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Non-destructive testing — Acoustic emission inspection — Secondary calibration of acoustic emission sensors

*Essais non destructifs — Contrôle par émission acoustique — Étalonnage
secondaire des capteurs d'émission acoustique*



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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 12714 was prepared by Technical Committee ISO/TC 135, *Non-destructive testing*, Subcommittee SC 3, *Acoustical methods*.

Introduction

The acoustic emission method of non-destructive testing is addressed by SC3 on acoustical methods of TC 135 on non-destructive testing. Standards for general procedures and requirements are required in order to insure quantitative results and wide applicability. This International Standard addresses the transfer of calibration, or secondary calibration, of acoustic emission sensors. In this method, the device under test is calibrated by comparison with a sensor that has previously undergone primary calibration. The sensor used for comparison is called the reference or secondary standard sensor. The aim of this International Standard is to establish uniformity of acoustic emission testing by standardizing the methods used to transfer calibrations of sensors.

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Non-destructive testing — Acoustic emission inspection — Secondary calibration of acoustic emission sensors

1 Scope

This International Standard specifies a method for the secondary calibration of acoustic emission sensors as receivers of elastic waves at the surface of a solid medium. The International Standard is applicable to laboratory tertiary standard sensors and acoustic emission applications sensors.

The secondary calibration yields the frequency response of a sensor to waves of a type normally encountered in acoustic emission work, namely Rayleigh waves. The source producing the signal used for the calibration is mounted on the same surface of a test block as the sensor under test (SUT). The sensitivity of the sensor is determined for excitation within the range of 100 kHz to 1 MHz. Sensitivity values are usually determined at frequencies approximately 10 kHz apart. The units of the calibration are volts per unit of mechanical input (displacement, velocity or acceleration).

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 12713:1998, *Non-destructive testing — Acoustic emission inspection — Primary calibration of transducers*.

ISO 12716:—¹⁾, *Non-destructive testing — Acoustic emission inspection — Vocabulary*.

ASTM E114-95, *Standard Practice for Ultrasonic Pulse-Echo Straight-Beam Testing by the Contact Method*.

ASTM E1106-86(1992)e1, *Standard Method for Primary Calibration of Acoustic Emission Sensors*.

ASTM E1316-97b, *Standard terminology for Nondestructive Examinations*.

3 Terms and definitions

For the purposes of this International Standard the terms and definitions in ISO 12716 and in ASTM E 1316 as well as the following apply.

3.1 reference sensor (RS)

sensor which has had its response established by primary calibration – see ASTM E 1106 or ISO 12713

NOTE Also called secondary standard sensor.

¹⁾ To be published.

3.2 secondary calibration

procedure for measuring the frequency or transient response of an acoustic emission sensor by comparison with an RS

3.3 test block

block of homogeneous, isotropic elastic material on which a source, an RS and a SUT are placed for carrying out secondary calibration

4 Abbreviations

AE: acoustic emission

ASTM: American Society for Testing and Materials

FFT: fast Fourier transform

ISO: International Organization for Standardization

RS: reference sensor

SUT: sensor under test

5 General requirements

5.1 Sensor Under Test

This method is applicable to the absolute calibration of normal motion sensors for use as tertiary standards and to the calibration of acoustic emission sensors for use in AE sensing. For tertiary standards purposes, the sensor being calibrated should be of a small aperture, high-fidelity type (such as the NBS Conical Transducer). In general, results from any sensor will be degraded by large aperture and lack of flatness of frequency response.

The stated accuracy applies only if the sensor being calibrated is highly damped. The signal from the sensor following the shock excitation of the calibration signal should be damped to an insignificant level (20 % of peak signal) within the time (30 μ s for the prototype secondary calibration system) of the allowed capture window, limited by echoes from boundaries of the calibration block. If this condition is violated, calibration accuracy will suffer. (See 8.1.)

5.2 Units for the Calibration

Secondary calibration produces the same type of information about a sensor as does primary calibration. An AE sensor responds to motion at its front face. The actual stress and strain at the front face of a mounted sensor depends on the interaction between the mechanical impedance of the sensor (load) and that of the mounting block (driver); neither the stress nor the strain is amenable to direct measurement at this location. However, the free displacement that would occur at the surface of the block in the absence of the sensor can be inferred from measurements made elsewhere on the surface. Since AE sensors are used to monitor motion at a free surface of a structure and interactive effects between sensor and structure are generally of no interest, the free motion is the appropriate input variable. It is required therefore, that the units of calibration be volts per unit of free displacement or free velocity, i.e. volts per meter or volt seconds per meter.

The calibration results may be expressed in the frequency domain as the steady-state magnitude and phase response of the sensor to steady-state sinusoidal excitation, or in the time domain as the transient response of the sensor to a delta function of displacement.

5.3 Importance of the test block material

The specific acoustical impedance (Z_{ac}) of the test block is an important parameter which affects the calibration results. Calibrations performed on blocks of different materials yield sensor sensitivities that are very different, e.g., a sensor that has been calibrated on a steel block, if calibrated on a glass or aluminum block, may have an average

sensitivity that is 50 % of the value obtained on steel, and, if calibrated on a polymethyl methacrylate block, may have an average sensitivity that is 3 % of the value obtained on steel [2].

For a sensor having a circular aperture (mounting face) with uniform sensitivity over the face, there are frequencies at which nulls in the frequency response occur. These nulls occur at the zeroes of the first order Bessel function, $J_1(ka)$, where $k = 2\pi f/c$, f is frequency, c is the Rayleigh speed in the test block and a is the radius of the sensor face [2]. Therefore, calibration results depend upon the Rayleigh wave speed in the material of the test block.

For the reasons outlined in the previous two paragraphs, all secondary calibration results are specific to a particular material; a secondary calibration procedure must specify the material of the block. Although this International Standard addresses secondary calibrations on test blocks of different materials, the only existing primary calibrations are performed on steel test blocks. To establish a secondary calibration on another material would also require the establishing of a primary calibration for the same material.

6 Requirements of the secondary calibration apparatus

6.1 Basic Scheme

A prototype apparatus for secondary calibration is shown in Figure 1. A glass-capillary-break device or other suitable source device (A) is deployed on the upper face of the steel test block (B). The RS (C) and the SUT (D) are placed equally distant from the source and in opposite directions from it. Because of the symmetry of the sensor placement, the free surface displacements at the locations of the RS and the SUT are the same. Voltage transients from the two sensors are recorded simultaneously by digital waveform recorders (E) and processed by a computer.

Actual dynamic displacements of the surface of the test block at the locations of the RS and the SUT may be different because the RS and the SUT may present different load impedances to the test block. However, consistent with definitions used for primary and secondary calibration, the loading effects of both sensors are considered to be characteristics of the sensors themselves, and calibration results are stated in terms of free displacement of the block surface.

6.2 Qualification of the test block

The prototype secondary calibration apparatus was designed for sensors intended for use on steel. The test block is therefore, made of steel (hot rolled steel A36 material). For a steel block, it is recommended that specification to the metal supplier require that the block be stress relieved at 566 °C or greater and that the stress relief be carried out subsequent to any flame cutting.

For a steel test block, there shall be two parallel faces with a thickness, measured between the faces, of at least 180 mm. The volume of the block shall contain a cylinder which is 400 mm in diameter by 180 mm long, and the two faces shall be flat and parallel to within 0,12 mm overall ($\pm 0,06$ mm).

For a steel test block, the top surface of the block (the working face) shall have an RMS roughness value no greater than 1 μm , as determined by at least three profilometer traces taken in the central region of the block. The bottom surface of the block must have an RMS roughness value no greater than 4 μm . The reason for having a specification on the bottom surface is to assure reasonable ability to perform time-of-flight measurements of the speed of sound in the block.

For blocks of materials other than steel, minimum dimensional requirements, dimensional accuracies and the roughness limitation shall be scaled in proportion to the longitudinal sound speed in the block material relative to that in steel.

The top face of the block shall be the working face on which are located the source, RS and SUT. These locations shall be chosen near the centre so as to maximize the distances of source and receivers to the nearest edge of the face. For a test block of any material, the distance from the source to the RS and the distance from the source to the SUT shall each be 100 mm $\pm$ 2 mm (the same as that specified for primary calibration).

The block shall undergo longitudinal ultrasonic inspection for flaws at a frequency between 2 MHz and 5 MHz. Procedure in accordance with ASTM E 114 shall be followed. The block shall contain no flaws which give a reflection greater than 12 % of the first back wall reflection.