm this.

Conclusion

The main aim from the mathematic modelling of deposit comes down to three basic function: understanding; foreseeing; control.
On the basis of the obtained results and other reference data related to the application of discreet interpolation in modelling of deposits may be seen the fact that this method is fairly useful which is first of all seen in its simplicity, flexibility and accuracy. The method isn't appropriate in deposits which posses an abrupt change in the modelled trait, for example deposits with explicit effect of native occurrence, the stockwork deposits etc.
The only issue that remains unsolved is the defining of the zone of influence. The selection of its shape and size is made experimentally or by intuition which may cause mistakes. Therefore, a scientific objective procedure for the defining of the zone of influence has not been developed. The degree of influential action of the distance is essential important component in the model which exerts a dumping action. The importance of this one becomes greater if the zone of influence has been defined with less accuracy.

The exactness of the results obtained by modelling of deposit in this method, mainly depends from boundary (contour) conditions, which in primary phase of modeling on the base of carefully done process of research informations (information points) and the choice of approximate net precisely are defined, and of the number of iterations is done in the determination of equations by Gauss-Seidl's method.

References

[1] Hildebrand F. B. INTRODUCTION TO NUMERICAL ANALYSIS, New Delhi, 1979.
[2] Krstev B., Golomeov B. THE APPLICATION OF DISCREET INTERPOLATION ABOUT THE MATHEMATIC MODELLING, Proceeding RGF Stip, Macedonia 1994.
[3] Krstev B, Golomeov B. THE OPAL BRECCIA - MINERAL MATERIAL FOR CEMENT INDUSTRY, Cement '96, Kosjeric, Yugoslavia, 1996.
[4] Radevic V., Vujic S. THE METHODS OF MATHEMATIC MODELLING FROM RAW MATERIAL DEPOSITS, Proceeding Opatija-Croatia, 1976.
[5] Sandev B., Krstev B., Golomeov B. THE PRECONDITION OF ORE HOMOGENISATION, 6th Balkan Conference on Mineral Processing, Ohrid, Macedonia 1995.
[6] Serra J. at all. LAWS OF LINEAR HOMOGENISATION IN ORE STOCKYARDS, XI IMPC Cagliari, Italy 1975.
[7] Vujic S. MATHEMATIC MODELING BY RAW MATERIALS DEPOSITS, RGF Beograd 1985.
[8] Vujic S., Ivic A. THE MATHEMATIC METHODS IN MINING AND GEOLOGY, RGF Beograd, Yugoslavia, 1991.