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Standard Guide for Application of Acoustic Emission for Structural Health Monitoring[1]

This standard is issued under the fixed designation E2983; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 Structural Health Monitoring (SHM) is a field of engineering that deals with diagnosis and monitoring of structures during their operation. The primary goal of SHM is detection, identification, assessment, and monitoring of flaws or fault conditions that affect or may affect the future safety or performance of structures. SHM combines elements of nondestructive testing and evaluation, condition/process monitoring, statistical pattern recognition, and physical modeling.

1.2 The acoustic emission (AE) method uniquely fits the concept of SHM due to its capabilities to periodically or continuously examine structures and assess structural integrity during their normal operation.

1.3 In this guide, the definitions and fundamental principles for applying the AE method for SHM tasks are elaborated. This includes:

1.3.1 Terminology and definitions of SHM by the AE method,

1.3.2 Outline the recommended process of AE-SHM, and

1.3.3 Fundamental requirements regarding development of the SHM procedures, including selection of appropriate AE apparatus, data acquisition and analysis methods, diagnosis, monitoring and prediction.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E543 Specification for Agencies Performing Nondestructive Testing

E1316 Terminology for Nondestructive Examinations

2.2 *ISO Standards*[3]

ISO/DIS 10303–226 Industrial Automation Systems and Integration—Product Data Representation and Exchange

ISO 9712 Non-destructive Testing—Qualification and Certification of NDT Personnel

2.3 *Other Referenced Documents*

ANSI/ASNT CP-189 Standard for Qualification and Certification of Nondestructive Testing Personnel[4]

NAS-410 NDT Certification[5]

SNT-TC-1A Personnel Qualification and Certification in Nondestructive Testing[6]

3. Terminology

3.1 *Definitions:* See E1316 for terminology related to this practice.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *diagnosis, n*—a process of detection, identification, and assessment of flaws, and identifying properties or conditions that may affect the future safety or performance of a structure.

3.2.2 *diagnostic AE, n*—an acoustic emission methodology capable of achieving the goals of diagnosis.

3.2.3 *fault, n*—an abnormal condition or defect at the component, equipment, or sub-system level which may lead to a failure. **Worden et al.**[7]

3.2.4 *monitoring, n*—a process of observing or detecting changes in the condition of a structure.

3.2.5 *prediction, n*—a process of estimation of the possible future flaw or fault deterioration based on results of monitoring, diagnostics, or numerical modeling, or a combination thereof.

[1] This test method is under the jurisdiction of ASTM Committee E07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.04 on Acoustic Emission Method.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, http://www.iso.org.

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[5] Available from Aerospace Industries Association of America, Inc. (AIA), 1000 Wilson Blvd., Suite 1700, Arlington, VA 22209-3928, http://www.aia-aerospace.org.

[6] Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, http://www.asnt.org.

[7] K. Worden, C. Farrar, G. Manson, G. Park, "The fundamental axioms of structural health monitoring", Proceedings of the Royal Society A, Vol. 463, 2007, p. 1639-1664.

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3.2.6 *sensing*—a process of detection of acoustic emission and conversion of measurements into data used during diagnosis.

3.2.7 *structural health monitoring (SHM), n*—a process of diagnosis and monitoring the condition of structures, normally performed during their operation.

4. Summary of Guide

4.1 The guide describes the AE-SHM process and provides a set of fundamental assumptions recommended in the application of the AE method in SHM tasks.

5. Significance and Use

5.1 This guide can be used in the development of acoustic emission applications for structural health monitoring.

5.2 Accuracy, robustness, and efficiency of AE-SHM can be enhanced by following the steps and fundamental principles described in the guide.

6. Basis of Application

6.1 The following items are subject to contractual agreement between the parties using or referencing this guide.

6.2 *Personnel Qualification:*

6.2.1 If specified in the contractual agreement, personnel performing examinations to this standard shall be qualified in accordance with a nationally and internationally recognized NDT personnel qualification practice or standard such as ANSI/ASNT CP-189, SNT-TC-1A, NAS-410, ISO 9712, or a similar document and certified by the employer or certifying agency, as applicable. The practice or standard used and its applicable revision shall be identified in the contractual agreement between the using parties.

6.2.2 *Qualification of Nondestructive Testing Agencies*—If specified in the contractual agreement, NDT agencies shall be qualified and evaluated as described in Specification E543. The applicable edition of Specification E543 shall be specified in the contractual agreement.

7. The Process of Structural Health Monitoring by the Acoustic Emission Method

7.1 The process of AE structural health monitoring can be divided into the following typical stages:

7.1.1 AE-SHM procedure development,

7.1.2 Sensing,

7.1.3 Diagnosis,

7.1.4 Monitoring, and

7.1.5 Prediction.

7.2 *AE-SHM Procedure Development*—The first stage of procedure development starts with the collection of all necessary information regarding the structure, its design and materials, operational conditions, statistics of failures, etc. In addition, laboratory or full scale tests, or both, are conducted on structures with known flaws or faults, at a known stage of development in order to develop the ability to detect, identify, and assess specific flaws or faults. Based on the collected information, the optimal instrumentation, methods of data acquisition and data analysis, and loading procedures are established.

NOTE 1—Results of laboratory testing of small scale specimens, and especially signal features derived therefrom, are not directly applicable to full scale structures due to such influences as sensor frequency and sensor mounting or spacing; wave propagation or reflections in small specimens versus large plate structures; noise backgrounds not replicated on small specimens; complex emission mechanisms that involve stress corrosion cracking, hydrogen embrittlement cracking, creep development, and the like that involve difficult-to-control environments in the lab. Specimen testing may be used to model the behavior and relative emissivity of mechanisms in materials, but may not be directly transferred to full scale structures for life prediction.

7.3 *Sensing*—Sensing is a process of data capture and measurement. It involves measurement of AE as well as parametric data such as pressure, temperature, strain, and other information according to the developed SHM procedure. There are several important aspects to address during the sensing stage. It is important to check that data collected during the data acquisition process is valid and can be satisfactorily used for the purposes defined in the developed SHM procedure. If this is not the case, additional measurements with a different setup or loading, operational or environmental conditions or both, may be required. Also, during the sensing process, a short evaluation of the structure should be performed to identify, or rule out, possible conditions that may threaten the structure immediately or in the short term.

7.4 *Diagnosis*—Diagnosis is one of the primary tasks of the SHM process. It effectively distinguishes typical noise-related AE from SHM-related AE. The objectives of the diagnosis process are not only to detect and locate flaws or faults as in typical NDE but also to identify and assess them. Diagnosis is performed based on collected data, numerical modeling including finite element analysis, history of the inspected structure, local application of different NDE methods, material and other relevant investigations.

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7.5 *Monitoring*—Monitoring is performed to assess the condition of a structure over time. It is performed periodically or continuously, depending on the particular application. For best results, it is recommended to identify quantitative or qualitative AE characteristics, or both, that are changing with the flaw or fault development. It is important to perform monitoring under normal operational and environmental conditions of a structure. If a change in stress or operational or environmental conditions occurs for any reason, or a structure has been subjected to extreme conditions and trauma, it may require a change in the monitoring policy. Another important goal of monitoring is to identify conditions causing flaw or fault origination and development in the inspected structure. Examples of such conditions are fatigue, mechanical and thermal overstresses, etc.

7.6 *Prediction*—The goals of prediction can include:

7.6.1 Assessment of suitability for continued service of structures when a proven and statistically valid experience or database is gathered.

7.6.2 Defining an appropriate re-inspection or monitoring policy based on diagnostic and monitoring results.

7.6.3 Providing information necessary for condition-based maintenance decisions.