CONTROL AND OPTIMISATION OF ROCK DISINTEGRATION BASED ON ACOUSTIC BACKGROUND OF DRILLING MACHINE

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Abstract: Rock disintegration is on of the most important operation s of mineral resources excavation and treatment technologies. This paper deals with of rock drilling control and optimization by acoustic signal. During the disintegration process, the thrust of the drilling tool, revolutions, drilling speed and disintegration power have been monitored. This paper analyses experiment results for disintegration process optimization with use of acoustic signal.

Keywords: optimisation, drilling, acoustic signal

1. INTRODUCTION

The processes of mineral mining and underground drilling belong to energetically demanding processes. In these processes, the method of rock separation by rotary drilling is widely used. Therefore it is necessary to investigate these processes from the viewpoint of reduction the energy costs.

One of the ways to cut energy costs of rock separation is to create a know-how. The classical use of optimisation requires the measurement of several quantities since we are dealing with multi-parameter optimisation (Kostúr and Futó, 2001). The aim of the research in 1999 through 2002 was to reduce the multi-parameter optimisation into single-parameter one.

A phenomenon accompanying the process of rock separation through drilling is the creation of noise. And this noise can be the ideal parameter for optimisation. Put in other words, based on the measurement of sounds emitted in this process an optimum control of rotary drilling should be attempted. The results of research hinted at the possibility of using the sound emittance analysis for different industry, for example in rock identification (Neustupa, 1998), undesirable phenomens prediction in steel production (Tréfa, 2004). Rock identification has double significance. The first one consists in the choice of suitable drilling tool (indentor) for the particular rock. The second one is in improving the geological knowledge (geological map) of rocks.

2. OPTIMIZATION CRITERIA

The aim of analysis has been investigation of objective function on independent variables (force, revolutions) and dependent variable (the acoustic signal).

The optimisation criterions are variously:

- the maximal lifetime of drilling tool
- the minimisation of specific energy
- the maximal output of drilling machine.

The optimisation criterions were formulated following:

- the minimisation of specific energy

$$w = \int_{\tau} \frac{P(\tau)}{V(\tau)}.d\tau \qquad \left[J.m^{-3}\right] \qquad (1)$$

- the maximisation of ratio

$$\varphi = \frac{v(\tau)}{W(\tau)} \qquad (2)$$

where
P is the power [W]
V is the drilled volume [m^3]
w is the deformation work [$J.m^{-3}$]
τ is the time [s]
v – is the average speed of infeed motion [$m.s^{-1}$].

The optimisation criterion (2) is realistically as w because it is complex. From measurement of the pressing force, the drilling volume, the speed and power we can compute values (1), (2) in some time.
Further in the paper we only deal with optimisation of rock separation from the viewpoint of energy cost minimisation.

3. LABORATORY ENVIRONMENT CHARACTERIZATION

The goal of the experiment conducted at the Slovak Academy of Science (SAV) laboratory at the trial stand was to determine, by using the Mediator 2238 sound meter of the Bruel Kjaer company, the effects of changes in the mode of separation and of the rock on the acoustical behavior of the environment and evaluate these changes in dependence on the optimum mode of separation.
The research in this field has been made on experimental drilling stand (see Fig 1).
The stand is situated in horizontal level. The rock is fixed in head. The core drill (31) is fixed in drilling head (2). The aim of research was to investigate the influences of exchange of force and revolutions on drilling regime.
Our monitoring system has measured following variables:

- the pressing force of core drill
- the revolutions of drilling head
- the length of drilling
- the time
- the power
- the acoustic signals.

The monitoring system has been realised by help PLC cards and standard PC.

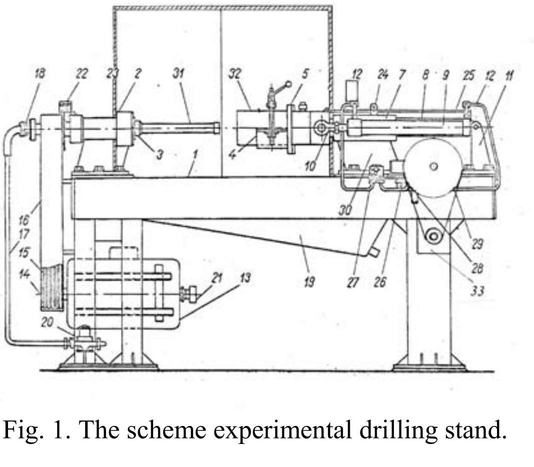

Fig. 1. The scheme experimental drilling stand.

4. THE ANALYSE OF ACOUSTIC SIGNAL AND WORKING CAPABILITY OF SEPARATION TOOL

In Figure 2 and 3 are plots showing the dependence of the working capability of separation tool on the pressure at various modes of separation of andesite and granite and its dependence on thrust. Based on these plots we can determine the value of φ and mutually compare individual working modes of the trial stand at equivalent revolutions and various pressures. In both cases in the plot of Figure 2 and 3 the each points are marked by number of measurement and also by different ‚dP‘.

The calculation of value φ is based on these variables:

- time of drilling
- the length of drilling
- used energy
- geometry of drilling tool

This method was theoretically describes in many publications. However, this method can not be used in real time control, because the variables needed to be measured are not available during drilling.

Therefore the next method of evaluating the working capability is useful in terms of possible real time drilling control. The algorithm of optimal control was described in (Kostúr and Futó, 2003) and therefore we present very briefly principal of optimal control. The method uses instead of mentioned variables the noise (sound). In the plot of Figures 4 and 5 are shown the measured equivalent levels of sound at the drilling of andeste (Fig. 4) and granite (Fig. 5) on frequency at various revolutions. In the Figure 6 we can see five columns for each frequency band (31,5 ; 63; 125 … 8000). The first four columns represents the levels of sound measured at drilling tool at various modes (revolutions, thrust). The curves in the plot are trends that approximate the course of sound levels in each band.

The fifth column is a special case represents a level of sound when drilling tool was in idle mode. It represents an ideal state in term of working capability and also in term of sound.

The estimating of working capability is based on comparing the areas below trends of columns 1 to 4 with area of special case, column 5. We get the different ‚dP’ that can be mathematically expressed:

$$dP = \int_a^b f(x)\,dx - \int_a^b g(x)\,dx. \qquad (3)$$

If dP is lower, it means that working capability is better on the other hand the higher value of dP says about non efficient working capability and therefore control system should change either revolutions or thrust. The control system in real time can processes the acoustic signal and calculates the dP in other words working capability.

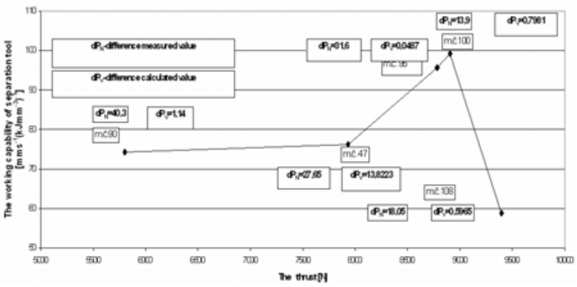

Fig. 2. The dependence of the working capability of separation tool on the thrust at various drilling modes of andesite.

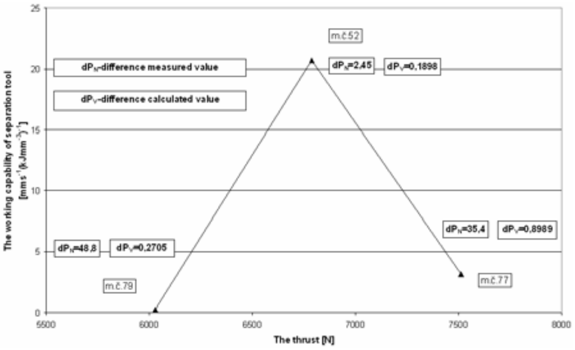

Fig. 3. The dependence of the working capability of separation tool on the thrust at various drilling modes of granite.

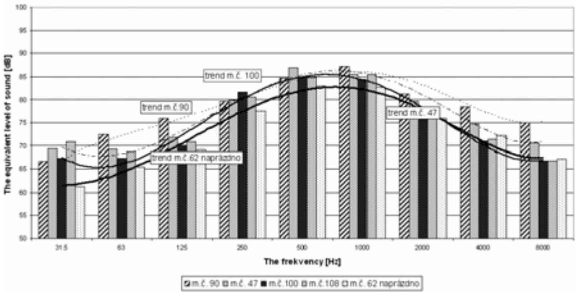

Fig. 4. The comparison of equivalent levels of sound and their trends at various frequencies in idle mode and during andesite disintegration.

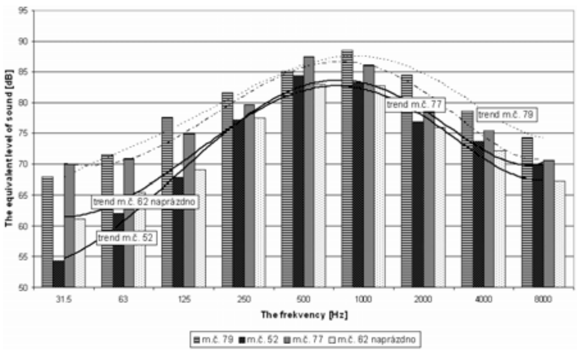

Fig. 5. The comparison of equivalent levels of sound and their trends at various frequencies in idle mode and during granite disintegration.

5. CONCLUSION

In the rock disintegration process acoustic signal is obtained. It was evaluated by different methods, as presented in (Chlebová, 2004, Futó, 2003, Miklúšová, 2004) There is Experimental measurements show the possibilities of utilising acoustic signals for optimal control drilling machine. Results of research in this field were used for creating of algorithm of optimal control. This algorithm was verified in laboratory. The equivalent level for representative frequency depends also on types of rock.

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