Measuring procedure of experimental data acquisition and data evaluation of acoustic emission in rock disintegration

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The paper describes the results of measurements of acoustic signal arising in rock disintegration on the drilling stand of the Institute of Geotechnics SAS in Košice. The acoustic signal was registered with sonometer Mediator 2238. Registration and processing of the acoustic signal is solved as a part of the research grant task within the basic research of the rock disintegration by drilling.

Key words: *acoustic signal, rock drilling, sonometer Mediator 2238.*

Introduction

Several research tasks concerning the character and mechanism of rock disintegration process and relations between the input parameters of the dynamic system indentor-rock, such as the thrust force and torque, and the output parameters of the system, i.e. rock chipping depth, instant advance drilling rate, specific disintegration energy, were investigated during the research of rock disintegration on laboratory experimental stand at the Institute of geotechnics SAS in Košice. As the rock disintegration process is accompanied by the transformations of various types of energy, one of available evaluation method of disintegration mechanism is connected with the use of one of such accessory effects of rock disintegration as an integrated information source, i.e. the use of acoustic signal. This conception formed an assumption that both the signal of mechanical vibrations and the accessory signal of noise contain information on conditions and state of the disintegration process, which might be used for its control and optimization (Leššo, 2004).

Parameters characterizing the rock disintegration process

Disintegration tool rotating around its own axis disintegrates the rock by rolling on its surface with simultaneous action of thrust force. The interaction of the tool and rock plays the main role in the rock disintegration process, as it determines the disintegration mechanism, thus defining the efficiency, energy consumption, advance rate of the machine in a given rock with certain parameters of rock disintegration regime, etc.

The torque of rotary tool is affected by thrust force *F*. Disintegration performance *P* is calculated from torque M_K and tool revolutions *n*

$$P = 2\pi n M_K , \qquad [kW] \tag{1}$$

Disintegration performance or a combination of torque and advance rate provide the determination of specific disintegration energy *w*

$$w = \frac{P}{S\,v} , \qquad [MJm^{-3}] \tag{2}$$

where *S* is disintegrated area and *v* is an instant drilling rate. Presented formula enables to determine the instantaneous value of specific disintegration energy with an assumption that we obtain the instantaneous

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values of power consumed for disintegration and instantaneous value of advance rate of drilling tool. Average values of specific disintegration energy for predefined time intervals are determined by

$$w = \frac{A}{V}, \ [MJm^{-3}] \qquad (3)$$

where A is a work consumed for rock disintegration in time t and V is a volume of disintegrated rock in the same time. Dependence of specific disintegration energy w, drilling rate v and the ratio of the two parameters φ on the uniaxial compressive strength of rock is presented in the Fig. 1. The dependence was confirmed by experiments at the UGT SAV and by the in-situ measurements on full profile tunnelling machines.

Presented formula can be transformed to the form

$$\varphi = \frac{v}{w} \quad [mms^{-1}(MJm^{-3})^{-1}] \qquad (4)$$

as presented in the Fig. 1.

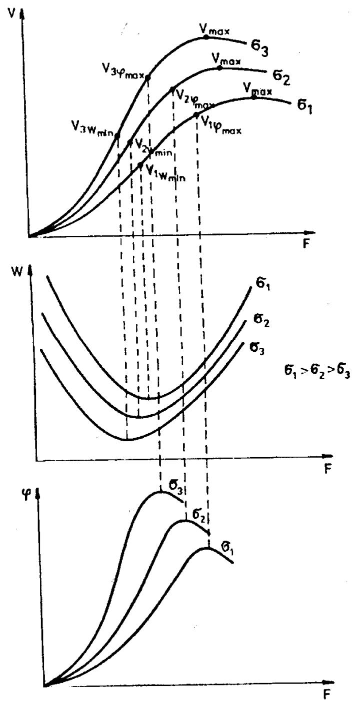

Fig. 1. Behaviour of instantaneous drilling rate v, specific disintegration energy w and the ratio of both variables φ depending on the thrust force F.

It is necessary to emphasize the bound of v, w and φ with the uniaxial compressive strength of rock σ. Increase of σ causes the decrease of v, increase of w and decrease of φ, which implies that the rocks "more resistant" to disintegration by drilling exhibit a flatter logistic behaviour of the curves. This case represents a sequence of spatially comparable data, arranged from the lowest to the highest thrust values, i.e. a two-dimensional data selection, where a random variable penetration depth is bound with the thrust, or forms an inseparable pair.

As the rock disintegration process is accompanied by the transformations of various types of energy, one of available evaluation method of disintegration mechanism is connected with the use of one of such accessory effects of rock disintegration as an integrated information source, i.e. the use of acoustic signal. Several research teams have focused their investigation on acoustic signal evaluation on various processes, e.g. use of acoustic signal for monitoring of metal cutting process (Kumičáková, Poppeová, 1994), use of acoustic signals for process control in coal and feigh separation (Neustupa, 1998; Neustupa, 1999; Neustupa, Létavková, 2005). In case of propagation of oscillation waves in solid environment, the accompanying signal is represented by vibrations; this research field has been covered in the work of Miklúšová (2006).

Procedure of evaluation required experimental data obtained from measurements with sonometer Mediator 2238.

Evaluation of presented data is based on:

1. dependence of instantaneous drilling rate *v*, of specific disintegration energy *w* and of the ratio of both variables *φ* on the thrust (Krúpa, Pinka, 1998),
2. experiments with data acquisition by sonometer Mediator 2238, which scanned and recorded the data on acoustic behaviour of the surroundings in various regimes of disintegration process.

Figures 2 and 3 present dependencies of working ability of disintegration tool on the thrust at andesite and granite drilling at measured disintegration regimes.

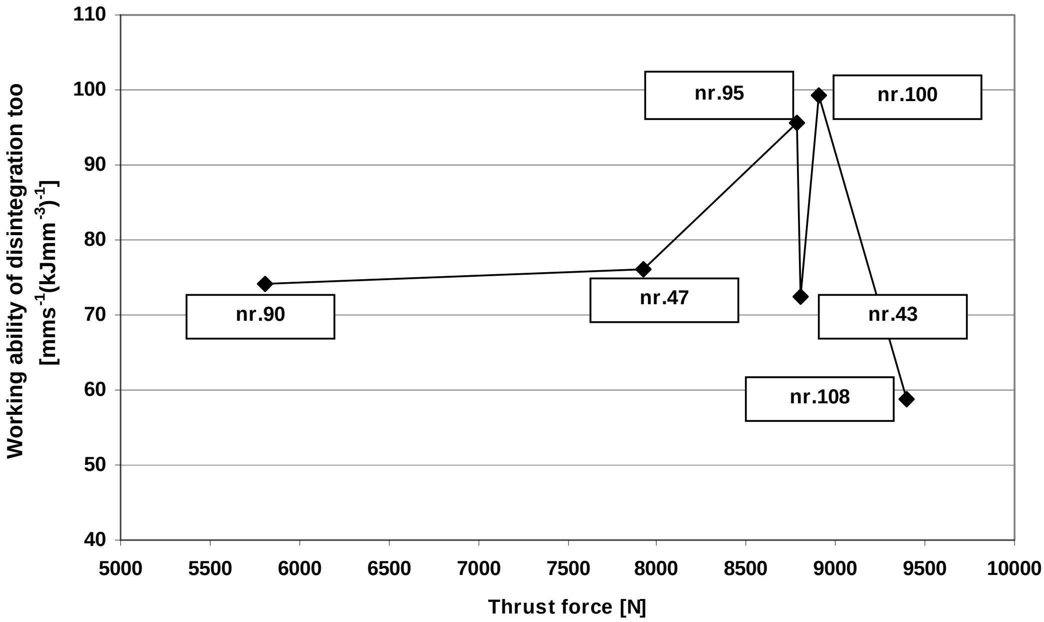

Fig. 2. Dependence of the working capability of drilling tool on the thrust force at various drilling regimes of andesite.

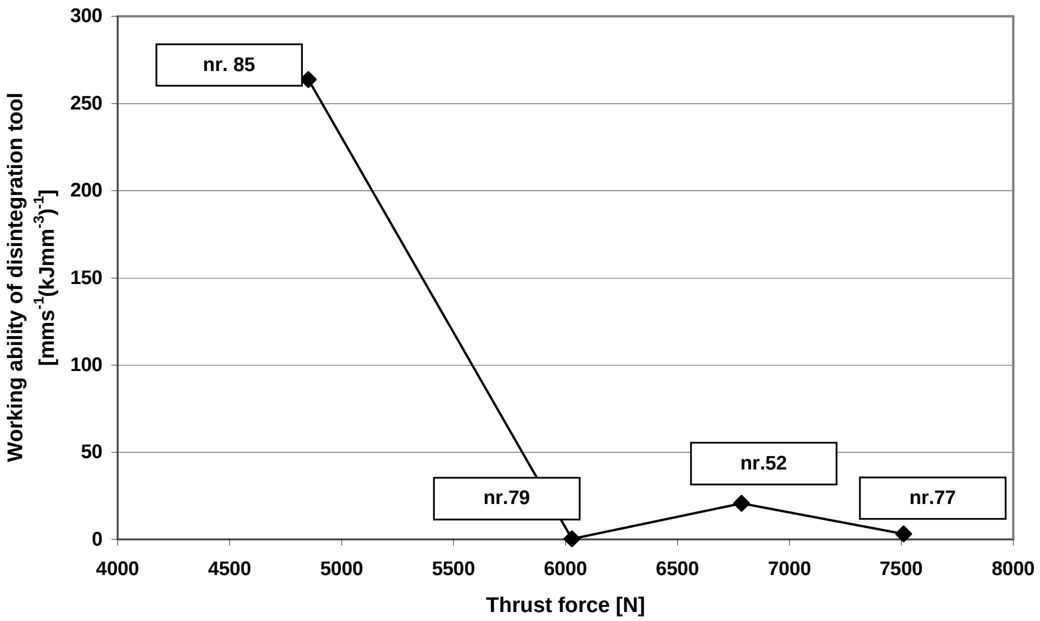

Fig. 3. Dependence of the working capability of drilling tool on the thrust force at various drilling regimes of granite.

Procedure of experimental data acquisition

The graphs were constructed based on measurements denoted by numbers 90, 47, 95, 43, 100, 108 (andesite) and 85, 79, 52, 77 (granite), which should have covered whole technological range of thrust and revolutions of experimental drilling stand. Typical curves fully corresponding to theoretical behaviour of variable φ were accompanied with inaccuracies.

In the first case (Fig. 2), the measurement nr.43 exhibits the working ability of disintegration tool approximately only half the size of assumed theoretical behaviour of the given dependence. In the second case (Fig. 3), the measurement nr. 85 represents such a working ability of disintegration tool that is comparable with the working ability of the disintegration tool at andesite drilling, which is much lower, that expected value.

Measured results can be explained by inhomogeneities of disintegrated rock, i.e. different mechanical or technological properties of the rock samples in the course of rock sample drilling. Measurements nr. 43 and nr. 85 were excluded from further acoustic signal evaluation.

Sound pressure levels in particular octave bands were measured by the sonometer Mediator 2238 in the experiments with andesite and granite drilling and in the idle run of the drilling stand at equivalent revolutions and thrusts applied.

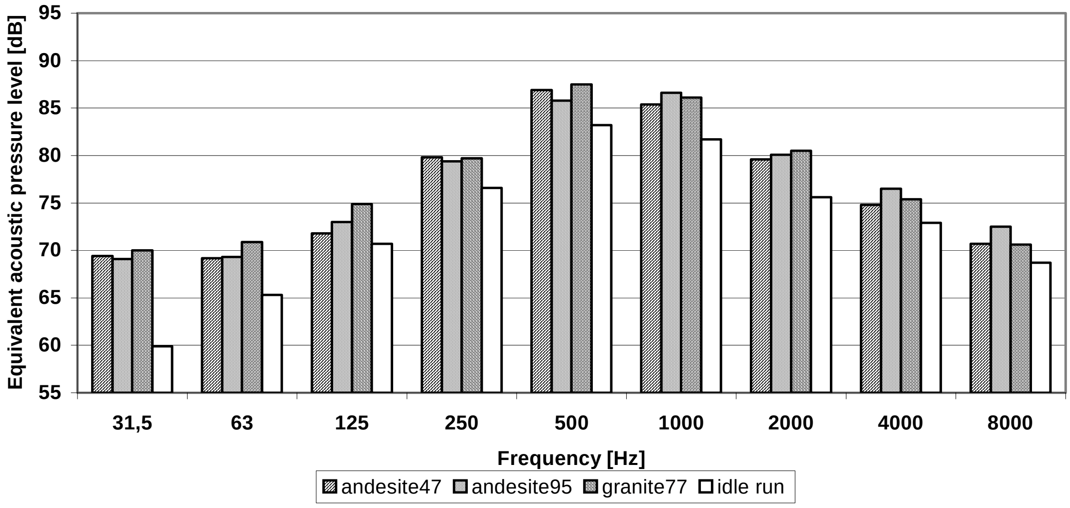

Fig. 4. Comparison of measured octave spectra at andesite and granite drilling (nominal thrust 8000 N and revolutions 18,33 s^{-1}).

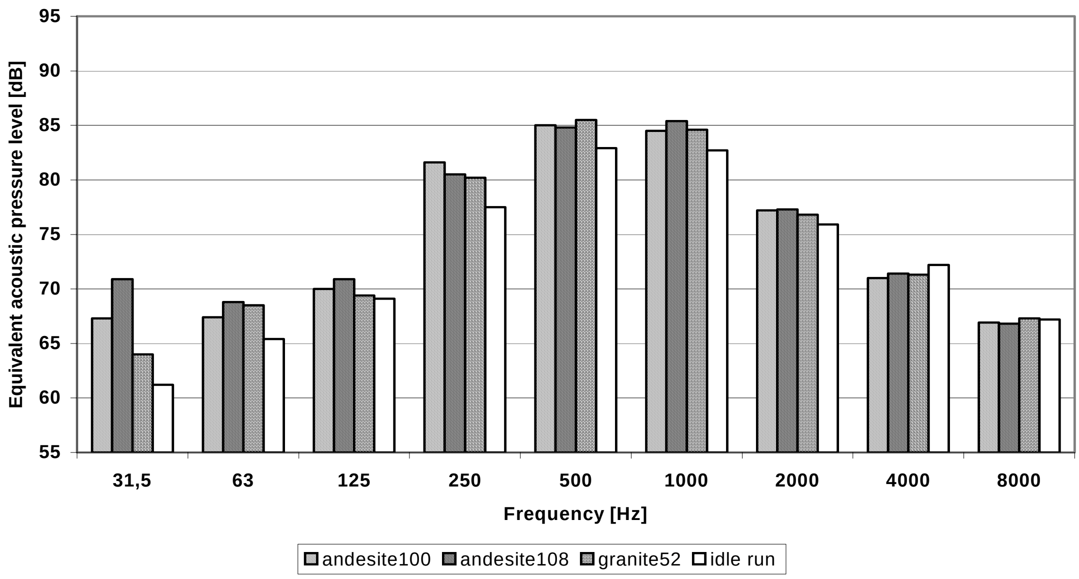

Fig. 5. Comparison of measured octave spectra at andesite and granite drilling (nominal thrust 9000 N and revolutions 13,33 s^{-1}).

All the measured behaviours were of similar character, whilst the acoustic pressure in individual octave bands ranges from 60 to 90 dB. Despite the different regimes and different drilled rock types in experiments, their acoustic behaviours show almost the same values in all the octave bands. The maximal values were reached in the fifth and the sixth octave band, i.e. at the frequencies of 500 Hz and 1000 Hz. Minimal values were present in the first and the ninth octave bands, i.e. 31.5 Hz and 8000 Hz.

Lower frequencies were present in the spectrum regarding the acoustic behaviour, which means that the rock disintegration process by drilling may be described as a low-frequency process. Measured differences in individual bands were minimal and range from several tenths of dB to 5 dB.

Fig. 4 shows behaviour of acoustic pressure in individual octave bands for two measurements in andesite drilling, one in granite drilling and one in idle run of drilling aggregate with equivalent revolutions and thrust applied. When comparing the values of acoustic pressure in individual octave bands, an increase of acoustic pressure was observed in the first five octave bands in both andesite and granite drilling. Decrease of acoustic pressure was present in the sixth and ninth octave band in andesite drilling and in the eighth octave band in granite drilling. Presented differences range from 1 to 3 dB.

Fig. 5 represents the graphs of two regimes for andesite drilling, one for granite drilling and for better orientation also one for idle run of drilling aggregate, at equivalent revolutions, which serves as an etalon for evaluation of other regimes. Increase on acoustic pressure was present on the first six octave bands in both andesite and granite drilling, and a slight decrease showed up in the seventh, eighth and ninth band in andesite drilling and in the eighth octave band in granite drilling, with presented differences ranging from 0,1 to 1 dB. The largest differences were present in the first octave band, from 2,1 to 9,9 dB when compared to the idle run. The largest difference between the acoustic behaviour of the andesite and the granite drilling were spotted in the first octave band as well.

The differences of acoustic pressure in individual octave bands were minimal when regarding the determination of the rock type using the sonometer at the measured disintegration regimes.

Conclusions

Comparison of both disintegration regimes was resumed as follows:

1. Acoustic pressure of granite drilling was higher in the first three octave bands and in the fifth and the seventh octave bands at nominal thrust F = 8000 N and nominal revolutions n = 1100 min^{-1}. The fourth, the sixth and the eighth octave bands exhibit values almost the same as at the andesite drilling. Only the ninth octave band shows slight decrease of acoustic pressure level at granite drilling. This lead to the claim that granite drilling with higher revolutions runs at lower frequencies that the andesite drilling.

2. Experiments with nominal thrust F = 9000 N and nominal revolutions n = 800 min^{-1} showed higher acoustic pressure in andesite drilling in the first four octave bands and in the sixth and seventh bands. Higher values of acoustic pressure level in granite drilling than in andesite drilling occurred in the fifth and the ninth octave bands. The eighth octave band showed almost equal measured values

We can claim that the granite drilling with higher revolutions exhibits lower frequencies of acoustic signal than the andesite drilling and vice versa, lower revolutions applied in andesite drilling caused lower frequencies of acoustic signal that the granite drilling. The values of acoustic pressure levels measured at various drilling regimes show only minimal differences, which disables to determine the drilled rock type or applied regime properly. It is necessary to note that measured values were also affected by an integrating character of used sonometer, i.e. the length of experiment during which the predefined parameters of drilling regime and the homogeneity of the rock were changing. It is necessary to search for a more proper model of the process regarding the identification of the drilled rock type. Presented measurements provided the determination of typical acoustic pressure level of the rock drilling, which reaches approximately 85 dB.

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