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CONTROL WITH ACOUSTIC METHOD OF DISINTEGRATION OF ROCKS BY ROTARY DRILLING

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The contribution describes the technical and algorithmic solution of the optimization of rotary drilling. The global optimization criteria express the minimum specific energy on drilling and the maximum speed of drilling. The article presents the first results of research on the utilization of acoustic methods in indirect measurement of criterion function by optimizing these processes.

Key words: *rotary drilling, monitoring and optimal control, acoustic signal by drilling*

Kontrola akustičnom metodom raspada stijena pri rotacionom bušenju. Rad opisuje tehničko i algoritmičko rješenje optimalizacije rotacionog bušenja. Globalna optimalizacija kriterija izražava minimalnu specifičnu energiju bušenja i maksimalnu brzinu bušenja. Članak predstavlja prve rezultate istraživanja primjene akustičkih metoda u neizravnom mjerenju funkcije kriterija optimaliziranjem tih procesa.

Ključne riječi: *rotaciono bušenje, monitoring i optimalna kontrola, akustički signal pri bušenju*

INTRODUCTION

The process of rotary drilling of rocks is determined by several factors, the main of them being:
- the physical - mechanical characteristics of rocks,
- characteristic of drilling tool,
- regime of drilling (P- power, n - revolution, v - drilling velocity, F - force, etc.),
- regime of washing out.

For an optimization of this process the following criteria are used:
- maximum lifetime of the tool,
- maximum speed of drilling,
- minimum specific energy of drilling.

Two optimization criteria were formulated in [1 - 3]:
- minimization of specific energy W (J·m^{-3}):

$$W = \frac{P \cdot t}{V} \tag{1}$$

- maximization of average drilling velocity v (mm·s^{-1}) or combined optimization criterion
- maximization of ratio φ (mm·s^{-1}(J·m^{-3})):

$$j = \frac{v}{W} \tag{2}$$

The process of rock separation, from the viewpoint of its control, has two basic control quantities: the pressure force F and the rpm of the drilling tool n. In Figure 1. the dependence of the criteria functions (1), (2) and (3) on the pressure force for three different rock types are shown [3]. It is clear from the Figure that an optimum pressure force exists. Obviously, a different situation will occur in the case of increased rpm when it is possible to assume a theoretically unbounded increase in the speed of separation. It follows that the location of the actual extremum of the criterion function can be outside the work area which is limited by the technical capabilities of the drilling device. The above fact determines the choice of suitable optimization method and the corresponding algorithm.

OPTIMIZATION ALGORITHMS

The process of rock separation is very complex and stochastic from the modelling and control points of view. It is a multi-parameter problem. In our work we have only considered two basic technological parameters of the process,

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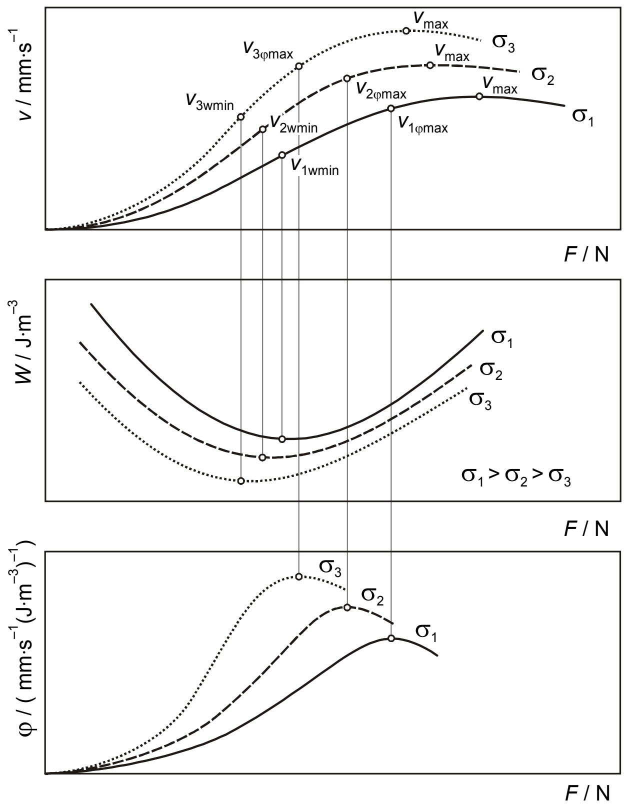

Figure 1. **Dependence of criteria functions on the pressure force for different types of rocks**
Slika 1. **Ovisnost kriterij funkcija o sili tlaka za različite tipove stijena**

namely the pressure force and the rpm. Thus a two-parameter optimization task arises with the criteria function:

$$j = j\ (F,\ n) \tag{3}$$

and the optimum conditions in the form:

$$\frac{\partial j\ (F,\ n)}{\partial F} = 0 \tag{4}$$

$$\frac{\partial j\ (F,\ n)}{\partial n} = 0 \tag{5}$$

It is unrealistic to exactly express the criterion function (3) for the purpose of optimization of the process. From the published works, e.g. [1], only its approximate geometric shape can be guessed, which eventually can affect the successfulness of the chosen optimization algorithm. Therefore, the method of direct search of the extremum was used based upon continuous measurements of the criterion function.

In particular, the simplex method which was used consists in mutual comparison of the measured values of the criterion function φ at the vertices of the simplex and in the search of the next direction of approaching the extremum. In doing that we had to follow the technological restrictions of the process.

To verify the suitability of the chosen optimization method and to verify its stability in this type of problem, simulations of the algorithm were performed in the

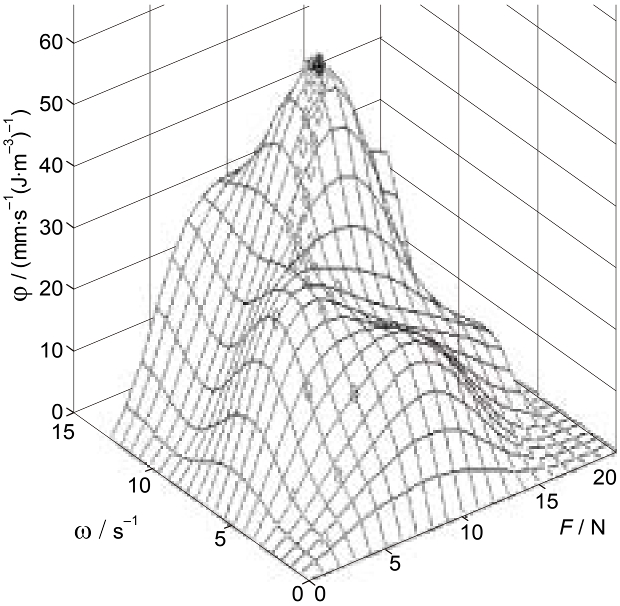

Figure 2. **Spatial representation of the search for the criterion function extremum by using the simplex method**
Slika 2. **Prostorni prikaz traženja ekstrema kriterij funkcija uporabom jednostavne metode**

MATLAB environment with a suitable type of a single-extremum criterion function. Some results are shown in Figures 2. and 3.

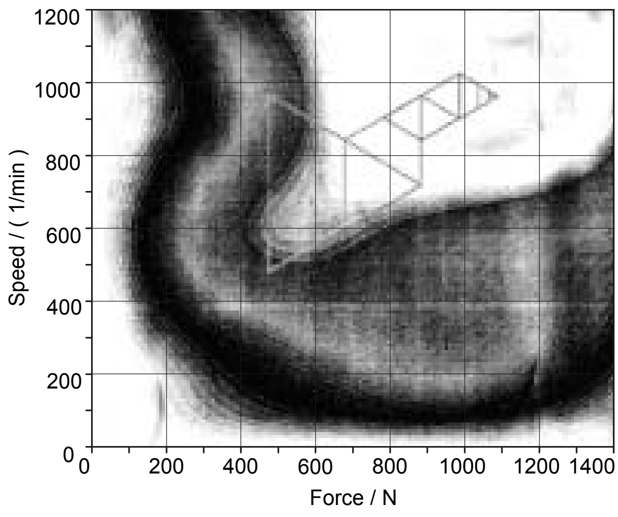

Figure 3. **2D representation of the search for the criterion function by using the simplex method with lower accuracy requirement**
Slika 3. **2D prikaz traženja funkcije kriterija uporabom pojednostavljene metode s nižim stupnjem točnosti**

The simulations confirmed that the simplex method is suitable for the solution of this type of problems. Its stability is good, the efficiency of the algorithm depends on the initial condition, the size of the simplex, and the required precision. The choice of a suitable modification of the basic algorithm is also important, especially at the stage of approaching the extremum.

USE OF THE ACOUSTIC EFFECT OF THE SEPARATION PROCESS FOR THE PURPOSE OF OPTIMIZATION

A separate problem that was and is paid attention to is the question of indirect measurement of the criterion function based on an analysis of acoustic signals which accompany the process of separation.

Preliminary experimental results (Figure 4.) confirm the correlation between the acoustic signal dissipation and the optimum pressure force. Maximum dissipation was reached in the neighborhood of optimum pressure force [4].

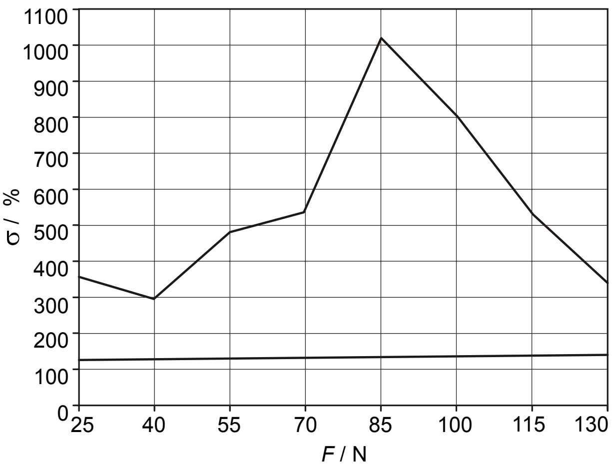

Figure 4. **Dependence of acoustic signal dissipation on the pressure force *F***
Slika 4. **Ovisnost rasipanja akustičnog signala o tlaku sile *F***

In this work a recognition algorithm was developed for rock classification from the viewpoint of its geomechanical properties, where the descriptor of the coresponding class is the associeted characteristic spectrum of the acoustic signal.

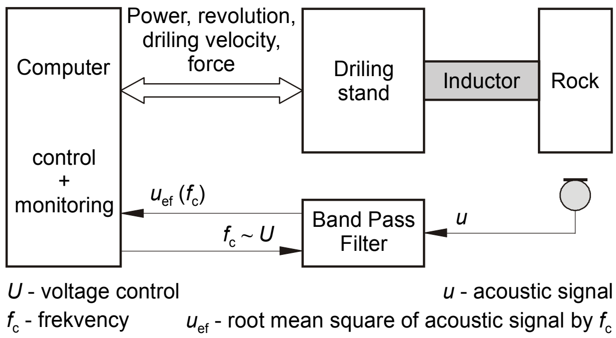

Figure 5. **Schematic diagram of the experimental stand**
Slika 5. **Shematski dijagram rasporeda opreme u provođenju eksperimenta**

CONCLUSION

The problem of optimum control of rock separation by rotary drilling process was defined. A simplex method was chosen for the search of the optimum of the process at minimum specific energy of separation. Simulations were used to verify the stability of the method. The determination of the criterion function in the control process is provided by direct measurement, namely by the measurement of the energy balance of the separation or accompanying acoustic signals.

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