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INTERVAL METHOD OF MATHEMATICAL MODELING OF WELL LOCATION FOR OBTAINING A CONTINUOUS LINE OF CRACKS USING NON-EXPLOSIVE DESTRUCTIVE MIXTURE (NDM)

Abstract*: This article discusses the problem of obtaining a solid straight line of cracks when using non-explosive destructive mixtures in rocks. An interval version of the mathematical model and an algorithm for solving this problem have been substantiated and obtained. A theorem is proved that summarizes the result obtained. An interval strip with a limited width is shown, where the centers of the wells should be located.*

Key words*: well, fracture, non-explosive destructive mixture (NDM), interval, interval width, middle of the interval, coordinates of the well center, strength, extensibility.*

Language*: English*

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Introduction

When using non-explosive destructive mixtures (LDS), it is very important to determine the location of the wells to obtain a solid straight line of cracks in the fractured rocks. Their location and the formation of cracks in a straight line depends on the structure, strength and degree of elongation, etc. processed breeds. Cracks appear in rocks after applying LDCs. These cracks are formed as a result of chemical-physical reactions of the applied LDC. Fractures can form anywhere in the well and develop in any direction. As a result, the resulting material may be unusable or some of it has to be rejected. For this reason, experts in this area are conducting research. Generally speaking, the formation of these cracks depends on many factors. For example, they depend on the composition of the mixture used, the material of the rock, the diameter and depth of the boreholes, the distance between the boreholes, strength, rock formation rate, etc. are taken into account. In this case, the solution of the problem of obtaining a solid line as a result of emerging cracks, when using LDCs, becomes a difficult task. If one or another method is used, then it is possible to give direction to these fractures in order to end up with connected fractures, which ultimately form a continuous line of fractures between the wells. One of these options is proposed in article [4]. In this article, in the process of solving this problem, a theorem is mathematically modeled and proved, which states that the centers of the wells are located along a straight line if the coordinates of these centers satisfy a certain condition. We present this theorem from [4].

Theorem. If the following condition is satisfied: the distance between the points of the coordinate axes $x_1, x_2, \dots, x_n$ and $y, \dots, y_n$ must be equal, i.e.

$$x_2 - x_1 = x_3 - x_2 = \dots = x_n - x_{n-1} = a,$$
$$y_2 - y_1 = y_3 - y_2 = \dots = y_n - y_{n-1} = b,$$

then the points $M_1(x_1;\ y_1)$, $M_2(x_2;\ y_2)$, …, $M_n(x_n;\ y_n)$, which are the centers of the wells, lie on one straight line given by the equation

$$y - y_1 = \frac{b}{a}(x - x_1) \qquad (1)$$

The result of this theorem is confirmed by examples, as well as by experimental data. This theorem is a real solution to this problem.

Below, a mathematical model will be given in the interval version, where the problem of the mutual arrangement of wells according to the design development for splitting off part of the rock from the main mass is solved, without causing damage to the non-design one, i.e. not developed part of the breed. The solution of this problem in the interval variant, or rather by the methods of interval analysis [2], is motivated by the fact that the diameter, depth of the well, as well as the distance between them can vary within a certain interval, depending on many parameters of the developed rock [3]. For example, according to [3], the borehole diameter $d \in [60; 100]$*мм*, depth $h \in [6d; 10d]$, distance between wells $l = 1000\frac{df}{\sigma}$*мм* etc., here f is the coefficient of rock expansion, σ is the coefficient of rock strength. For this reason, naturally, these parameters need to be considered in a certain interval. Consideration of the mathematical model in the interval version guarantees two-sided estimates of these parameters for the lower and upper boundaries of the obtained intervals.

Consider the following problem: at what location of the wells can a continuous fracture be obtained between the wells?

In order to answer this question, we will proceed as follows.

Taking into account the given motivation of the interval option, the well diameter d and the coordinates of the well center $M_i(x_i;\ y_i)$are taken as an interval value, ie $\boldsymbol{d} = [\underline{d},\ \overline{d}]$, $\boldsymbol{x}_i = [\underline{x_i},\ \overline{x_i}]$ and $\boldsymbol{y}_i = [\underline{y_i},\ \overline{y_i}]$, here $\underline{x_i}$-is called the lower bound and $\overline{x_i}$–is the upper bound of the interval $\boldsymbol{x}_i$, respectively, which are real numbers. Further, the intervals, according to the generally accepted rules, are designated in bold, and real numbers in regular fonts. In what follows, all arithmetic operations on interval values will be carried out, according to [1], in the complete interval arithmetic of Kaucher, which is usually denoted ***KR***. Интервальное пространство и классическую интервальную арифметику в этом пространстве обозначим через ***IR*** [1].

Let, $* \in \{+, -, \cdot, /\}$, then $* \in \boldsymbol{KR}$ means that operations of addition, subtraction, multiplication and division are performed in full interval arithmetic ***KR.***

Now let's get down to solving the problem.

Without loss of generality, we will proceed as follows. The considered intervals are located in the positive part of the abscissas and ordinates. Then these intervals are positive and non-zero containing intervals. The intersection of the intervals $\boldsymbol{x}_i$ and $\boldsymbol{y}_i$ in R^2 form rectangles containing points $M_i(x_i;\ y_i)$, the sides of which are equal to $\overline{x_i} - \underline{x_i}$, $\overline{y_i} - \underline{y_i}$ respectively.

We present some characteristics of interval quantities according to [2], which we will use in further reasoning.

The middle of the interval $\boldsymbol{a} = [\underline{a},\ \overline{a}]$ is the quantity $mid(\boldsymbol{a}) = \frac{1}{2}(\underline{a} + \overline{a})$, the width of this interval is the quantity $wid(\boldsymbol{a}) = \overline{a} - \underline{a}$.

The interval version of a straight line is considered in [5], in the form of a generalized line, defined as a strip containing rectangles $\boldsymbol{x}_i \cap \boldsymbol{y}_i$ obtained as a result of intersection of intervals $\boldsymbol{x}_i$ and $\boldsymbol{y}_i$. In the real version of the problem under consideration, according to [4], the coordinates of the point should satisfy the condition:

1. abscissas of point $x_2 - x_1 = x_3 - x_2 = \ldots = x_n - x_{n-1} = a$, (*)
2. the ordinates of the point $y_2 - y_1 = y_3 - y_2 = \ldots = y_n - y_{n-1} = b$. (**)

Note that $x_i \in \boldsymbol{x}_i$ and $y_i \in \boldsymbol{y}_i$for all $i = 1, 2, \ldots, n$.

Now, using the introduced notation, we rewrite equalities (*) and (**) in the following form

$$\mathrm{mid}(\boldsymbol{x}_2) - \mathrm{mid}(\boldsymbol{x}_1) = \mathrm{mid}(\boldsymbol{x}_3) - \mathrm{mid}(\boldsymbol{x}_2) = \cdots = \mathrm{mid}(\boldsymbol{x}_n) - \mathrm{mid}(\boldsymbol{x}_{n-1}) = a, \qquad (2)$$

$$\mathrm{mid}(\boldsymbol{y}_2) - \mathrm{mid}(\boldsymbol{y}_1) = \mathrm{mid}(\boldsymbol{y}_3) - \mathrm{mid}(\boldsymbol{y}_2) = \cdots = \mathrm{mid}(\boldsymbol{y}_n) - \mathrm{mid}(\boldsymbol{y}_{n-1}) = b, \qquad (3)$$

where a and b are constant numbers.

Further, as in the real case [4], we require the location of the middle of the intervals Mi on one straight line, since the middle of these intervals, by definition, are real numbers. Then these points lie on one straight line and satisfy the equation of the straight line

$$\frac{x - x_1}{x_2 - x_1} = \frac{y - y_1}{y_2 - y_1}.$$

Substituting in this equation instead of x and y the corresponding interval values, we obtain

$$\left.\begin{array}{l}\dfrac{\boldsymbol{x}-\operatorname{mid}(\boldsymbol{x}_1)}{\operatorname{mid}(\boldsymbol{x}_2)-\operatorname{mid}(\boldsymbol{x}_1)}=\dfrac{\boldsymbol{y}-\operatorname{mid}(\boldsymbol{y}_1)}{\operatorname{mid}(\boldsymbol{y}_2)-\operatorname{mid}(\boldsymbol{y}_1)},\\ \dfrac{\boldsymbol{x}-\operatorname{mid}(\boldsymbol{x}_1)}{\operatorname{mid}(\boldsymbol{x}_3)-\operatorname{mid}(\boldsymbol{x}_1)}=\dfrac{\boldsymbol{y}-\operatorname{mid}(\boldsymbol{y}_1)}{\operatorname{mid}(\boldsymbol{y}_3)-\operatorname{mid}(\boldsymbol{y}_1)},\\ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.\dots\\ \dfrac{\boldsymbol{x}-\operatorname{mid}(\boldsymbol{x}_1)}{\operatorname{mid}(\boldsymbol{x}_n)-\operatorname{mid}(\boldsymbol{x}_1)}=\dfrac{\boldsymbol{y}-\operatorname{mid}(\boldsymbol{y}_1)}{\operatorname{mid}(\boldsymbol{y}_n)-\operatorname{mid}(\boldsymbol{y}_1)}\end{array}\right\} \quad (4)$$

By term addition of the left and right sides of equality (4), respectively, gives

$$\frac{\boldsymbol{x}-\operatorname{mid}(\boldsymbol{x}_1)}{\operatorname{mid}(\boldsymbol{x}_2)-\operatorname{mid}(\boldsymbol{x}_1)}+\frac{\boldsymbol{x}-\operatorname{mid}(\boldsymbol{x}_1)}{\operatorname{mid}(\boldsymbol{x}_3)-\operatorname{mid}(\boldsymbol{x}_1)}+\dots+\frac{\boldsymbol{x}-\operatorname{mid}(\boldsymbol{x}_1)}{\operatorname{mid}(\boldsymbol{x}_n)-\operatorname{mid}(\boldsymbol{x}_1)}=$$
$$=\frac{\boldsymbol{y}-\operatorname{mid}(\boldsymbol{y}_1)}{\operatorname{mid}(\boldsymbol{y}_2)-\operatorname{mid}(\boldsymbol{y}_1)}+\frac{\boldsymbol{y}-\operatorname{mid}(\boldsymbol{y}_1)}{\operatorname{mid}(\boldsymbol{y}_3)-\operatorname{mid}(\boldsymbol{y}_1)}+\dots+\frac{\boldsymbol{y}-\operatorname{mid}(\boldsymbol{y}_1)}{\operatorname{mid}(\boldsymbol{y}_n)-\operatorname{mid}(\boldsymbol{y}_1)} \quad (5)$$

By virtue of equalities (2) and (3), we can write

$\operatorname{mid}(\boldsymbol{x}_2)-\operatorname{mid}(\boldsymbol{x}_1)=a,\ \operatorname{mid}(\boldsymbol{x}_3)-\operatorname{mid}(\boldsymbol{x}_1)=2a,\dots,\operatorname{mid}(\boldsymbol{x}_n)-\operatorname{mid}(\boldsymbol{x}_1)=(n-1)a$ and $\operatorname{mid}(\boldsymbol{y}_2)-\operatorname{mid}(\boldsymbol{y}_1)=b,\operatorname{mid}(\boldsymbol{y}_3)-\operatorname{mid}(\boldsymbol{y}_1)=2b,\dots,\operatorname{mid}(y_n)-\operatorname{mid}(y_1)=(n-1)b.$

Further, using the properties of the interval operation [1], the denominators of the fractions in equality (5) will be replaced by the corresponding numbers, this is possible since the denominators contain numbers, then we have

$$\frac{\boldsymbol{x}-\operatorname{mid}(\boldsymbol{x}_1)}{a}+\frac{\boldsymbol{x}-\operatorname{mid}(\boldsymbol{x}_1)}{2\mathrm{a}}+\dots+\frac{\boldsymbol{x}-\operatorname{mid}(\boldsymbol{x}_1)}{(\mathrm{n}-1)\mathrm{a}}=$$
$$=\frac{\boldsymbol{y}-\operatorname{mid}(\boldsymbol{y}_1)}{\mathrm{b}}+\frac{\boldsymbol{y}-\operatorname{mid}(\boldsymbol{y}_1)}{2\mathrm{b}}+\dots+\frac{\boldsymbol{y}-\operatorname{mid}(\boldsymbol{y}_1)}{(\mathrm{n}-1)\mathrm{b}}. \quad (6)$$

In equality (6), putting the common factors outside the bracket, we get:

$$\frac{\boldsymbol{x}-\operatorname{mid}(\boldsymbol{x}_1)}{a}\left(1+\frac{1}{2}+\dots+\frac{1}{(\mathrm{n}-1)}\right)=\frac{\boldsymbol{y}-\operatorname{mid}(\boldsymbol{y}_1)}{\mathrm{b}}\left(1+\frac{1}{2}+\dots+\frac{1}{(\mathrm{n}-1)}\right).$$

Reducing the expressions in parentheses in both parts of the last equality, we have:

$$\frac{\boldsymbol{x}-\operatorname{mid}(\boldsymbol{x}_1)}{a}=\frac{\boldsymbol{y}-\operatorname{mid}(\boldsymbol{y}_1)}{\mathrm{b}}. \quad (7)$$

After making simple transformations, we rewrite the last equality in the following form:

$$\boldsymbol{y}-\operatorname{mid}(\boldsymbol{y}_1)=\frac{b}{\mathrm{a}}\big(\boldsymbol{x}-\operatorname{mid}(\boldsymbol{x}_1)\big). \quad (8)$$

Equation (8) defines the strip widths on the plane located in the first quarter of the *Oxy* plane.

This means that the centers of the wells are located within this strip, and the distance between the centers of the wells is constant, i.e. equal, this follows from conditions (2) and (3). The coordinates of the well centers are located at points $\mathrm{M}_i(mid(\boldsymbol{x}_i);\ \operatorname{mid}(\boldsymbol{y}_i))$. The direction of the strip determines the $\frac{b}{\mathrm{a}}$ value. The distance between the centers of the wells is defined by the equalities

$$\mathrm{M}_{i+1}\big(\operatorname{mid}(\boldsymbol{x}_{i+1});\ \operatorname{mid}(\boldsymbol{y}_{i+1})\big)-\mathrm{M}_i\big(\operatorname{mid}(\boldsymbol{x}_i);\ \operatorname{mid}(\boldsymbol{y}_i)\big)=l, \quad (9)$$

where $i=1,2,\dots,n-1$.

Now let us determine the width of the resulting strip, given by equation (8).

This is the same as specifying the width of the intervals $\boldsymbol{x}-\operatorname{mid}(\boldsymbol{x}_1)$ and $\boldsymbol{y}-\operatorname{mid}(\boldsymbol{y}_1)$. Determine the width of the interval $\boldsymbol{x}-\operatorname{mid}(\boldsymbol{x}_1)$.

By definition and the interval width property

$$wid\big(\boldsymbol{x}-\operatorname{mid}(\boldsymbol{x}_1)\big)=wid(\boldsymbol{x})+wid\big(\operatorname{mid}(\boldsymbol{x}_1)\big)=wid(\boldsymbol{x})+\operatorname{mid}(\boldsymbol{x}_1)=$$
$$=\overline{x}-\underline{x}+\tfrac{1}{2}(\overline{x}_1+\underline{x}_1)=\left(\overline{x}+\tfrac{1}{2}\overline{x}_1\right)-\left(\underline{x}-\tfrac{1}{2}\underline{x}_1\right). \quad (10)$$

In the same way, we get the result for the interval $\boldsymbol{y}-\operatorname{mid}(\boldsymbol{y}_1)$:

$$wid\big(\boldsymbol{y}-\operatorname{mid}(\boldsymbol{y}_1)\big)=\left(\overline{y}+\tfrac{1}{2}\overline{y}_1\right)-\left(\underline{y}-\tfrac{1}{2}\underline{y}_1\right). \quad (11)$$

From equality (10) and (11) it is seen what the width of the resulting strip given by formula (8).

Consequence. Since we need to find the strip with the smallest width, in equality (8) the expressions $\boldsymbol{x} - \mathrm{mid}(\boldsymbol{x}_1)$ and $\boldsymbol{y} - \mathrm{mid}(\boldsymbol{y}_1)$, without loss of generality, can be replaced by $wid(\boldsymbol{x})$ and $wid(\boldsymbol{y})$, which are often found and are convenient for use in practical tasks. Then we get

$$wid(\boldsymbol{y}) = \frac{b}{a}\, wid(\boldsymbol{x}). \qquad (12)$$

If we put $wid(\boldsymbol{x}) = min x_i$ and $wid(\boldsymbol{y}) = min y_i$ for all i=1, 2, …, n, then equality (12) takes the form

$$\min_i y_i = \frac{b}{a} \min_i x_i. \qquad (13)$$

Equality (13) is of practical value, since engineers work with real numbers, not intervals, and this equality sets the strip with the smallest width. Figure 1 shows the determination of the swath width and the location of the well centers, for three points as the center of the wells.

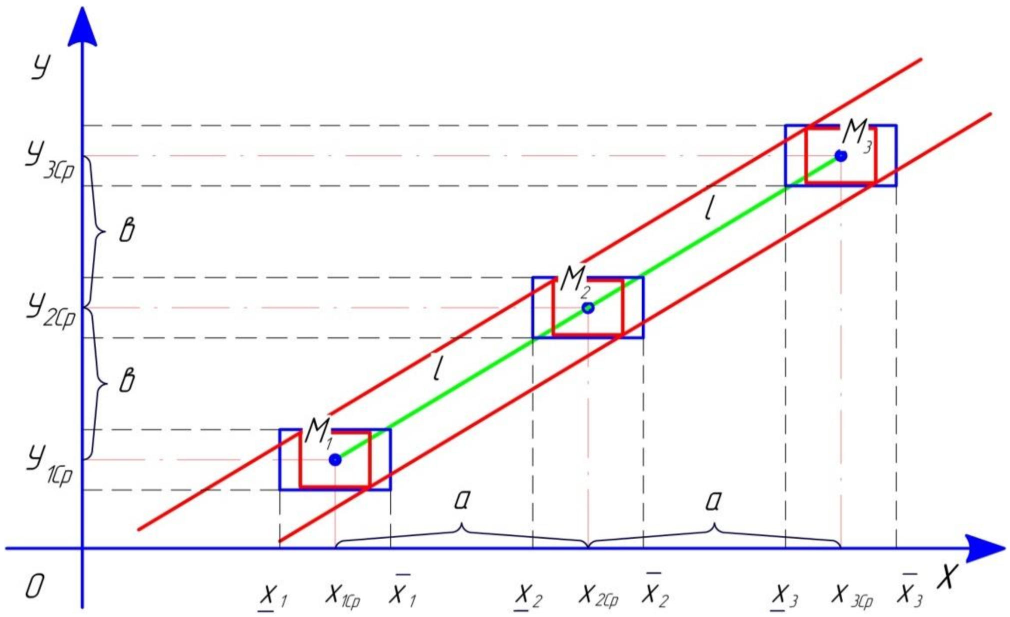

Figure 1. The image of the strip and the location of the centers of the wells.

It is known that the smallest area of a rectangle is equal to the area of a square obtained from this rectangle with a smaller side.

Further, let us denote by ρ the width of the strip and by c the side of the square obtained from the rectangle $\boldsymbol{x}_i \cap \mathbf{y}_i$. The side of a square is determined by the following equality

$$c = \begin{cases} \min\limits_i x_i\,, & if\ \min\limits_i x_i \le \min\limits_i y_i \\ \min\limits_i y_i\,, & if\ othewise. \end{cases}$$

for $i = 1, 2, \dots, n$.

In this case, the bandwidth ρ will be equal to

$$\rho = \sqrt{2}c, \qquad (14)$$

if the strip is sloping and

$$\rho = c, \qquad (15)$$

In this case, the well, like a circle, is inscribed in a square with side c, therefore, for the diameter of the well, the inequality

$$d \le \rho.$$

Thus, the derivation of equation (8) and, as a consequence, equation (12) and equality (13), are the solution to the problem posed. Equalities (14) and (15) determine the width of the resulting strip. As a result of obtaining these equations, the following theorem was proved.

Theorem. If for the intervals $\boldsymbol{x}_i, \boldsymbol{y}_i \in \boldsymbol{IR}$, i=1, 2, …, n, conditions (2) and (3) are satisfied, then

1) the coordinates of the points of the center of the wells are located along the strip determined by equality (8), and the smallest width of this strip is given by equalities (14) (or (15));

2) the distance between the wells is determined by equality (9).

Figure 2 shows a general view of the location of wells in the area of processed rocks, specified by the customer's technical regulations.

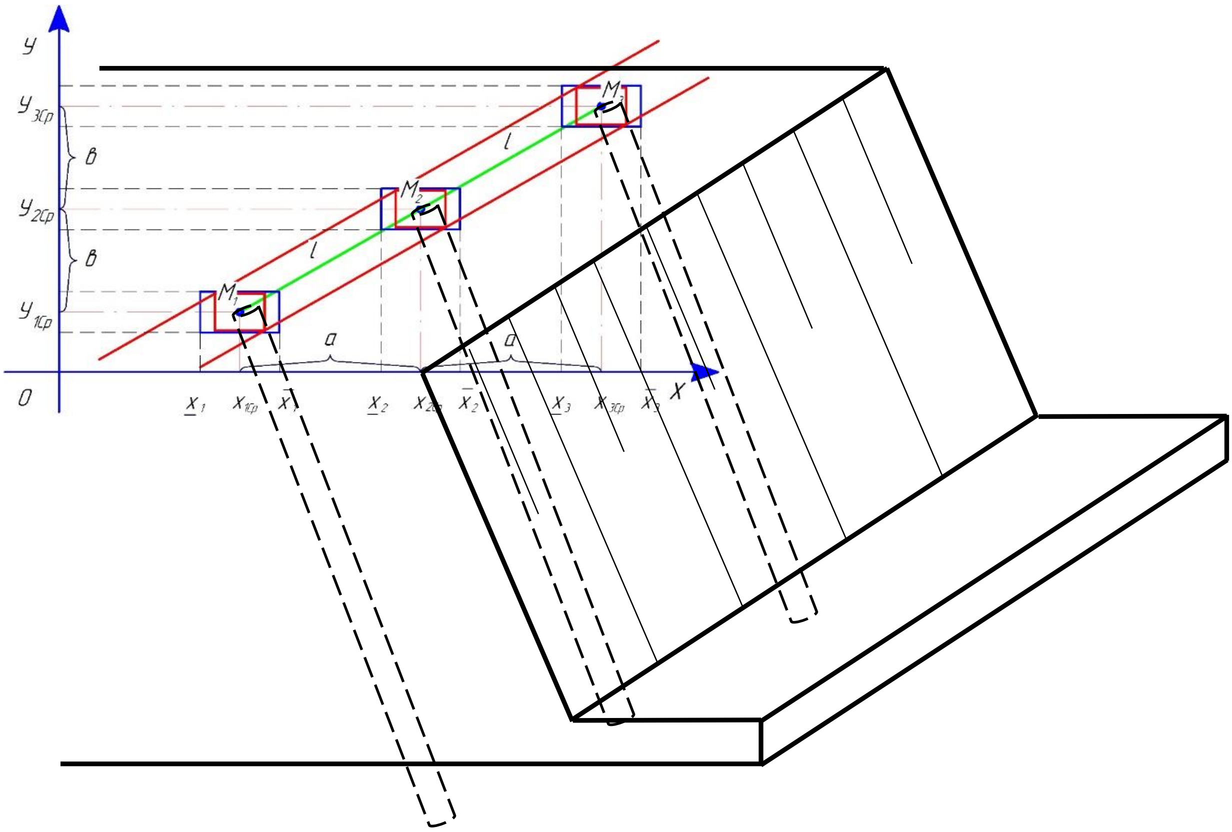

Figure 2. Images of a general view of the location of wells in the area of the treated rocks.

Conclusion

In recent years, there has been an intensive search for methods for the effective development of rocks. Arbitrary location of wells, when used for blasting purposes, after the explosion of the rock, those parts of the rock mass that were not the object of design development will suffer. The shock is free from the explosion, forming many cracks in this part of the mountain range, loosening it, which can subsequently lead to emergency situations. It is these circumstances that force researchers to search for optimal solutions. The solution of the problem posed in the interval variant gives a wide range for the location of the wells, but indicates the exact boundaries, which is one of the essential factors in the consideration of the tasks of blasting operations on rocks. If equality (8) determines the width of the strip for the location of the wells, then using equalities (12) and (13) it is possible to obtain the exact boundaries of the strip width and coordinates of the center of the wells, respectively.

References:

1. Shary, S.P. (2019). *Finite-dimensional interval analysis*. Novosibirsk: Publishing house "XYZ".
2. Kalmykov, S.A., Shokin, Yu.I., & Yuldashev, Z.Kh. (1986). *Interval analysis methods*. Novosibirsk: Publishing house "Science".
3. Sakhno, I.G. (2015). *Scientific foundations for managing the state of rocks with non-explosive destructive mixtures in underground mining.* Diss. for a job. uch. step. Doctor of Technical Sciences Krasnoarmeysk: Donetsk National Technical University.
4. Khudaiberdiev, O. Zh., Dzhuraeva, N.M., Norov, G.M., & Zhumaboev, E.O. (2020). Mathematical modeling of continuous cracks in boreholes using non-explosive destructive mixtures. *Scientific Bulletin of Bukhara State University*, №3.
5. Khudayberdiyev, O. (2020). *Generalized Equation of a Straight Line in the Interval Version*, Vol 23, No 2, November_IJPSAT.

6. Pismenniy, D.T. (2009). *Lecture notes on higher mathematics.* Publishing house. Moscow: Iris Press.
7. Hudajberdiev, O. Zh., Rahmatov, S. H., Karabekjan, S. H., & Zhumaboev, Je. O. (n.d.). *Matematicheskoe modelirovanie vychislenija shemy vozdushnogo potoka cherez fil`tracionnoe ustrojstvo*.
8. Zairov, Sh. Sh., Ravshanova, M. H., & Hudajberdiev, O. Zh. (2020). Matematicheskoe modelirovanie sozdanija vysokogo vnutrennego davlenija v shpurah pri ispol`zovanii nevzryvchatoj razrushaushhej smesi. *Journal of Advances in Engineering Technology*, (2).
9. Haag, G. S. (2001). *Alternative geometry hybrid rockets for spacecraft orbit transfer*. University of Surrey (United Kingdom).
10. Glyzin, S. D., Kolesov, A. Y., & Rozov, N. K. (2013). On a method for mathematical modeling of chemical synapses. *Differential Equations*, *49*(10), 1193-1210.