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ACOUSTIC EMISSION WITH TESTING THE PRESSURE RESISTANCE AND STRUCTURAL INTEGRITY IN MINERAL FEEDS

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This work deals with a specific method of non-destructive testing – acoustic emission. The theoretical part of the article is focused on the underlying principle of this method and its applicability. The experimental part is focused on the research of pressure resistance in mineral feed using acoustic emission. Mineral feed is a condensed cube of rock salt (sodium chloride) with supplementary minerals, which is fed to livestock and game to supply the mineral elements necessary for their health and condition. Acoustic emission gives the overview of internal changes in material structure. With use of specific software we can interpret the acoustic signal and identify the current state of material integrity in real time.

Keywords: acoustic emission; non-destructive method; mineral feed; pressure resistance

Mineral feeds are compacted cubes of rock salt with added mineral nutrients, which are fed to livestock and game. The level of mineral nutrients in animal diet has a direct influence on their condition and health. This is of utmost importance especially for herbivores who intake excess of potassium in forage and pasture grass (Losertová, 2007).

The topic of this study is assessment of mineral feed durability against pressure tension. For an exact description of destruction progress in material, the acoustic emission (AE) method was selected (Fiala et al., 2003). Acoustic emission is a non-destructive passive method, which means it does not affect the examined object and reports integral information considering the momentary dynamic state of material, which is considered its main benefit. Acoustic emission signals are caused by dynamic structural changes in material and manifest themselves as a gradual elastic wave. The source of these wave hits is a sudden release of energy in material. This process accompanies deformational, break, respective phase changes in material (Kopec, 2008).

Material and methods

Acoustic emission

A Xedo analyser (Fig. 1) manufactured by a Dakel company is a modern high-performance modular apparatus for measuring and analysing the parameters of acoustic emission. The analyser is designated for connecting the passive piezoelectric corundum sensors without the amplifier, or active sensors with integrated pre-amp supplied with 12/24 V. Processing of signal sampled in 2–8 MHz with 12-bit resolution is fully digital. For this specific case of measuring, we selected an IDK-09 sensor with a corundum connection plate (Figure 2).

For the testing set of mineral feed samples, the optimum dimensions were suggested, which represent real

Figure 1 Xedo analyser

Figure 2 Sensor of acoustic emission

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Figure 3 Samples of mineral press

dimensions in a 1 : 5 ratio for pressure testing. The tested object was shaped in truncated cone shape (Figure 3). For precise measurement, the top and bottom surfaces were milled perpendicular to its longest axis. On the sample surface, a notch was filed for easier fixation of the sensor to ensure better contact between the sample and sensor.

Examined samples were divided into 4 different groups (A, B, C, D), each containing 10 samples. Each group of samples represented different characteristics, which were compared with each other. For designating the best variety of sample durability, the least favourable variant should be considered, in our case the worst values occur in the groups B and C. For further experiment, the samples of the A and D groups were selected. Samples were fitted with the piezoelectric AE sensor for detailing characteristic assessment.

Course of assessment

For testing the pressure resistance of mineral feeds, we have used the manual press. Individual samples were placed into the mechanical press (Kopec, 2008). Tested samples were subjected to a constant pressure of $10 \text{ mm} \cdot \text{min}^{-1}$. It is possible to record the continuous deformation and log the acoustic emission signals in this process (Pazdera et al., 2004). To obtain accurate results, the measuring system needed to be calibrated according to specific prerequisites for material using the pentest in Table 1.

The root mean square (RMS) of AE was observed. This parameter means the effective signal value. In alternating current, RMS is equal to direct current value, which after employment of resistance load would exhibit the same average performance. The RMS is reported in the range of

mV. This value describes the quantitative characteristic of measured AE events (quantum of energy).

Table 1 Configuration of the Xedo measuring apparatus

Setting the configuration for AE	Value
Amplifier	5 dB
Starting event	110
Ending event	110
Count 1	102 mV
Count 2	200 mV

Acoustic emission signals in pressure testing were recorded with one corundum piezoelectric pickup sensor Dakel, fixed in the upper part of tested sample with a spring-loaded clip. To ensure the optimal acoustic transfer between the sensor and material, we used 'ultrasonic gel'. The primary function of cohesive medium is to repel the air present between contact surfaces, thus to enhance the signal transfer (Askeland et al., 2006).

For individual samples in experiment, the unified testing procedure was used. Data were measured consecutively in whole test duration with the AE system installed on the testing apparatus, see Figure 4.

Results and discussion

Parameters were assessed with the mean level of detected signal – RMS and the count of overshoots over threshold levels in selected intervals. The measuring system Daemon

Figure 4 Mounting diagram of sample and acoustic emission sensor at a test facility

Figure 5 Representative parameters of acoustic emission output from the specimen A5

Figure 6 Representative parameters of acoustic emission output from the specimen D4

Figure 7 Representative acoustic emission event and PSD functions for the specimen A5

evaluates RMS and overshoots count in two threshold levels (Count 1 and Count 2).

In Figure 5 it is clear to distinguish two relevant periods of AE signal. The

first signal (1) was recorded to the third second of pressure application, and the second signal (2) took place from the fifth to ninth second and further with descending trend until

the end of testing. This means that the first signal emission is an indicator of rapid destruction in material. The second rapid emission with the following descending trend indicates consecutive crushing, in which structure cohesion decreases.

From the test results of the A5 sample it is obvious that the maximum RMS is approximately 30 mV in the first period kHz in the sum of both measurements. The sample is hard and fragile, structure has low resistance to pressure load. The sample still shows distinctive cohesion, which continuously ceases from the eighteenth second of load, when crumbling of sample begins.

Figure 5 shows high AE periods of mineral feed. The count of local deformation damage corresponds to AE events with high peak amplitude and low peak of frequency. Some of new cracks are not 'heard' by the sensors. Hypothetically, these continuing events can be related to propagation of the earlier formed cracks. However, for all observed cracks, it is not possible to get the correlations of all individual readings of AE events locations. High AE periods should represent failure material (Masmoudi et al., 2015), which can be observed in the figure; therefore, these events do enter the analysis of mineral feed cracking.

Figure 6 represents the record of acoustic emission for the sample D4. There is visible continuous destruction of material without a significant primary AE impulse, thus without primary rapid destruction of structure. Cohesion is lost gradually. From the fifth second, there are distinctive accented acoustic manifestations in the process of crumbling of material.

From the test results of the D4 sample, it is certain that the maximal RMS is achieved at 15 mV in the first period and AE frequency is 75 kHz in both temporal periods.

Table 2 Displays parameters of RMS and frequency of AE signal for individual specimens

Specimen	Specimen density ρ in $\text{kg}\cdot\text{m}^{-3}$	Maximum root mean square (Max RMS) in mV	Maximum number of events in kHz
A5	1347.875	30	90
D4	1259.133	15	75
C3	1003.372	10	29
B3	1017.412	9	21

Figure 8 Representative acoustic emission event and PSD functions for the specimen D4

The highest RMS was reported for the A5 sample as well as the highest count of recorded signals. The D4 samples show lower values of the RMS parameter. From this we can conclude that the samples from the A4 group show higher resistance to primary destruction of structure, which occurs earlier than in tougher samples of the D group.

Figures 7 and 8 display the sample of signal on the left and on the right the frequency analysis of signal (Power Spectral Density – PSD function), which expresses the AE signal energy. The horizontal axis in the right window of PSD function designates the frequency in kHz, and the vertical axis represents energy in mV. The PSD function characterises the samples of individual events of AE and represents the overview of frequency constituents of the signal. The assessment of experiment was conducted by visual comparison of PSD functions with a goal to distinguish the most important phenomena occurring in both diagrams and determination of basic mapping of both signals.

Representing A5 sample of AE (see Figure 7 right) determines the selective area for the PSD analysis. The maxima of recordable events for the PSD function occurred at 90 kHz. This information indicates the part of acoustic signal recordable at initiation of destructive fissure. The analysis of sample indicates the wider amplitude. The energy of the signal is therefore higher. It is possible to claim that the mechanical resistance of group samples is higher than the resistance of the D group. Primary destruction of material occurs from the third second further, but is followed by gradual disintegration of material.

The samples of AE signal and PSD analysis at representative sample D4 (see Figs. 6, 8) display lower values of PSD. There is obvious the descending trend of signal energy. From this we can conclude that cohesion of material is disturbed continually without discernible fatal breaks.

Conclusion

From the pilot experiment we can deduce the whole palette of new discoveries. It was concluded that samples subjected to stress show the obvious declination of values.

The experiment was focused on measuring the resistance of mineral feed subjected to mechanical pressure. Conducted tests revealed better characteristics in the group A, which show better resistance compared to other variants. The samples of the A category resist greater pressure, but disintegrate after pressure application, while the samples of the D category disintegrate gradually. Considering the number of samples in the group, this claim is statistically conclusive.

Modern instrumentation and pattern recognition helps, but operator training and procedures still play a major part in achieving meaningful measurements (Cole, 2005).

The experiment showed the applicability of AE survey for analysis and represented an interesting view on the behaviour of internal AE sources in the structure of material subjected to mechanical pressure stress testing. From this hypothesis we can conclude that applicability of AE represents a viable approach for further research. One perspective application of this method is development of automated measuring institute for quick continuous sample analysis.

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