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STRUCTURE INTEGRITY TESTING OF MINERAL FEED BY MEANS OF ACOUSTIC EMISSION

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Abstract

ZAČAL JAROSLAV, DOSTÁL PETR, ŠUSTR MICHAL. 2016. Structure Integrity Testing of Mineral Feed by Means of Acoustic Emission. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis,* 64(2): 573–577.

This work deals with specific method of non-destructive testing – Acoustic emission (AE). Theoretical part of article is focused on underlying principle of this method and its applicability. The experimental part is focused on research of pressure resistance in mineral feed using the AE. Mineral feed is 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. Using the AE sensor is possible to provide monitoring of internal changes in the material.
AE 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, mineral feed, RMS, Power Spectral Density

INTRODUCTION

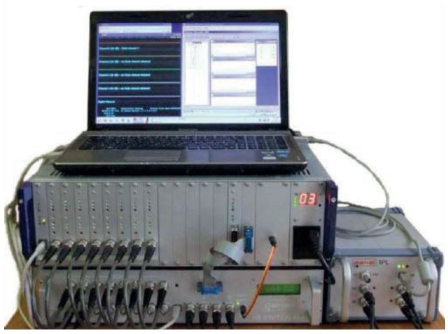
Mineral feeds are compacted cubes of rock salt with added mineral nutrients, which are fed to livestock and game. Level of mineral nutrients in animal diet has a direct influence on their condition and health. This is of utmost importance especially for herbivores, who intake excess of potassium in forage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

Topic of this study is assessment of mineral feed durability against pressure tension. For exact description of destruction progress in material the acoustic emission (AE) method was selected (Fiala *et al.*, 2003). AE is a non-destructive passive method, which means it doesn't affect the examined object and reports integral information considering the momentary dynamic state of material, which is considered its main benefit (Dostal *et al.*, 2011). AE signals are caused by dynamic structural changes in material and manifest themselves as gradual elastic wave (Askeland *et al.*, 2006). 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).

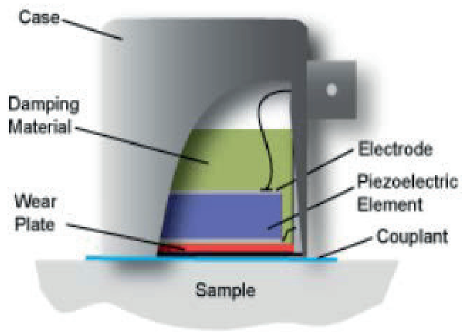
MATERIAL AND METHODS

Acoustic Emission

Xedo analyzer Fig. 1 manufactured by Dakel company is a modern high-performance modular apparatus for measuring and analysing the parameters of acoustic emission. Analyzer is designated for connecting the passive piezoelectric corundum sensors without the amplifier, or active



1: *Analyser Xedo*



2: *Sensor of acoustic emission*

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 sensor IDK-09 with corundum connection plate Fig. 2.

Material

For testing set of mineral feed samples the optimum dimensions were suggested, which represent real dimensions in 1:5 ratio for pressure testing. Tested object was shaped in truncated cone shape Fig. 3. For precise measurement the top and bottom surfaces were milled perpendicular to its longest axis (Pluhař *et al.*, 1987). On the sample surface a notch was filed for easier fixation of sensor to ensure better contact between sample and sensor.

Examined samples were divided to 4 different groups A, B, C, D, each containing 10 samples. Every 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 groups B and C. For further experiment the samples of A and D groups were selected. Samples were fitted with piezoelectric AE sensor for detailing characteristic assessment.

Course of Assessment

For testing the pressure resistance of mineral feeds we used the manual press. Individual samples were placed into mechanical press (Kreidl *et al.*, 2006). Tested samples were subjected to constant pressure of 10 mm.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 Tab. I.

I: *Configuration measuring apparates Xedo*

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

Root mean square (RMS) of AE emission was observed. This parameter means the effective signal value. In alternating current the RMS is equal to direct current value, which after employment of resistance load would exhibit the same average performance. The RMS is reported in range of mV. This value describes the quantitative characteristic of measured AE events quantum of energy (Brooks, 2002).

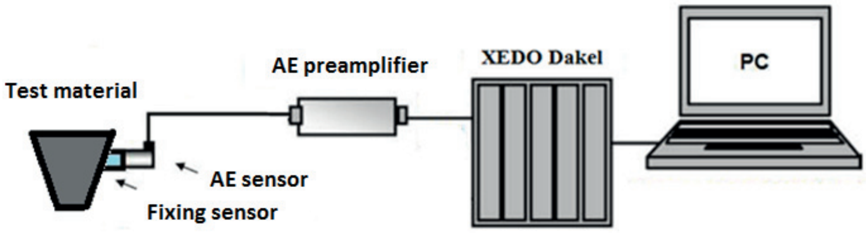
AE signals in pressure testing were recorded with one corundum piezoelectric pickup sensor Dakel, fixed in upper part of tested sample with spring-loaded clip. To ensure the optimal acoustic transfer between sensor and material we used „ultrasonic gel“. Primary function of cohesive medium is to repel the air present between contact surfaces, thus 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 AE system installed on testing apparatus, see Fig. 4.

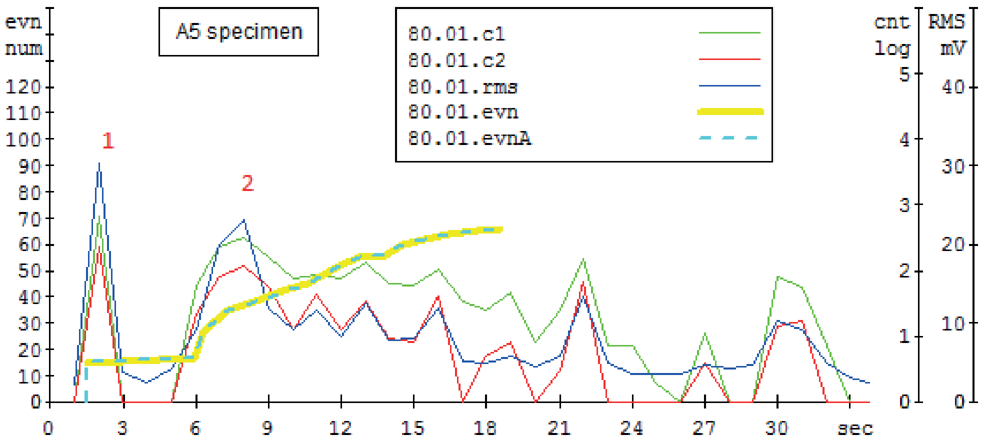
RESULTS AND DISCUSSION

Parameters were assessed with mean level of detected signal – RMS and count of overshoots over threshold levels in selected intervals. Measuring system Daemon evaluates RMS and overshoots count in two threshold levels Count1 and Count2.

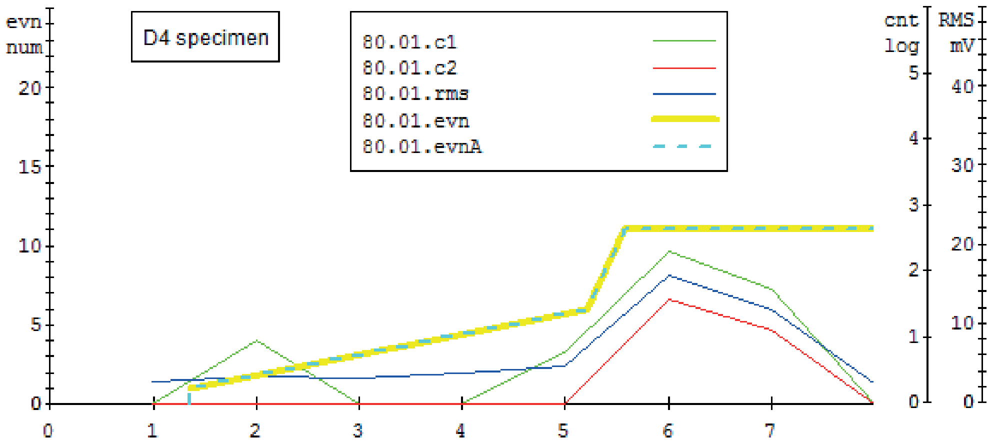
3: *Samples of mineral press*



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



5: *Representative parameters of acoustic emission output from the specimen A5*



6: *Representative parameters of acoustic emission output from the specimen D4*

On Fig. 5 it is clear to distinguish two relevant periods of AE signal. First signal (1) was recorded to 3rd second of pressure application and second signal (2) took place from 5th to 9th second and further with descending trend until end of testing. This means that first signal emission is indicator of rapid destruction in material. Second rapid emission with following descending trend indicates consecutive crushing, in which the structure cohesion decreases.

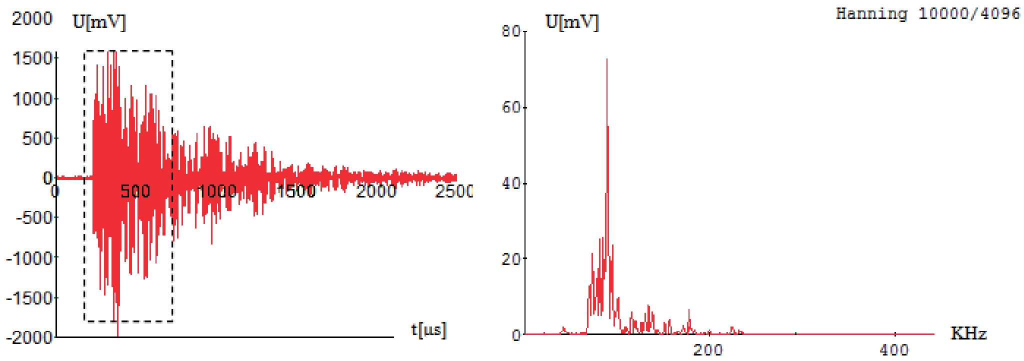
From the test results of A5 sample is obvious that maximum RMS is approximately 30 mV in first period of signal and average frequencies of further events (see representative Fig. 8) is approximately 90 kHz in sum of both measurements. The sample is hard and fragile, structure has low resistance to pressure load. Sample still shows distinctive cohesion, which continuously ceases from 18th second of load, when crumbling of sample begins.

Fig. 6 represents the record of acoustic emission for 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 5th second there are distinctive accented acoustic manifestations in process of crumbling of material.

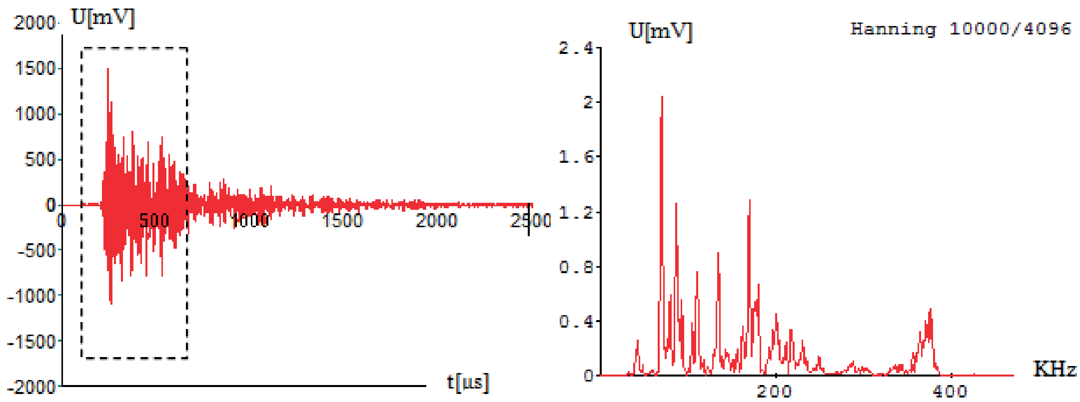
From the test results of D4 sample is certain that maximal RMS is achieved at 15 mV in first period and AE frequency is 75 kHz in both temporal periods.

II: *Displays parameters of RMS and frequency of AE signal for individual specimen*

Specimen	Specimen density ρ ($kg \cdot m^{-3}$)	Maximum root mean square (Max RMS) [mV]	Max. numer of events [kHz]
A5	1347,875	30	90
D4	1259,133	15	75
C3	1003,372	10	29
B3	1017,412	9	21



7: *Representative acoustic emission event and PSD functions for specimen A5*



8: *Representative acoustic emission event and PSD functions for specimen D4*

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

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

Representing A5 sample of AE (see Fig. 7 right) determines the selective area for PSD analysis. Maxima of recordable events for PSD function occurred at 90 kHz. This information indicates the part of acoustic signal recordable at initiation of destructive fissure. Analysis of sample indicates the wider amplitude. Energy of the signal is therefore higher. It is possible to claim that mechanical resistance of a group samples is higher than resistance of D group. Primary destruction of material occurs from 3^{rd} second further, but is followed by gradual disintegration of material.

Samples of AE signal and PSD analysis at representative sample D4 (see Figs. 6, 8) display lesser 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.

Experiment was focused on measurement the resistance of mineral feed subjected to mechanical pressure. In conducted tests were found better characteristics in group A, which show better resistance compared to other variants. Samples of A category resist the greater pressure, but disintegrate after pressure application, while samples of D category disintegrate gradually. Considering the number of samples in the group this claim is statistically conclusive.

Experiment showed the applicability of AE survey for analysis and represented the interesting view on 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.

Acknowledgement

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