JOINTED TIME FREQUENCY ANALYSIS OF ACOUSTIC EMISSION SIGNALS DURING CONCRETE HARDENING

ANALÝZA SIGNÁLŮ AKUSTICKÉ EMISE ČASOVĚ FREKVENČNÍMI SPEKTRY PŘI TUHNUTÍ A TVRDNUTÍ BETONU

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Abstract
Because concrete is most popular civil engineering material and their properties are changed during life time it is suitable to followed it by help of non destructive techniques. Acoustic Emission Method seems to be very powerful tool for this evaluation. Chosen analyses have been used to assessment of recorded acoustic emission signals.

Key words: concrete, acoustic emission, hardening, time frequency spectra

Abstrakt
Jelikož beton je významným stavebním materiálem a jeho vlastnosti se mění v průběhu jeho životního cyklu, je užitečné je sledovat s pomocí nedestruktivních metod. Metoda akustické emise se jeví být velmi výkonným nástrojem pro hodnocení. Vybrané metody časově frekvenční analýzy byly užity pro vyhodnocení zaznamenaných signálů akustické emise.

Klíčová slova: beton, akustická emise, tuhnutí, časově frekvenční spektra

1. Introduction
Concrete is a construction material composed of cement (commonly Portland cement) and other cementitious materials such as fly ash and slag cement, aggregate (generally a coarse aggregate made of gravels or crushed rocks such as limestone, or granite, plus a fine aggregate such as sand), water, and chemical admixtures. [Kosmatka et all 1988] Concrete is used more than any other man-made material in the world. [Lamborg 2006] The strength and durability of concrete structures are enhanced significantly by proper moist curing of early-age concrete, where improper moist curing conditions can affect significantly the concrete strength development. [Mindess et all 2003]
A sound understanding of the early-age cracking problem is important because it may lead to ingress of moisture and salt, reinforcement corrosion, concrete spalling and, ultimately, to a reduced inservice performance of the concrete structure. [Lachemi et all 1997]
Thus following concrete life time is most important for constructions properties. One of the more promising non destructive evaluation techniques for detecting and monitoring, in real-time, the strain energy release and corresponding stress-wave
propagation produced by actively growing flaws and defects in composite materials is acoustic emission. [El Gueflounia et all 2001]. Acoustic emission is a nondestructive testing technique that is applied frequently to materials like metals or compounds. Due to the complicated structure of the material, its application to concrete is not yet well established. [Bradshaw et all 2002]

Therefore acoustic emission method can help to describe cracks during concrete lifetime.

Two different approaches to record and acoustic emission analyze signals are typically distinguished: the classical and the quantitative or signal-based acoustic emission technique. Classical technique records a set of parameters evaluated acoustic emission events, but the signal itself is not stored. Quantitative acoustic emission technique, as many signals as possible are recorded and stored along with their waveforms converted from analogue-to-digital. [Grosse et all 2002] But analysis this signal is too ambitious on computing power. One solution is the division of the time series into smaller units and the sequential application of Fourier transform techniques. This procedure is called Short Time Fourier Transform or Windowed Fourier Transform [Gabor 1991]

Next possibility of long time acoustic emission testing is recording only hits. Their frequency analysis is jointed with time, but no constant time step of recording hits can be set.

Each hit could be analyzed by Fourier, wavelet, Choi-Williams or other transformation. [Choi et all 1989, Mallat 1998, Zhao et all 2000]

2. Time frequency spectra of acoustic emission hit

Fourier analysis $FT$ is basic frequency analysis appear from [Pazdera et all 2007]

$$FT(f) = \int s(t) \cdot \exp(-i \cdot 2 \cdot \pi \cdot f \cdot t) \cdot dt$$

(1)

where $s(t)$ is analysed signal, $f$ is frequency, $t$ is time. Because acoustic emission hits are time limited burst signals recorded in given time, their spectra are easy computed. Then each hit limited length can be transformed into own frequency spectrum. Consequently [Cooley et all 1969]

$$F_k(t_m) = \sum_{n=0}^{N-1} r_n(t_m) \cdot \exp\left(-i \cdot 2 \cdot \pi \cdot k \cdot \frac{n}{N}\right) \text{ for } k = 0, 1, \ldots, N - 2, N - 1$$

(2)

where $t_m$ is time, when the hit was recorded, $r_n$ are $N$ measured hit values with constant time step $\Delta t$, and $k$ means $k^{th}$ frequency component of spectra.

Note, that series $t_m (m=1,2,\ldots,M)$ is not recorded with constant time differences. Commonly $t_i - t_{i-1} \neq t_{i+1} - t_i$. In this case, it is not possible to use classical Short Time Fourier transform [Giurgiutiu & Yu 2003]

$$STFT(f, t) = \int s(t) \cdot w(t - \tau) \cdot \exp(-i \cdot 2 \cdot \pi \cdot \tau \cdot f) \cdot d\tau$$

(3)

because it needs “continuous” signal, not only burst hits as acoustic emission has.
3. Experimental acoustic emission system

Acoustic emission measuring has been applied by system XEDO. This acoustic emission system is made as modular. One communication card and up to fifteen input cards can be located in a metal box. Communication between cards within a box is realized by hi-speed bus. Each box is connected to control computer via Ethernet. Configuration of all units is automatically recognized after system switching (plug & lay). Time bases of all input units in system are synchronized via Ethernet and hi-speed bus with 1 µs accuracy. All parameters of input cards can be set from computer and central reset for all boxes can be transmitted. [Chmelík et all 2004]

Acoustic emission parameters are evaluated by unit XEDO-AE. Allows sampling of signal from one sensor (speed up to 8 MHz), enumerates standard acoustic emission parameters, process emission events parameters for possible emission source localization. [Varner & Varner 2008]
Acoustic emission sensors IDK-09 (diameter 9 mm, height 10.5 mm) have glued by sweep wax on surface. Their frequency characteristic is in Fig. 1. [Mazal et all 2005] Preamplifiers with gain 35 dB (see Fig. 2) are produced using hybrid technology - surface mounting and thin film components on ceramic substrate, dimensions 7 mm by 7 mm. Very good is temperature range -20°C to +85°C, too. [Malcharczikova et all 2006]

4. Experimental set up

There was made a mortar sample 100 m x 100 m x 400 mm with mixture in Tab. 1.

<table>
<thead>
<tr>
<th>Composition</th>
<th>Weight [kg]</th>
</tr>
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<tbody>
<tr>
<td>Ordinary Portland Cement</td>
<td>450</td>
</tr>
<tr>
<td>Water</td>
<td>225</td>
</tr>
<tr>
<td>Sand 0/4 mm</td>
<td>1350</td>
</tr>
<tr>
<td>Plasticizer</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 1 Mortar mixture

Three sensors were fixed on sample surface and one out of sample for guarding noise hits. Second day sample was unmoulded (Fig. 4).
5. Results

Cumulative number of acoustic counts in Fig. 5 for low $N_{cb}$ and high $N_{cb}$ threshold demonstrate decreasing acoustic emission activity during concrete setting. Similar result is shown in Fig. 6 where events amplitude $A$ decreasing with time and more number of events is in early time.

![Figure 5 Time history of acoustic emission counts](image1)
![Figure 6 Time history of events amplitudes](image2)

Time distribution of frequencies (see Fig. 8) eventually events distribution frequencies (see Fig. 7) contained interest frequency range from 200 kHz to 350 kHz.
Figure 7 Frequency spectra of events.

Figure 8 Time / frequency spectra of acoustic emission events
6. Conclusion

Application of acoustic emission method during setting concrete and its analysis by help of time frequency analysis will be presented. These experiments show advantages of using time frequency analysis at acoustic emission method application here.

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References


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