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VISUALISATION OF CORROSION ACOUSTIC SIGNALS USING QUALITY TOOLS

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Abstract

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The article deals with the application of chosen quality tools for visualisation of acoustic signals from corrosion process. For continuous monitoring of corrosion the acoustic emission (AE) is used. This is one of the non-destructive testing methods. Using this method it is possible to receive signals and perform basic analysis. For a thorough prediction of process conditions or degradation is necessary to combine this method with other analyzes in the field of statistics, especially quality tools. For these purposes, the control charts are used in this work. Effective prediction of corrosion status of the material is very important with regard to damages caused by corrosion worldwide. The objective of this paper is to describe the possibility of signal analysis in Minitab program, where is possible to continuously produce qualitative evaluation by means of quality tools, in this case control charts. The control chart is one of the seven basic tools of quality control. Typically control charts are used for time-series data, though they can be used for data that have logical comparability. This work demonstrates the possibility of use this quality tool for the analysis of corrosion acoustic signals.

Keywords: corrosion, acoustic emission, control charts

INTRODUCTION

Nondestructive testing (NDT) is defined as the technical method to examine materials or components in ways that do not impair future usefulness and serviceability. NDT can be used to detect, locate, measure, and evaluate flaws; to assess integrity, properties, and composition; and to measure geometric characteristics. Various NDT technologies, such as ultrasonic-based methods, radiographic methods, dynamic methods, acoustic emission (AE) techniques, and acoustoultrasonic (AU) techniques have been studied. Each NDT technique has both advantages and dis-advantages with regard to cost, speed, accuracy, and safety.

Acoustic emission is a phenomenon frequently encountered in everyday life. An example of acoustic emission is the sound of a pencil being broken or wood being split. Technically, acoustic emission (AE) is defined as the class of phenomena in which transient elastic waves are generated by the rapid release of energy from a localized source or sources within a material. The term also applies to the transient elastic waves so generated (Kawamoto, Williams, 2002).

This paper focuses on the feasibility of the AE techniques for monitoring defects caused by corrosion. Tested specimens have to be loaded by static tension because of simulation of real conditions and crack propagation. Acoustic emission energy is released when a crack propagates. In the normal corrosion of carbon steel the corrosion of 1 mm of steel results in up to 12 mm of the hydrated iron oxide. It is during this expansive process that there are multiple micro-fractures and de-laminations of the oxide that cause acoustic emission. The emission from corrosion usually releases much less energy than emission from crack growth, and so is more difficult to detect in the field environment. That is the reason why the combination with static loading is used. The sensor frequencies used to detect these signals are determined more on the basis of the environmental noise under test conditions than on the frequency spectrum of the emission (Cole, Watson, 2005). Signals of AE are continuously monitored and processed in MINITAB statistic software using chosen statistic tools to predict the future state of specimen.

MATERIALS AND METHODS

A carbon steel EN 10025 was used as an experimental material. The salt chamber following standard ISO 9227 has been used for acceleration of corrosion process. Concurrently the specimens have been loaded by static bend. The specimens have been loaded by this accelerated degradation for 20 days.

The AE method makes it possible to "hear" the micro-structural changes in the specimen. An accumulated energy is released in certain localities of the material due to static loading, such as the formation and crack propagation (Dostál *et al.*, 2012). Acoustic emission sensors as devices mounted on the surface of the structure being tested. When transient waves propagate through the structure, the piezoelectric crystal in acoustic emission sensor will resonate in response to the structure's surface motion. The change in stress in the crystal will generate an electric current, which can be monitored. This information will then be stored by the acoustic emission data acquisition system (Ativitavas, 2002).

Fig. 1 shows the equipment for static bend simulation. On Fig. 2 is visible the montage of AE sensor.

By means of DAKEL – XEDO diagnostic system (Fig. 3) is possible to analyse the acoustic signals during degradation. This system is an advanced device for capturing and recording of AE parameters, localization of AE sources, and signal sampling. Its main purpose is to monitor periodical pressure tests to detect any potential hidden defects in primary circuit technology material and to identify locations that have the highest probability of material defect occurrence.

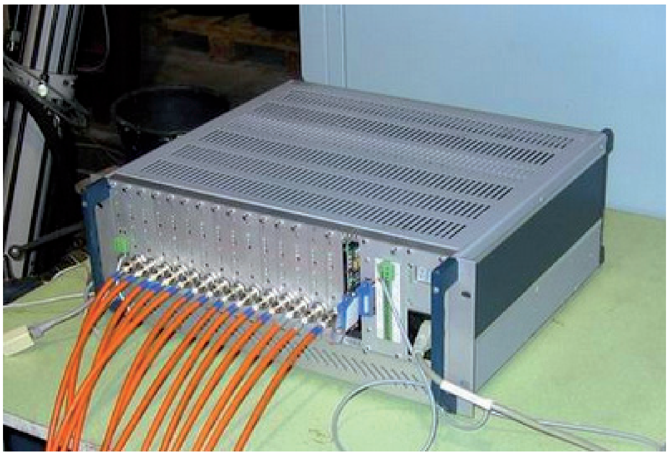
1: *Static bend simulation*

2: *AE sensor location*

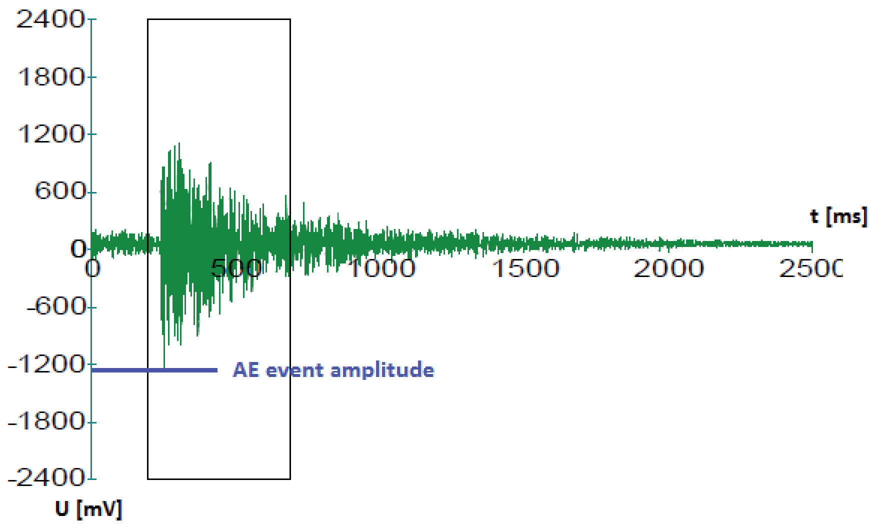
Systems sensors can act as electronic transmitters (pulsers) enabling the function check and calibration of sensors. Signals from the sensor were analyzed by Dakel XEDO AE 4.0 in 80–400 kHz frequency range. Measured dataset was stored on the hard drive of a standard PC and analyzed by Minitab statistic software. Using software Daeshow are visualised acoustic emission events corresponding with synergy of corrosion and stress loading. The sample of typical AE event shows Fig. 4.

The AE event consists of many frequency components. The higher frequency components will attenuate more quickly as the wave travels and can only be detected close to the source. Background noise such as that from external sources will be lower frequency. Therefore, the resonant frequency of the sensor is chosen to give maximum sensitivity without background noise. The piezoelectric material in the acoustic emission sensor transforms the signal to voltage. Since the magnitude of the voltage is very small, a preamplifier is required to amplify the voltage to more suitable range.

Using statistical software MINITAB are the amplitudes of AE signals processed for statistical analysis. This is necessary for monitoring of material state prediction. Minitab Inc. has been providing global solutions for quality improvement professionals and educational institutions.



3: *Dakel-Xedo equipment*



4: *AE event – visualisation of signal amplitude*

RESULTS AND DISCUSSION

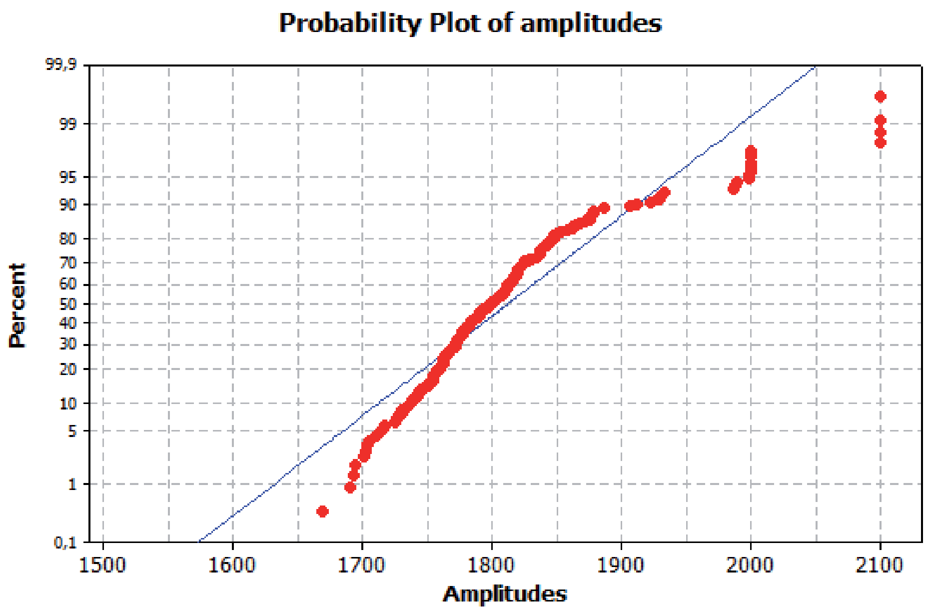
Authors of publication (Dostál *et al.*, 2011, 2012) demonstrate that the amplitudes of AE events in corrosion process show a normal distribution in the "safe" stage of corrosion degradation in synergy of high-cyclic fatigue. This work demonstrates the validity of this statement also in the case of static stress loading in synergy of corrosion. With the loss of normality distribution of amplitudes of AE events leads to major changes in the test material and starts the crack propagation stage. These trends were compared with results of other publications (Cole, Watson, 2005) where has been achieved similar trends.

The amplitudes of individual acoustic events were transformed and analysed using Daeshow and Minitab software. Amplitudes of AE events were continuously processed. As a first analyse was performed a normality test for data distribution evaluation. This analysis is shown on following Fig. 5.

Tab. I shows the main values for statistic analysis gained from normality test. For determination of the type of measured values distribution is the p-value significant. For normal distribution it must be less than 0.05. It was found that the distribution of AE amplitudes shows normal distribution therefore is possible to use control charts for other analysis.

Fig. 6 shows control charts for mean and standard deviation from 200 amplitudes from AE events. Subgroup size is 10 points. The measurement has been performed in 20 days, each day was ten values recorded and continuously transformed into control charts and visualised.

The central lines and control limits (UCL and LCL) are determined experimentally. There is obvious that from the beginning to day 12 is the corrosion process stable. It can be supposed that there are no risks of damage. This selected series of acoustic events amplitudes indicated the acoustic signal during the corrosion under loading which are not dangerous for specimen, respectively equipment life. Up to day 19 the lower and upper line of control limits are not exceeded by visualised points. The

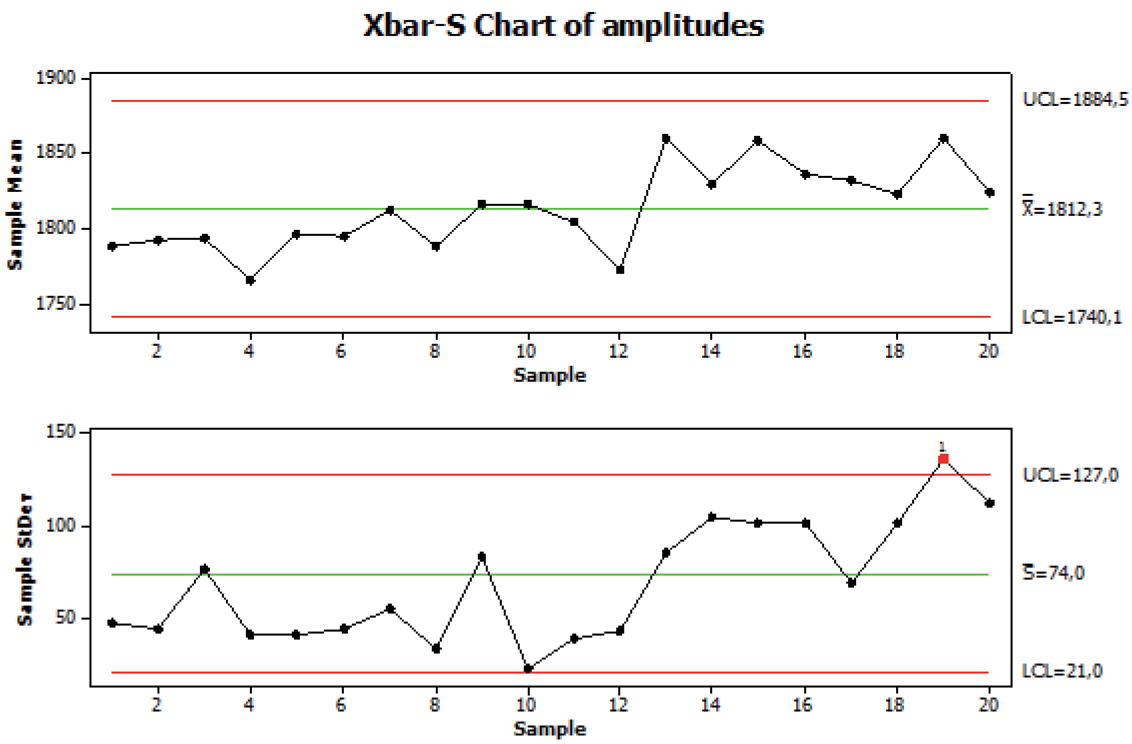


5: *Normality test of AE amplitudes*

I: *Values from analysis of distribution type*

Mean [mV]	1 812
Standard deviation	77,19
Number of values	200
p-value	**< 0,005**

process in this stage is in normal cycle. But from day 13 to day 19 is the corrosion process changing and there is possible to see slowly increasing trend of AE signal amplitudes. In day 19 is upper control limit (UCL) exceeded. It means that degradation process is in unstable state. In this case the degradation process became dangerous. When this level of loading will be continuing, poses a serious risk of destruction. This is described also by other authors (Ativitavas, 2002).



6: *Xbar-S Chart of AE amplitudes*

CONCLUSIONS

Detection of corrosion by acoustic emission is not a new phenomenon. However, years of experience and continuing development have helped to make the use of the method practical and in some cases even quantitative. Recognising and eliminating noise is still the main challenge due to the small size of the signals in the presence of potential process noise. Modern instrumentation and pattern recognition helps, but operator training and procedures still play a major part in achieving meaningful measurements (Cole, Watson, 2005). Use of quality tools in recognising sinals of AE is very useful especially in corrosion proces where the sinals have continuous character.

SUMMARY

The objective of this paper is to find the possibility for analysing AE signals continuously for prediction the future state of monitored specimen or equipment. The experimental approaches selected for analysis of the acoustic signals from corrosion process and described above are surely sufficient for the needs of presented research.

This work demonstrates the possibility of use the quality tools, especially control charts, to assess AE signals applied to corrosion and mechanical degradation process. The control charts as one of seven basic quality tools was used for determination of current state of the degradation. The data obtained from the measuring device (especially amplitudes) are transferred to the appropriate program for statistical analysis.

One of the most common indications found during acoustic emission monitoring of corrosion in synergy of static loading is an activity resulting from spalling of corrosion scale. In described control charts, the upper control limit is exceeded by in day 19 where the critical degradation is starting. The control chart indicates that the degradation in this stage is dangerous for specimen, respectively for equipment. On the basis of this evaluation is possible to predict the accident and to take adequate precautions.

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REFERENCES

KAWAMOTO, S. and WILLIAMS, R. S., 2002: Acoustic Emission and Acousto-Ultrasonic Techniques for Wood and Wood-Based Composites. A review. *Gen. Tech. Rep. FPL-GTR-134*. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, p. 16.

PHIL COLE, JON WATSON, 2005: Acoustic Emission for Corrosion Detection. *Middle East Nondestructive Testing Conference & Exhibition*. Bahrain, Manama: NDT.net, 27–30

DOSTÁL, P., KUMBÁR, V., CHRÁST, V., ČERNÝ, M., 2012: Use of quality tools in monitoring of high-cyclic fatigue. In: *Deterioration, dependability, diagnostics*. 1. vyd. Brno: University of defence, s. 139–145. ISBN 978-80-7231-886-5.

DOSTÁL, P., ČERNÝ, M., LEV, J., VARNER, D., 2011: Proportional monitoring of the acoustic emission in crypto-conditions. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis*, 55, 1: 31–38. ISSN 1211-8516.

DOSTÁL, P., ČERNÝ, M., KUMBÁR, V., 2012: Využití statistických nástrojů pro monitoring akustické emise. In: *Quality and reliability of technical systems*. 1. vyd. Nitra: SPU v Nitře. 208—214. ISBN 978-80-552-0798-8.

ATIVITAVAS, N., 2002: *Acoustic Emission Signature Analysis of Failure Mechanisms in Fiber Reinforced Plastic Structures*. Dissertation Presented to the Faculty of the Graduate School of The University of Texas at Austin. Austin. [cit. 2011-01-18].

DAKEL, TECHNICAL DEPARTMENT, 2005: *XEDO Analyzer Manual*, DAKEL, ZD Rpety.

DOSTÁL, P., KUMBÁR, V., 2013: Hodnocení korozní rezistence konstrukční oceli pomocí NDT. *Technická diagnostika*, 22, z1: 19. ISSN 1210-311X.

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