SLOVENSKI STANDARD
SIST EN 17391:2022

01-november-2022

Neporušitvene preiskave - Akustična emisija - Nadzorovanje akustične emisije pri uporabi kovinske tlačne opreme in drugih kovinskih struktur - Splošne zahteve

Non-destructive testing - Acoustic emission testing - Inservice acoustic emission monitoring of metallic pressure equipment and structures - General requirements

Zerstörungsfreie Prüfung - Schallemissionsprüfung - Überwachung der Schallemission von metallischen Druckgeräten und -strukturen im Betrieb - Allgemeine Grundsätze

Essais non destructifs - Contrôle par émission acoustique - Surveillance en service par émission acoustique des équipements et structures métalliques sous pression - Exigences générales

Ta slovenski standard je istoveten z: **EN 17391:2022**

ICS:

19.100	Neporušitveno preskušanje	Non-destructive testing

SIST EN 17391:2022 **en,fr,de**

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 17391

June 2022

ICS 19.100

English Version

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Ref. No. EN 17391:2022 E

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European foreword

This document (EN 17391:2022) has been prepared by Technical Committee CEN/TC 138 “Non-destructive testing”, the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by December 2022, and conflicting national standards shall be withdrawn at the latest by December 2022.

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Introduction

Acoustic emission testing (AT) is well established for the detection of discontinuities in metallic structures. Furthermore, AT is widely accepted and applied during hydraulic or pneumatic test. In-service acoustic emission (AE) monitoring can provide global surveillance of structural details for early detection of active cracks and damage evolution. It allows through life damage assessment guiding subsequent non-destructive testing (NDT) for damage verification and damage sizing purposes.

1 Scope

This document specifies general requirements for in-service acoustic emission (AE) monitoring. It relates to detection, location and grading of AE sources with application to metallic pressure equipment and other structures such as bridges, bridge ropes, cranes, storage tanks, pipelines, wind turbine towers, marine applications, offshore structures. The monitoring can be periodic, temporary or continuous, on site or remote-controlled, supervised or automated. The objectives of AE monitoring are to define regions which are acoustically active as a result of damage or defect evolution.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 1330-1:2014, *Non destructive testing — Terminology — Part 1: List of general terms*

EN 1330-2:1998, *Non destructive testing — Terminology — Part 2: Terms common to the non-destructive testing methods*

EN 1330-9:2017, *Non-destructive testing — Terminology — Part 9: Terms used in acoustic emission testing*

EN 13477-1:2001, *Non-destructive testing — Acoustic emission — Equipment characterisation — Part 1: Equipment description*

EN 13477-2:2010, *Non-destructive testing — Acoustic emission — Equipment characterisation — Part 2: Verification of operating characteristic*

EN 13554:2011, *Non-destructive testing — Acoustic emission testing — General principles*

EN 60529:1991, *Degrees of protection provided by enclosures (IP Code)*[1]

EN ISO/IEC 17025:2017, *General requirements for the competence of testing and calibration laboratories (ISO/IEC 17025:2017)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 1330-1:2014, EN 1330-2:1998 and EN 1330-9:2017 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

4 Personnel qualification

It is assumed that acoustic emission monitoring is performed by qualified personnel. In order to prove this qualification, it is recommended to qualify the personnel in accordance with EN ISO 9712.

[1] As impacted by EN 60529:1991/corrigendum May 1993, EN 60529:1991/A1:2000, EN 60529:1991/A2:2013, EN 60529:1991/AC:2016-12 and EN 60529:1991/A2:2013/AC:2019-02.

5 Information prior to testing

5.1 Structural information

The monitoring of the structure depends on the historical operational data. The knowledge of the operating conditions (e.g. maximum load level, cycling, environmental conditions) and possible repairs are key factors for the determination of the monitoring strategy.

The accessibility of the structure shall be considered when the monitoring task is planned, designed and performed.

The type and size of the structure (as well as other factors) shall determine whether the monitoring can be global or local. If damage is expected in some specific areas of the structure, the sensor configuration shall focus on these areas to monitor for possible damage evolution. In this case the monitoring may be restricted to:

— a known damage mechanism at a specific location from experience; or

— highly stressed areas (hot spots) of known or predicted susceptibility to failure (e.g. finite element analysis).

5.2 Operating conditions

In the case of a potentially explosive environment, the instrumentation used and its installation should conform to Directive 2014/34/EU (ATEX) [7]. In particular sensors and preamplifiers shall be ATEX certified.

For structures operating above or below a certain temperature level (e.g. above +80 °C or below −40 °C), specific high/low temperature instrumentation shall be used. Appropriate attention shall be given to the sensor coupling agent (see 7.2.3).

A high operating temperature, either by itself or in combination with the load, can influence the damage mechanisms in the structure (e.g. high-temperature corrosion requires a high-temperature environment).

In case of low-temperature operating conditions, attention shall be paid to the fracture toughness (ductile-to-brittle transition) of the structure material. If the structure is insulated, as in many cases, the formation of frost in the insulation windows should be avoided so that cracking of the frozen product does not disturb AE monitoring.

Where the structure is located outside (in the open air), natural phenomena like wind, rain or hail can disturb the AE monitoring. Such phenomena shall be taken into account during the preparation of the monitoring methodology. If the structure cannot be protected from the environment, these natural phenomena shall be measured as well as recorded and the data of the associated parametric inputs correlated with the AE data.

In case of aggressive and/or corrosive environment such as exist in:

— marine or offshore structures (e.g. saline mist, waves, storms, etc.);

— chemical plant structures (e.g. acid);

— nuclear plants (e.g. radiation);

special care shall be taken for the protection of all the exposed AE instrumentation, sensors and preamplifiers. The acquisition system shall be located as far as possible away from the above risks.

In case of high- or low-temperature operating structure, preliminary measurements shall be performed in conditions as close as possible to real operating conditions.

The influence of the process noise on the sensitivity of the monitoring shall be identified before starting the monitoring itself.

All information on the various phases of the process shall be provided by the customer/owner/operator. The severest process periods shall be taken into account to determine if the monitoring is possible continuously or periodically.

5.3 AE event mechanisms

5.3.1 General

In technical application, detectability of early stages of structural degradation or damage, e.g. due to fatigue and stress corrosion, is supported by material embrittlement (low temperature, hydrogen or radiation induced embrittlement, hardened heat-affected zone of weld). Detectability can be enhanced by major induced AE events in the material volume from secondary effects or processes. Secondary effects are often of greater importance for early detectability compared to stable crack growth.

Simultaneously occurring secondary effects or processes can create intense sources of high AE activity and/or higher burst signal maximum amplitudes from overlapping of many single low-energy events e.g.:

— dislocation avalanche processes within an extended plastic zone at the tip of large cracks;

— fretting of non-corroded or corroded crack faces or stress transfer induced local interfacial friction during opening/closure actions of fatigue cracks without any crack growth itself;

— AE emitting processes due to material morphology caused by local stress fields around/ahead of crack tips, e.g. breakage of hard inclusions or high melting impurity phases in the ferrite grain or of grain boundary precipitations;

— breakage of corrosion products (e.g. rust particles) internally or on corroded crack faces, etc.

5.3.2 Crack growth

Fatigue is the most common cause of mechanical failure of machinery and structures subjected to cyclic loading. Stress corrosion cracking (SCC) is one of the common causes for failure in chemical reactors and fluid transmission lines.

AE is sensitive to the brittle microscopic fracture events accompanying stable fatigue crack propagation and corrosion related fracture events. The relationship between the acoustic emission from stable crack growth in metals and the associated damage mechanisms, whether fatigue or stress corrosion cracking, requires greater understanding of the physics of plastic deformation and fracture on the crystal microstructure scale.

Annex A contains fracture parameters associated with acoustic emission from stable fatigue crack growth with reference to marine structures. The driving force behind crack growth is the stress concentration at the crack tip. Unless the crack is continually supplied with strain energy it will cease to propagate.

Other stable crack growth mechanisms giving rise to acoustic emission include hydrogen cracking and thermally induced cracks. AE monitoring may be used also for detection of hydrogen blistering, delamination, creep and aging (material degradation).

5.3.3 Corrosion

The mechanisms of corrosion are different to stable crack growth. General corrosion is usually a surface oxidation over a large area. The AE activity and intensity depends on the severity of the ongoing corrosion process.

Furthermore, stress due to pressure or temperature cycling usually leads to cracking and de-bonding of the brittle oxide layer resulting in high AE activity over the corroded area.

Other localized corrosion processes may lead to damage with local stress concentration and subsequent crack initiation (e.g. at the area of pin holes or pitting).

5.3.4 Friction, fretting and cavitation erosion

These damage mechanisms are particularly intense sources of acoustic emission.

Cavitation in a liquid leads to the implosion of bubbles that generates strong intensity (up to 1000 MPa) and short duration (approximately µs) pressure waves. Notably AE from cavitation results in discrete events, whose acoustic energy is at least an order of magnitude higher than those events generated by turbulence phenomenon.

Fretting and friction phenomena generate AE of high energy and these mechanisms can be produced within a crack during loading and unloading of the structure.

6 Monitoring methodology

6.1 Periodic, temporary or continuous monitoring

The integrity or health of a structure can be investigated by AE monitoring at any time of its working life, i.e. in-service under normal operating loads, start up and shutdowns, provided that possible variations of operating conditions do not come into conflict with the technical specifications of the AE instrumentation or the measurement setup during data acquisition.

Large-scale and/or complex structures, e.g. ship hulls, offshore platforms or bridges permit AE monitoring only for areas identified as highly stressed and fatigue and/or corrosion-sensitive.

Different in-service AE monitoring methodologies can be adapted depending on the objective of the measurement, e.g.:

— temporary (short or medium term), if the monitoring is performed for a single short (hours/days) or medium (weeks/month) time interval;

— periodic, if the monitoring is done repeatedly on the same structure for specific time periods not necessarily based on the same time interval;

— continuous, if the monitoring is conducted permanently on the same structure for a long duration (months or years).

The methodology and the time period of AE monitoring shall be selected taking into account:

— type of known or expected damage mechanisms activating AE sources like crack growth, corrosion, cavitation;

— operating conditions such as temperature, hazardous environment, rate of pressure changes, flow of fluids, vibration or frictional noise, process cycle duration;

— environmental noise, e.g. caused by wind, rain, thermal stress release.

The required time periods and minimum duration of AE monitoring shall be specified for each type of defect or damage mechanism as well as the stage and rate of degradation.

Other factors to be taken into account include for example: plant age, material type and wall thickness, changing of fluids or storage media with different corrosiveness dependent on time or in-service use, the service pressure and temperature.

If the parameters needed to estimate the minimum duration of AE monitoring are known only with a large uncertainty, continuous monitoring shall be applied.

In any case, the minimum AE monitoring duration shall be extended if relevant indications (e.g. AE location clusters) are detected or significant variation of the AE activity or intensity rate occurs.

The AE measuring system shall be adapted with respect to the monitored structure, the damage mechanism to be detected and the particular measuring conditions.

In-service AE monitoring of the structure may not be possible if disturbances due to intense operating or environmental noise sources appear. In this case actions shall be taken to eliminate or reduce the effect of the noise to acceptable limits using AE hardware or software filters or to discriminate them by subsequent classification of the AE signals.

AE monitoring of structures may also be supported by acoustic emission testing (AT) in conjunction with the application of appropriate stressing of the structure to stimulate AE from damaged regions during dwell times, or could be performed in line with routine periodic inspection during shutdown.

6.2 On-site or remote-controlled monitoring

AE monitoring can be carried out either on-site or remote-controlled.

Apart from the traditional AE wired-sensor technology, the AE monitoring based on Wireless Sensor Network (WSN) is also useable as long as the requirements for AE source location and the power supply autonomy are met.

The written test instruction shall specify the type of supervision of the AE monitoring instrumentation.

During on-site controlled monitoring the AE system is supervised by the operator, who shall immediately undertake appropriate actions (hardware and software) or adaptations, if necessary.

The advantages of remote-controlled monitoring are:

— the possibility to view and control data as well as to perform data processing from remote locations using the Internet data transfer without the permanent presence of an AE system operator on-site; and

— the possibility to supervise multiple sites with one team.

The limitations for a remote-controlled system are:

— risk of a delayed reaction time of the operator for necessary changes of the acquisition settings and hardware solutions for problems occurring during data acquisition; and

— need to handle and compress AE data to key features by specific algorithms for fast data transfer and hardware cost reduction.

6.3 Supervised or automated monitoring

An automated monitoring instrumentation has warning and alert capabilities. A supervised AE monitoring instrumentation requires the presence of the AE test operator either on-site or off-site with appropriate remote access.

In cases where AE monitoring has never been carried out or, where no experience exists with the AE behaviour due to initiation and evolution of a specific damage under particularly critical in-service conditions, a careful initial trial monitoring is strongly recommended. The AE data acquisition should be supervised until an acceptable learning status is achieved, as well as reliable alarm/warning settings are defined and false alarms avoided.

Frequently encountered AE sources, which exhibit one or more characteristics of growing cracks or which may mask the AE from fatigue crack growth include:

— welds of poor quality with innocuous (insignificant) non-metallic inclusions, which can fracture or de-bond under cyclic stress without developing a crack;

— localized fretting, abrasion, friction at contact points with other metal components within the sensor array;

— friction between two components as a result of relative movement due to vibration, thermal expansion, e.g. on pipe support saddles;

— repetitive impacts of particles, liquid drops at the same spot on a structure;

— occasional use of mechanical tools during maintenance works;

— de-bonding and fracture of brittle coatings and corrosion products;

— fluid leaks.

In cases where such AE sources are non-relevant the AE monitoring instrumentation shall be configured to avoid false alarms.

7 Monitoring instrumentation

7.1 System requirements

The AE monitoring instrumentation consists of the AE system, the AE sensors and preamplifiers, the cables as well as all other components necessary to perform the monitoring.

The hardware and software components of the monitoring instrumentation shall conform at least to the requirements of EN 13477-1:2001 and EN 13477-2:2010.

7.2 Sensors and preamplifiers

7.2.1 General requirements

AE sensors, preamplifiers, coupling agent and cables shall be selected in compliance with the functional needs and the mechanical and environmental conditions where they are installed.