ACOUSTIC EMISSION DURING TESTING INTEGRITY AND PRESSURE RESISTANCE OF JAPANESE QUAIL EGGS

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Abstract: This paper deals with standard testing of egg shell integrity including breaking the shell with destructive pressure testing and monitoring the acoustic emission (AE) signal in real time. Purpose of this experiment was to verify the suitability of AE recording during the pressure test with continuous force load. Experiment was conducted on 18 samples of Japanese quail (*Coturnix japonica*) eggs, divided to four categories according to quality. Testing was also conducted on eggs with fractured shell structure. According to terminology coined in National technical standard (ČSN EN 1330–9), the acoustic emission means elastic tension waves generated by dynamic release of mechanical tension inside the material structure. AE recordings show low level of impulses. It was found that RMS values are insignificant in the recordings, there is no observable elastic tension wave generated with dynamic tension inside the egg shell in course of force load.

Key Words: Quail Egg, Acoustic Emission, Egg Integrity, RMS

INTRODUCTION

Sturdiness of egg shell is determined by its structure. The shell needs to be strong enough to bear the weight of hatching bird and simultaneously brittle enough to allow the chickens to hatch. The eggshell constitutes of anorganic compounds (95%) and organic compounds (4%). Water content reaches up to only 1–2%. Commonly described firmness of quail egg shell should be in 14 to 18 N interval (Kumbar et al. 2015).

Acoustic emission is a physical phenomenon caused by plastic deformation in material accompanied with acoustic crackling or noise emitted inside the material, or process causing the emergence of tension waves on the material surface (Pazdera et al. 2004). Acoustic emission method is term describing acoustic emission detection, subsequent electronic processing of recorded signal and finally analysis of characteristics of detected AE signal (Kopec 2008).

Quality of eggs is regularly mentioned in connection to consumer's demand. Aside of economic loss the broken egg presents also a health hazard, because the shell functions as a natural barrier against microorganisms penetrating from the surface to the egg inside. In eggs with damaged shell the microbial contamination was recorded many orders higher in occurrence compared to eggs with intact shell. The thickness of sub-shell membranes related to total volume of shell is in quail eggs 4× higher compared to hen eggs, which facilitates the storage and extends the storage period (Shanaway 1994).

Entire process of emergence and detection of AE consists of several steps: AE event, spread of tensile waves from source to detector, recording the AE with sensor, translating it to electric signal and finally assessment of electric AE signal with measuring system (Dostal et al. 2011).

Disadvantage could be seen in fact that cause of acoustic wave emission is still unclear, because emitted energy is influenced with a broad spectrum of factors including object shape and surface properties, trajectory path of wave conditioned by material homogeneity and structure, etc. (Kreidl, Smid 2006).

MATERIALS AND METHODS

Samples of Japanese quail eggs (*Coturnix japonica*) were used in this experiment. Laying hens were bred using the cage technology and fed with complete feed mixture. Eggs were stored at sustained 6°C temperature and 70–45% relative air humidity. In total we used 72 quail eggs to observe following parameters: egg mass, length and width, egg shape index, shell thickness and ratio to egg mass. The mass was measured with scale, length and width were determined with mechanical calliper. Damaged eggs were also subjected to measuring. The defects of eggs were assessed visually by obvious external indicators. Most common defects include visible cracks, abnormal structure and high porosity of the shell.

For measurement we employed the universal apparatus for measurement of physical characteristics TIRATEST 27025 (Germany), see Figure 1. The apparatus allows measurement of various materials in tension, pressure and flexion. This particular test was conducted with compression plates, which compress the egg to the point of shell rupture. Result of this test is the pressure part of working diagram, which records the data for pressure resistance of eggshell.

Table 1 Configuration of compression test

Parameter	Value
Load capacity	200 N
Test type	Compression plate
Crosshead velocity	10 mm/min
End threshold	Decrease in strength 30%

Figure 1 Universal testing device TIRATEST 27025 (right, photo: Sarka Nedomova)
Figure 2 AE sensor fixing on tested sample (left, photo: author)
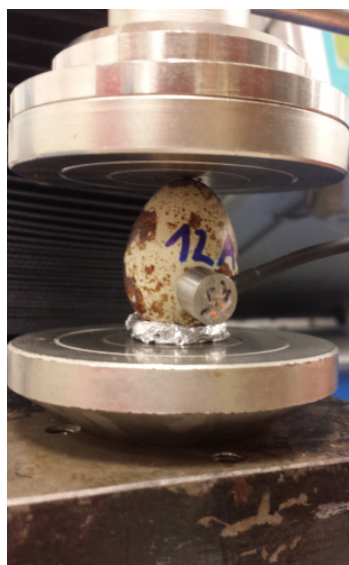
AE signals were captured in the test with one piezoelectric sensor (Dakel), fixed with special acoustic glue, which created optimal binding environment Figure 2. To obtain reliable data from measuring it is necessary to fix the AE sensor to tested sample thoroughly to ensure best transmission of AE signal. Contact of front sensor surface is conducted with minimal areas at peaks of microscopic irregularities of sample surface. Most of the space below the front side of sensor is filled with air, which has the acoustic impedance of five orders lower than direct surface contact and dampens the AE signal transmission significantly. Primary function of adhesive is to expel the air from between the contact surfaces and facilitate the signal transmission. Measuring of AE was conducted using Dakel XEDO measuring apparatus. Parameters of measuring setup are logged in Table 2.

Table 2 Configuration of measuring equipment

Parameter AE	Value
Sampling frequency	4 MHz
Gain sensor	30 dB
Gain pre-amp	35 dB
Value interval reach	± 2000 mV

It has been observed Root mean square (RMS) of acoustic emission. This parameter describes the signal effective value. For alternating current the RMS equals the value of direct current, which would show the same performance when subjected to resistance load. Units of RMS are mV. This value describes the quantitative characteristics of measured AE event (amount of energy).

RESULTS AND DISCUSSION

For clarity we introduce only representative samples in graphs and tables. In the experiment the egg samples were sorted to four groups according to quality.

Firmness of the shell determines the resistance of egg against damage. Thickness of the shell is related to firmness, which although isn't directly proportional to shell thickness. Shells with higher porosity show lesser firmness. Shell firmness is relatively high despite its fragility; flawless egg could endure the load even greater than 15 N (see Figure 3).
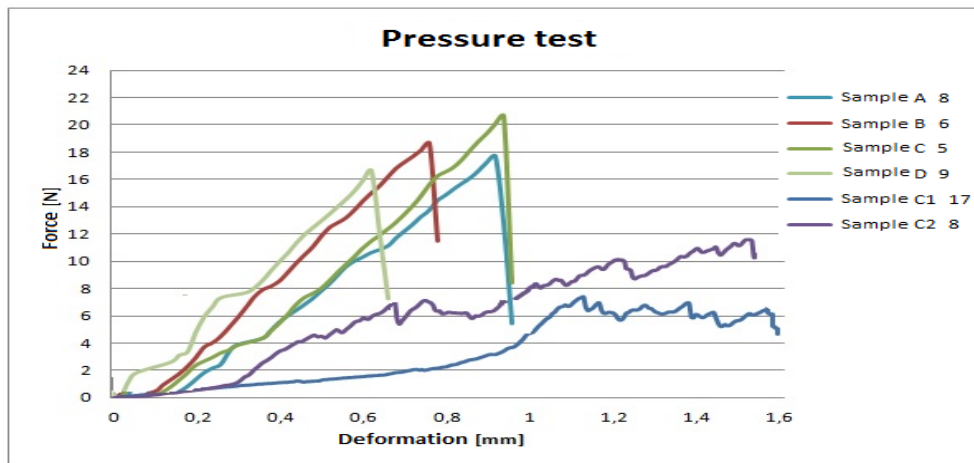
Figure 3 Pressure testing

Table 3 Representative quail eggs for acoustic emission

Sample	Weight [g]	Length [mm]	Width [mm]	Index shape [%]	Force [N]	Deformation [mm]	Weight of eggshell [g]	Ratio of eggshell [%]	Sharp [mm]	Blunt [mm]	Equator [mm]	Average thickness [mm]
A8	8.63	30.45	22.41	73.60	16.60	0.13	0.75	8.69	0.132	0.094	0.103	0.110
B6	11.47	32.39	25.27	78.02	18.61	0.11	0.98	8.54	0.099	0.098	0.112	0.103
C5	13.65	35.92	26.57	73.97	16.64	0.14	1.09	7.99	0.104	0.123	0.14	0.122
D9	6.30	26.32	20.72	78.72	16.62	0.09	0.52	8.25	0.095	0.088	0.101	0.095
C17	11.66	32.63	25.46	78.03	13.97	0.85	1.02	8.75	0.101	0.111	0.113	0.108
C8	11.91	32.96	25.45	77.21	13.07	1.47	1.02	8.56	0.099	0.124	0.103	0.109

For discovering the best variety of samples for AE recording we respected the least favourable variety, in these cases the samples with pressure resistance lower than 15 N were not considered. In my opinion these samples should be decommissioned with regards to insignificant difference in RMS record, because the occurrence of elastic tensile wave was not recorded in course of force load.

For comparison of two interesting measurements we selected individual results of A group, sample 8 and C group, sample 17 with already damaged shell structure. Compared values of AE record are exhibited in figure 4 and 5. It is obvious in comparison that all tested samples exhibit the unified AE course characteristics in test run, as demonstrated in representative sample - Figure 4.

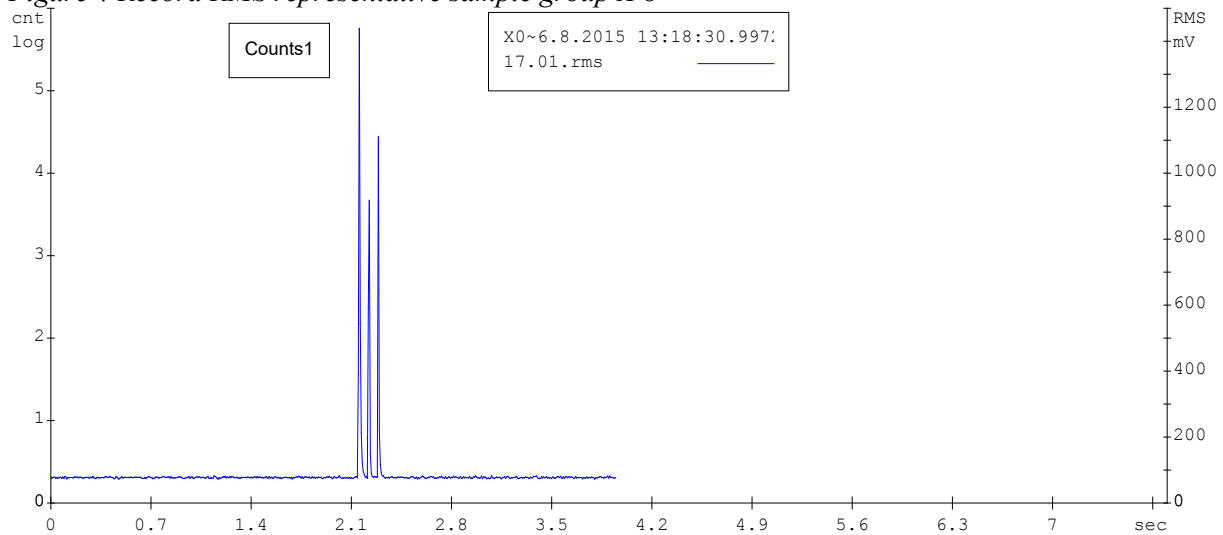*Figure 4 Record RMS representative sample group A 8*

Figure 4 demonstrates one clearly distinguishable period of AE signal. The signal was recorded through entire measuring period. This indicates that first high peak in the graph denotes the pulse occurring after crossing the threshold of firmness, followed by peak of collapsing structural integrity of the shell. This indicates that with increasing force load no deformation or breaking changes occur in the shell, but only after crossing the firmness threshold. From results of reference test of A8 sample it is obvious that maximum RMS is 1400 mV in signal period. These points to fact that first signal emission indicates the rapid destruction of material.

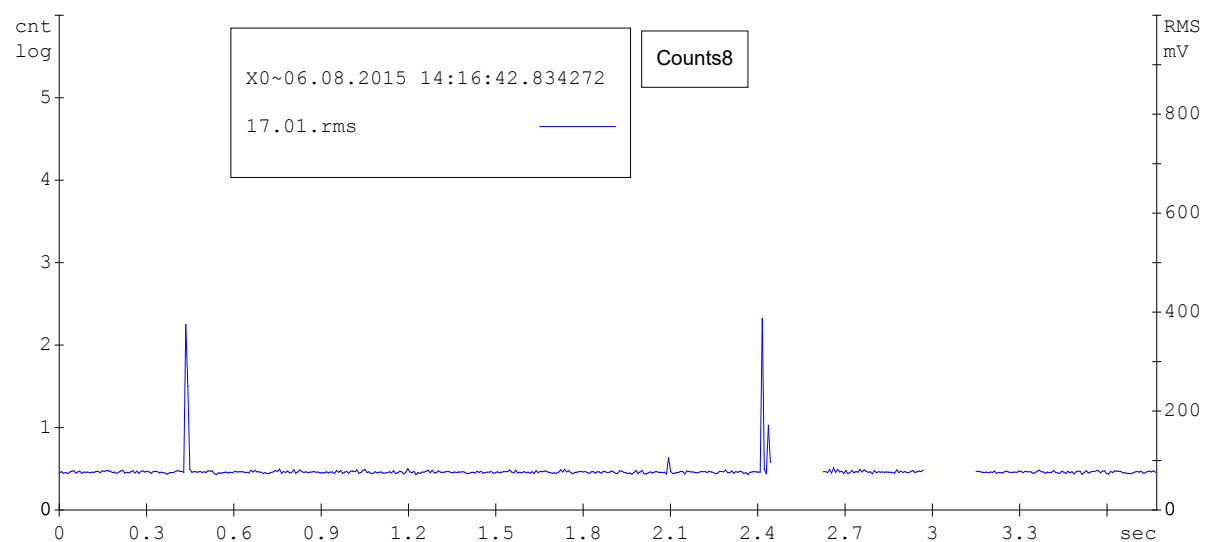*Figure 5 Representative RMS record for sample C 17*

Figure 5 depicts the RMS level for sample C 17. Here the signal is recorded for egg sample with already damaged shell structure. The graph indicates that there is no occurrence of first rapid burst

in AE emission, as depicted in previous graph. The clear destruction of material without initial AE impulse is visible.

From the results of sample C 17 we can state that maximum RMS reaches up to approximately 400 mV. This suggests that shift of individual shell parts occurred in course of continuous force-loading of sample. The structure exhibits a low resistance to pressure load.

CONCLUSION

From the pilot experiment we conclude many new findings. AE method was tested for crack detection. Specimens don't show significant differences in AE signal values in course of force load. Behaviour of all AE signal sources reflected the same pattern as in reference sample A 8.

Acoustic emission is a non-destructive passive method, thus the sample characteristics are not influenced directly by measurement and testing gives integral information of momentary dynamic state of material, which its undisputable advantage.

There was no occurrence of emission packets recorded in course of force load, therefore it is impossible to interpret the measurement unambiguously. Another disadvantage is that during the force load there is no observance of gradual shell cracking. Formation of micro fissures in the material is considered a key factor in AE recording. When subjected to consecutive force load, the shell resists the pressure up to firmness threshold without any structural changes. After crossing this threshold the shell shows multiple AE pulses recorded on detector.

Overall, this method reported low suitability for eggshell firmness assessment due to high technological demands on AE recording.

AE presents precise tool to assess any structural changes in material subjected to continuous force load, however, in this particular application the method is unpromising for further research.

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