The use of Acoustic Emission method for detection and location corrosion defects on railway steel bridges

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Abstract

In the article there are presented the results of laboratory tests with Acoustic Emission Method on elements (truss joint) from railway steel bridge. These investigations were performed both on elements without and with loading, in corrosive environment. The AE signals from corrosive defects, acquired during performed tests, were used to build the preliminary classifier in Visual Class application.

The first tests, carried out with applying of the classifier on real object for checking the correctness of received measuring methodology are also presented.

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Introduction

Steel bridge structures are the objects exposed to intensive influence of corroding medium, acting also in a zonal variable stress field. In steel bridge structures the process of corrosion is one of the major initiators of the destruction process, gradually developing from the surface corrosion to the pitting corrosion. It leads then to the local fracture of the structure material.

An important element of the bridge construction inspection conducted in Poland, mainly by visual methods, is to describe and identify areas affected by the intense corrosion. Major difficulty in carrying out such an assessment is the size and geometry of this type of structure. In the scope of used or proposed for use non-destructive methods, in this case, the effective option for detection and location of such destruction processes is the Acoustic Emission method (AE).

Preliminary tests

The starting point for subsequent laboratory tests and the tests on real objects were the preliminary measurements, carried on different steel and truss bridge structures, that aim was to record the AE signals from environmental noise for determine the level of background noise. These measurements were conducted in different environmental conditions, such as: humidity, temperature, sunlight, rainfall, and during the train passing, on the bridge under the investigation. In order to gather the widest possible spectrum of AE signals, the measuring points were layout in different nodes and elements of the bridge construction. At this stage of research, in each measuring point, it was used several types of sensors with different frequency ranges and different values of gain.

There were also used different ranges of frequency filters in the systems of measurement channels. These measurements were used to determine initially the frequency range of AE signals recorded, and they became the initial state for further laboratory measurements.

All the studies, presented in this paper were conducted with using the AMSY5 (Vallen) measurement system and Vallen software.
Laboratory tests

As part of the work, it was subsequently carried out the laboratory testing on base samples cut out from the bridge traverse, and on the elements (nodes) of the metal truss bridge. These elements were obtained from the scrapped railway bridge.

The base samples with a thickness of 12 mm, were subjected to different load values, and to intensify the corrosion process there were made the "chambers" for the local long-term corrosive effect on the test samples.

The Figure 1 shows a sample view of the "chamber" and the AE sensors.

![Fig.1 A sample mounted with AE sensors and the corrosion “chamber”](image)

The measurements were carried out in various states of degradation of the corrosion samples, for different load conditions and in changing environmental conditions. In order to assess the impact of changes in loading samples and environmental conditions on the intensity of corrosion degradation of the material, the reference sample was not subjected to the load, and only the constant corrosive environment.

The graph (Fig. 2) of the quantity of hits for the sample with loading subjected to varying environmental conditions, and the sample subjected to standing corrosive action, shows the influence of these factors on the number of recorded AE signals.

All graphs presented in this article do not cover the following periods after the load of samples or modification of the corrosive environment, when activity of the AE recorded signals is very large and does not reflect the real conditions of the test.
Laboratory tests were also carried out on elements of the truss bridge with visible corrosion defects, illustrated in Figure 3.

Tests on nodes with visible corrosion defects were also carried out with AE sensors using, with different frequency characteristics. The aim was to examine the dominant frequency. Figure 4 shows the frequency distribution of AE signals recorded on a node treated with corrosive medium used to accelerate the corrosion process.
The main frequency range of recorded signals were within the 30±110kHz, therefore in subsequent studies, mainly there were used sensors with resonant frequencies of 30kHz and 75kHz. Research on large elements was conducted only in free of charge conditions, however it was possible to carry out the attempt of the corrosion sources location with using an activator of corrosion, in order to intensify the process of corrosion. The measurements were conducted on a small node with no load and with different loads. Loading of elements had an impact on the intensity of recorded signals, their amplitude and energy, as shown in Figure 5. Loading of an element had no effect on the frequency value of the recorded signals. Therefore, subsequent experiments on real objects were carried out during normal operation of the bridge facility with passing trains. Duration of this test took several hours in variable environmental conditions, it was especially watched the variable humidity.
The use of VisualClass application for the classification of AE signals

The laboratory tests were conducted in order to gather AE signal frequency characteristics from corrosion defects, which were then analyzed with using the VisualClass application. The collected measurement data was analyzed with the aid of two methods - Supervised Method (data from samples of base and nodes) and Unsupervised Method (tests on nodes). After the final analysis there were obtained five classes of signals, which separation is shown in
Figure 6. The signals intensity of the given class, on the test element, was the basis for determining the extent of corrosive degradation.

Figure 7 shows the linear location of given class signals (1 to 5) on a large node. The apparent greater number of 4 and 5 classes signals reveals that there are sources of the advanced surface corrosion, and the pitting corrosion.
Research on real objects

The tests on real objects were performed, in order to check the location possibilities of the signals from corrosion defect of the bridge structure, to check the influence of corrosive degradation grade of the actual constructions material on the intensity of recorded signals, to determine the effect of structures (trains) loading, and changeable environmental conditions (change in temperature and humidity) on recorded AE signals, and in order to verify the effectiveness of the developed AE signals classifier for evaluation of occurring corrosion defects.

The study was conducted, among other things, on two parallel bridge constructions, with the same structure, but with different technical condition - various corrosive defect. This comparison confirmed the existence of differences, especially in the recorded signals intensity and slight differences in the average amplitudes recorded.

For the AE sources location there was used a linear algorithm appearing in the Visual AE software.

The example of AE sources location along the spans with corrosion defect is shown in Figure 8. The studies gave an additional opportunity to verify the initial positive result, and to check the applicability of the previously created classifier in Visual Class application.

![Fig. 8 Location of AE sources along the spans of different technical conditions.](image)

Conclusion

The laboratory test investigations allowed to gather the characteristics of AE signals, corresponding to various degradation states of the material used for the bridge constructions.

Collecting these characteristics allowed to establish a preliminary classifier of AE signals, coming from corrosion defects.

The research on real objects confirmed the possibility of AE source location on bridge structures, coming from corrosion defects.

At the current level of knowledge, the primary purpose of using AE method for the bridge
construction testing is the ability of detecting location, and preliminary assessment of critical defects.

The studies indicated that defect diagnosis is possible with the aid of AE method, and they showed the need to conduct further laboratory studies, as well as the studies on various bridge structures to develop the exact patterns of defect.

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