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E. O. Tarasenko, **A. V. Gladkov** (Stavropol, NCFU). **Statistical modeling of the economic efficiency of blasting operations for compaction of subsidence soils by the method of random optimization.**

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Резюме: Планирование технологических производственных работ по уплотнению просадочных грунтов глубокими взрывами требует значительных инвестиций и трудозатрат. В то же время статистическое моделирование позволяет оптимизировать производственный процесс для достижения его экономической эффективности и стабильности показателей. Моделирование взрывных работ приводит к решению задач многокритериальной оптимизации. В данной статье предложен подход к решению в статистической модели методом случайной многокритериальной оптимизации. Методы случайной оптимизации, в отличие от детерминированных методов, требуют меньших вычислительных ресурсов при увеличении размерности решаемой задачи.

Ключевые слова: лесс, многокритериальная оптимизация, производство, случайный поиск, экономическая эффективность, уплотнение просадочных грунтов.

Mathematical modeling of geological processes is currently being actively carried out by researchers. Among the variety of methods and methods of compaction of subsidence soils, the method of deep explosions occupies a special place [1].

In the process of economic and mathematical modeling of blasting operations, there is a need to solve multi-criteria problems by random optimization methods, since direct methods do not lead to the solution of the problems under consideration.

Let's evaluate the economic efficiency of geological works on compaction of subsidence soils to obtain the maximum revenue of the production enterprise at its minimum costs.

The mathematical model of the production problem can be written as

$$\sum_{i=1}^{m}\sum_{j=1}^{n} p_{ij}y_{ij} \to \max, \tag{1}$$

$$\sum_{i=1}^{m}\sum_{j=1}^{n} z_{ij}y_{ij} \to \min, \tag{2}$$

$$\begin{cases} \sum\limits_{j=1}^{n} a_{ij}y_{ij} \leqslant \overline{\alpha}_i, \quad \sum\limits_{j=1}^{m} b_{ij}y_{ij} \leqslant \overline{\beta}_i, \\ y_{ij} \leqslant 0,\ i = 1\ldots,m;\ j = 1,\ldots,n \end{cases} \tag{3}$$

Here is y_{ij} — the volume of compacted subsidence soil; p_{ij} — the cost of explosives; z_{ij} — financial costs for the production of technological works, including the wages of employees of the enterprise.

The statistical investigation of the production of blasting operations for compaction of subsident soils allows us to obtain a multi-criteria optimization problem (1)–(3), respectively, with criteria (1), (2). The private optimization subtask (1) leads to maximizing the income of the production enterprise. The optimization subtask (2) allows minimizing the total financial investment in the production under consideration.

The financial expenses for the production of technological works z_{ij} are described by a complex function that depends on a number of characteristics and parameters of the production process. In the theory of decision-making, there are various methods for solving multi-criteria optimization problems. Thus, in [2], the authors showed the adaptation of the criteria convolution method for solving multi-criteria optimization problems.

Analytical methods for solving optimization problems, in contrast to numerical ones, often lead to significant time and machine expenses in the process of finding solutions. And they don't always lead to a solution.

Let's construct the solution of the production optimization multi-criteria problem within the framework of the considered economic and mathematical model of the geological system by the method of random directions of the search for the optimum.

Considering the boundary conditions (3) of the minimax problem, we arbitrarily choose the initial approximation y_{ij}^0 from the range of acceptable values.

During the search for a solution to the problem, we implement a random step in the direction

$$y_{ij}^{k+1} = y_{ij}^k + \varphi h^k, \qquad i = 1, \ldots, m; \quad j = 1, \ldots, n, \tag{4}$$

where h — a single random vector $(h = 1)$, the direction of it is random; φ — step proportionality coefficient. A random step is made from the current (or starting) point.

Then we transform the problem (1)–(3) to the next iterative optimization problem

$$\sum_{i=1}^{m}\sum_{j=1}^{n} p_{ij} y_{ij}^k \to \max, \tag{5}$$

$$\sum_{i=1}^{m}\sum_{j=1}^{n} z_{ij} y_{ij}^k \to \min, \tag{6}$$

$$\begin{cases} \sum_{j=1}^{n} a_{ij} y_{ij}^k \leqslant \overline{\alpha}_i, \quad \sum_{j=1}^{m} b_{ij} y_{ij}^k \leqslant \overline{\beta}_i, \\ y_{ij}^k \leqslant 0, \ i = 1 \ldots, m; \ j = 1, \ldots, n \end{cases} \tag{7}$$

At the next step, we check the minimax optimality conditions:

$$\sum_{i=1}^{m}\sum_{j=1}^{n} p_{ij} y_{ij}^k \leqslant \sum_{i=1}^{m}\sum_{j=1}^{n} p_{ij} y_{ij}^{k+1}; \tag{8}$$

$$\sum_{i=1}^{m}\sum_{j=1}^{n} z_{ij} y_{ij}^k \geqslant \sum_{i=1}^{m}\sum_{j=1}^{n} z_{ij} y_{ij}^{k+1}. \tag{9}$$

There are two possible cases:

1) if conditions (8) and (9) are satisfied, then we fix the new point y_{ij}^{k+1}. Further, the implementation of a random search is already carried out from it in order to find a more optimal point y_{ij}^{k+1};

2) if conditions (8) and (9) are not fulfilled, then we return to (4) and make another attempt — a new step φh^k.

At the next stage of solving the optimization problem, we check the condition for the end of the search for the optimum — if, for a given number of tests N, no more optimal value is found at each point y_{ij}^{k+1} , in which the objective functions (5) and (6) are optimal, then the search stops.

Thus, the statistical modeling of the economic efficiency of the technological production of compaction of subsidence soils by deep explosions is carried out in the work. An approach to solving a statistical model by the method of random multicriteria optimization is proposed.

СПИСОК ЛИТЕРАТУРЫ

1. *Galay B. F.* Compaction of subsidence soils by deep explosions. Stavropol, NCFU, 2015, 240 p.
2. *Tarasenko E. O.*, *Shaposhnikov A. V.*, *Gladkov A. V.*, *Tarasenko V. S.* Mathematical modeling of multidimensional optimization of production of thin-film structures by convolution criteria. Inzhenernyj vestnik Dona, 2019, No 4. http://www.ivdon.ru/ru/magazine/archive/n4y2019/5927
3. *Tarasenko E. O.*, *Tarasenko V. S.*, *Gladkov A. V.* Mathematical modeling of consolidation of subsidence loess soils of the North Caucasus deep explosions. — Izvestiya Tomskogo politekhnicheskogo universiteta. Inzhiniring georesursov, 2019, v. 330, № 11, p. 94–101. http://izvestiya.tpu.ru/archive/article/view/2352

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Statistical modeling of the economic efficiency of blasting operations for compaction of subsidence soils by the method of random optimization

Abstract: Planning of technological production works on compaction of subsidence soils by deep explosions requires significant investments and labor costs. At the same time, statistical modeling allows you to optimize the production process to achieve its economic efficiency and stability of indicators. Modeling of blasting operations leads to the solution of multi-criteria optimization problems. In this article, an approach to solving a statistical model by the method of random multicriteria optimization is proposed. Random optimization methods, in contrast to deterministic methods, require less computational resources with an increase in the dimension of the problem being solved.

Keywords: economic efficiency, compaction of subsidence soils, loess, multi-criteria optimization, production, random search.