

Selecting main technical specifications of the data acquisition system to improve the accuracy of using the electric response parameters

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Abstract. Based on the conducted experimental studies, the necessary parameters were selected to provide reliable testing of concrete defects. The measuring system must have: input sensitivity of the receiving electromagnetic channel of at least 100 μV , the working frequency range of 1–120 kHz; the sampling frequency of 500 kHz, as well as a device that allows fast Fourier transform. The registration of the electrical response during an elastic impact should be made by a differential electric sensor, which allows measurements under conditions of external electromagnetic interference.

1. Introduction

Engineering structures are mainly operated under high loads, so determining the reliability and durability of such structures is a very important task. The method of non-destructive testing, based on the phenomenon of acoustoelectric transformations under the pulsed mechanical impact [1-3], which is being developed at Tomsk Polytechnic University, can be used to solve this problem. To implement reliable monitoring of concrete structures using the non-destructive testing method based on the phenomenon of acoustoelectric transformations, it is necessary to establish requirements for the main technical characteristics of the measuring system being developed.

2. Methods

The research was carried out using a hardware and software unit that allows producing pulsed mechanical impact of concrete samples and registration of an electric signal. A more detailed description of the hardware and software unit is given in the work [4].

To select and justify the main technical specifications of the data acquisition system, which will allow more reliable non-destructive testing, the following studies were performed.

3. Results and discussion

In this research, samples of heavy concrete were used. The creation of natural defects in the samples was carried out by cyclic freezing-thawing. The samples were frozen in a climatic chamber at a temperature of minus 45 °C, and thawing was carried out in a universal curing chamber at a temperature of 20 °C and a humidity of about 95 %.



Figure 1 shows electrical signals registered from the concrete sample without cracks before freezing-thawing cycles (a) and a sample that underwent 20 cycles of intensive freezing-thawing (b), after which a grid of visible cracks became visible on its surface.

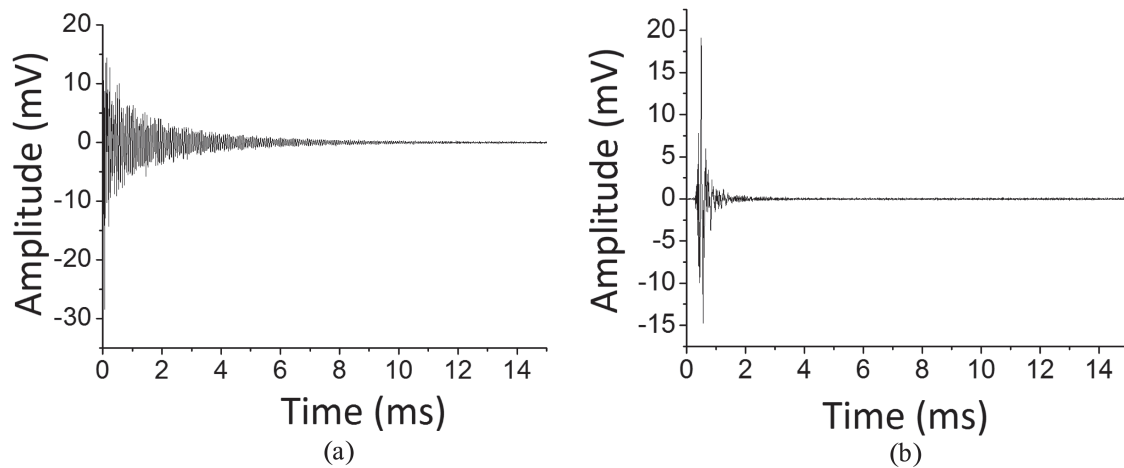


Figure 1. Electrical responses acquired from defect-free (a) and defective (b) samples of heavy concrete.

As can be seen from the figure, the maximum value of the electric signal for both samples was 15–20 mV. The value of the noise level, in this case, was less than the maximum value of the useful signal by 1.5–2 orders, which cannot be achieved when testing wet samples.

Figure 2 shows an electric signal registered from a defective sample with a humidity of 7 %.

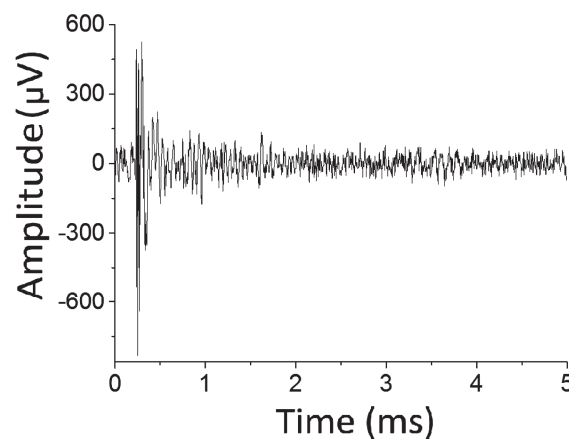


Figure 2. Electric response obtained from a wet concrete sample.

As can be seen from figure2, in the case of the wet sample, the useful signal was much smaller, therefore it was very difficult to register, process and interpret it, which means that the sensitivity of the electromagnetic channel input should be at least 100 μV .

In order to more reliably determine the correlation coefficient and a frequency offset, at which the maximum correlation coefficient is observed, it is necessary to select the frequency range of the electrical signal. To do this, measurements were made on the same samples of heavy concrete at different sampling frequencies: 100 kHz, 250 kHz, and 500 kHz. Figure 3 shows the spectra of electric signals registered from the sample before cyclic freezing-thawing and the sample that has passed 20

freeze-thaw cycles at different sampling frequencies. Figures 3a and 3d show the amplitude-frequency characteristics of the signals obtained at a sampling frequency of 100 kHz, Figures 3b, 3e at a frequency of 250 kHz, and Figures 3c, 3f at a frequency of 500 kHz.

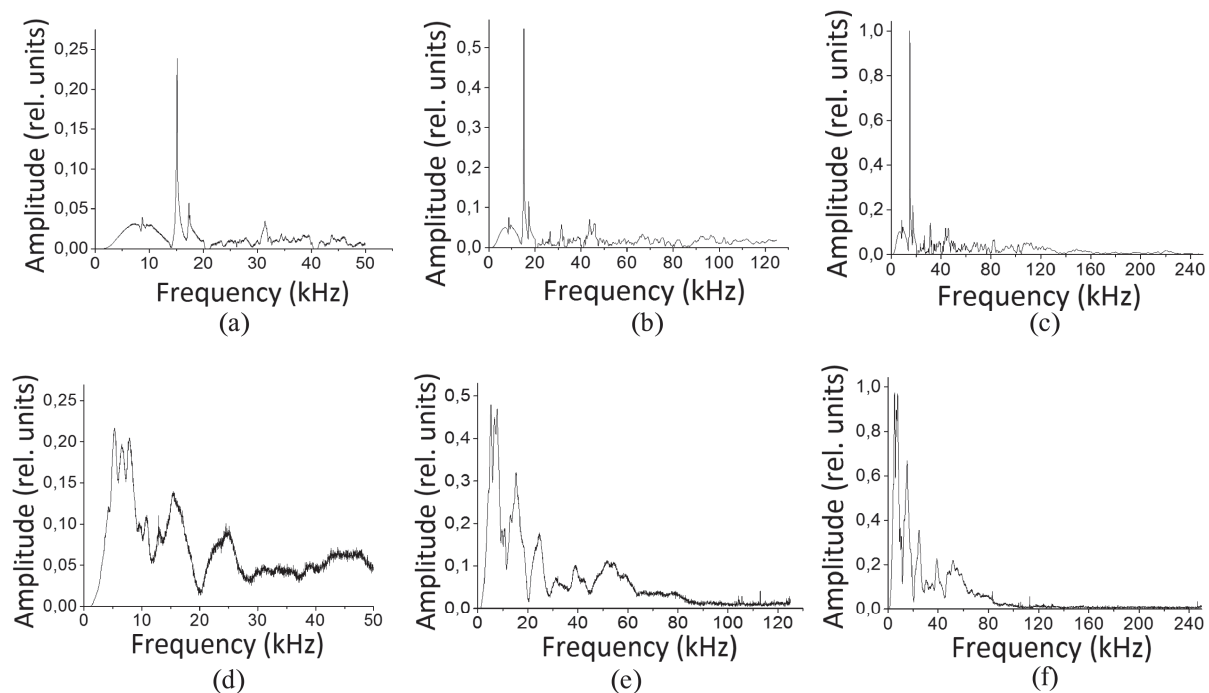


Figure 3. Changing in the amplitude-frequency characteristics of electric signals registered from defect-free (a), (b), (c) and defective (d), (e), (f) heavy concrete samples depending on the sampling frequency.

It can be seen from figure 3 that the sampling frequency in the range from 250 to 500 kHz was optimal for testing this type of sample since in this case, all the main spectral maxima characteristic of both the defective and defect-free samples are present in the signal spectrum. The calculations showed that at such a sampling frequency, there is a maximum difference in the correlation coefficient, which is proposed to identify the defect.

It should also be determined whether there is a need to obtain a high resolution of the spectral characteristics of the electric signal during testing using the developing method of non-destructive testing. The resolution capability is determined by the specified measurement range and the resolution of the analog-to-digital converter (ADC).

Figure 4 shows the changes in the parameters of the electric signal when using devices with different ADC bit depths. In this case, the PCS-500 oscillographic set-top box (8-bit ADC) and the multifunctional data input/output board “NI PCI-6251” with a 14-bit ADC were used.

It can be seen from figure 4 that the spectral composition had insignificant changes in the region of 30–40 kHz. The change in the value of the correlation coefficient did not exceed 5%, therefore, there is no great need to use devices with a high ADC bit depth, since devices with a high-bit ADC are much more expensive.

An increase in the accuracy of the measurement of the electric response parameters can be obtained by repeated tests and averaging of the obtained data. Figure 5 shows the amplitude-frequency characteristics averaged over several measurements.

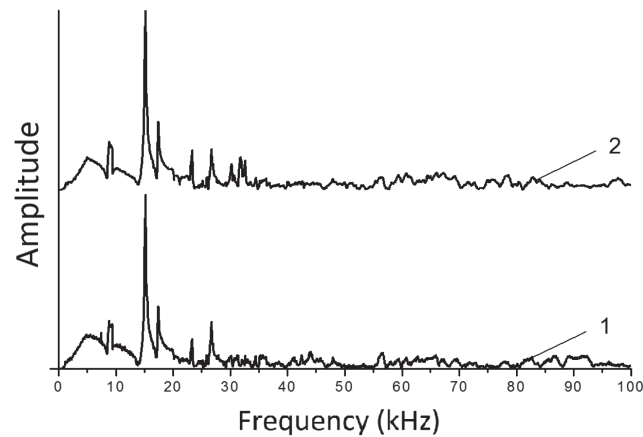


Figure 4. The spectral characteristics of electric signals from one sample recorded using different devices having: 1 – 8-bit ADC; 2 – 14-bit ADC.

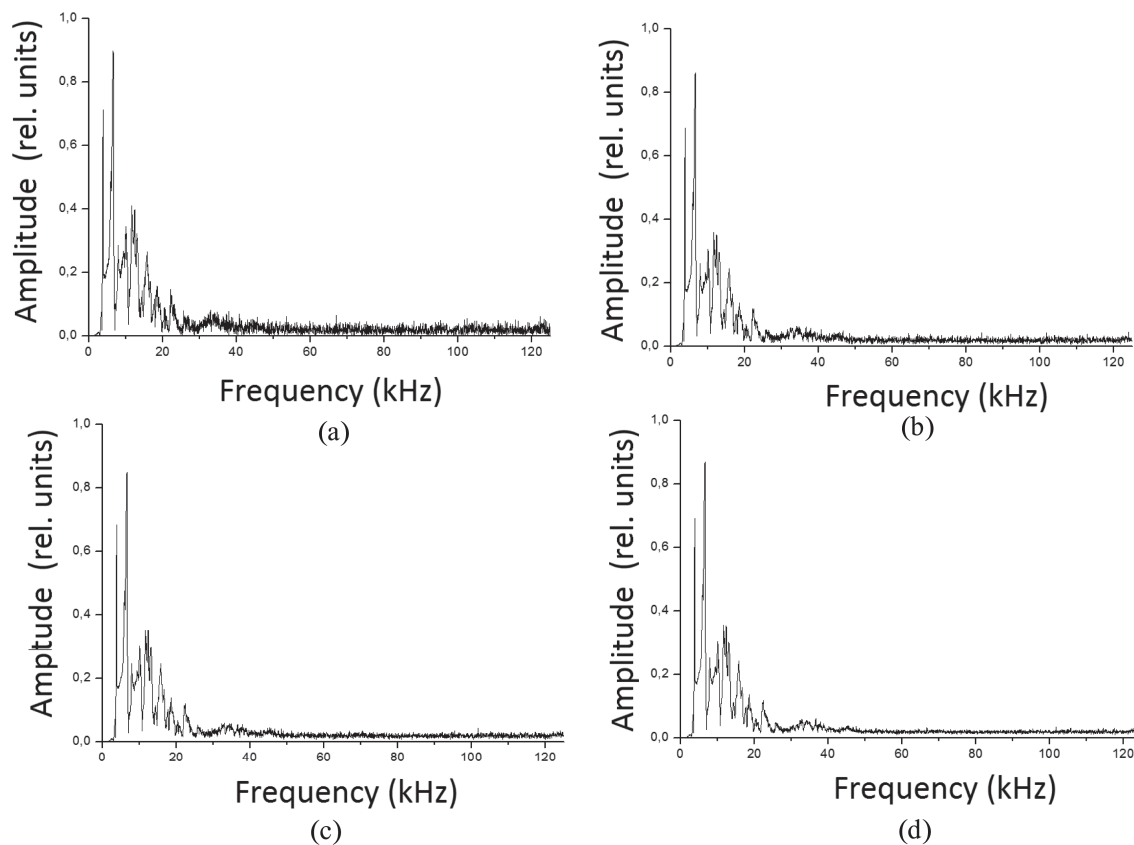


Figure 5. Spectra obtained by averaging several electric responses:
(a) – one test, (b) – three tests, (c) – five tests, (d) – ten tests

Figure 5 shows that even when averaging the three spectra, the resulting spectrum changes, namely, some values of the random noise component decrease.

Table 1 shows the values of the maximum correlation coefficient for a different number of averaged spectra.

Table 1.

Number of tests	1	3	5	10
r_{\max}	0.6557444	0.6717818	0.672102	0.674874

Using the method of several tests with their further averaging, it is possible to increase the accuracy of determining the value of the correlation coefficient by about 3%. The research showed that it is necessary to make at least three measurements and average them, this will improve the accuracy of the proposed control method.

4. Conclusion

The research confirmed that reliable monitoring of concrete by the method of nondestructive testing based on the phenomenon of acoustoelectric transformations, the measuring system must have the following technical characteristics: input sensitivity of the receiving electromagnetic channel of at least 100 μV , the working frequency range of 1–120 kHz; the sampling frequency of 500 kHz. Also, the system must have a device that allows fast Fourier transform, and a differential sensor that allows measurements under external electromagnetic interference. To reduce the measurement error, it is also recommended at least 5 measurements of the electrical signal.

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References

- [1] Fursa T, Osipov K and Dann D 2011 *Russ. J. Nondestr. Test.* **47** 323
- [2] Osipov K and Fursa T 2013 *Tech. Phys. Lett.* **39** 481
- [3] Fursa T, Savelev A and Osipov K 2003 *Tech. Phys.* **48** 1419
- [4] Fursa T, Osipov K., Lukshin B and Utsyn G 2014 *Meas. Sci. Technol.* 055605