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Non-destructive testing — Ultrasonic testing — General principles

Essais non destructifs — Contrôle par ultrasons — Principes généraux

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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 2.

The main task of technical committees is to prepare International Standards. 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.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 16810 was prepared by Technical Committee ISO/TC 135, *Non-destructive testing*, Subcommittee SC 3, *Ultrasonic testing*.

Introduction

This International Standard is based on EN 583-1:1998, *Non-destructive testing — Ultrasonic examination — Part 1: General principles*.

The following International Standards are linked.

ISO 16810, *Non-destructive testing — Ultrasonic testing — General principles*

ISO 16811, *Non-destructive testing — Ultrasonic testing — Sensitivity and range setting*

ISO 16823, *Non-destructive testing — Ultrasonic testing — Transmission technique*

ISO 16826, *Non-destructive testing — Ultrasonic testing — Examination for discontinuities perpendicular to the surface*

ISO 16827, *Non-destructive testing — Ultrasonic testing — Characterization and sizing of discontinuities*

ISO 16828, *Non-destructive testing — Ultrasonic testing — Time-of-flight diffraction technique as a method for detection and sizing of discontinuities*

Non-destructive testing — Ultrasonic testing — General principles

1 Scope

This International Standard defines the general principles required for the ultrasonic examination of industrial products that permit the transmission of ultrasound.

The specific conditions of application and use of ultrasonic examination, which depend on the type of product examined, are described in documents which could include:

— product standards;

— specifications;

— codes;

— contractual documents;

— written procedures.

Unless otherwise specified in the referencing documents the minimum requirements of this International Standard are applicable.

This International Standard does not define:

— extent of examination and scanning plans;

— acceptance criteria.

2 Normative references

The following referenced documents are indispensable for the application 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.

ISO 9712, *Non-destructive testing — Qualification and certification of personnel*

ISO 7963, *Non-destructive testing — Ultrasonic testing — Specification for calibration block No. 2*

ISO 16811, *Non-destructive testing — Ultrasonic testing — Sensitivity and range setting*

ISO 16823, *Non-destructive testing — Ultrasonic testing — Transmission technique*

ISO 2400, *Non-destructive testing — Ultrasonic testing — Specification for calibration block No. 1*

EN 12668-1, *Non-destructive testing — Characterization and verification of ultrasonic examination equipment — Part 1: Instruments*

EN 12668-2, *Non-destructive testing — Characterization and verification of ultrasonic examination equipment — Part 2: Probes*

EN 12668-3, *Non-destructive testing — Characterization and verification of ultrasonic examination equipment — Part 3: Combined equipment*

3 Qualification and certification of personnel

The examination shall be performed by personnel qualified in accordance with ISO 9712.

The requirements for qualification and certification shall be specified in the product standards and/or other applicable documents.

4 Information required prior to examination

Prior to examination the following information shall be available, as applicable:

— purpose of examination;

— qualification and certification of personnel;

— environmental conditions and state of examination object;

— requirement for a written examination procedure;

— any special requirements for preparation of scanning surface;

— examination volume;

— examination sensitivity and method of setting-up sensitivity;

— requirements for evaluation and recording level;

— acceptance criteria;

— extent of examination including scanning plan;

— requirements for a written examination report.

5 Principles of ultrasonic examination

5.1 General

An ultrasonic examination is based on propagation of ultrasonic waves through the object to be examined, and monitoring either the transmitted signal (termed the transmission technique), or the signal reflected or diffracted from any surface or discontinuity (termed the pulse echo technique).

Both techniques can employ a single probe acting as both transmitter and receiver, or double (twin) transducer probe, or separate transmitting and receiving probes. Similarly, both techniques can involve intermediate reflection from one or more surfaces of the object under examination.

The examination can be performed manually or by the use of semi-automatic or fully automatic equipment, and can use contact, gap or immersion scanning, or other coupling methods adapted to specific problems.

5.2 Vibration mode and direction of sound propagation

The most commonly used types of waves are longitudinal and transverse, and these can be propagated either perpendicular, or at an angle, to the test surface. Other types of modes, e.g. Lamb waves or Rayleigh waves can also be used for special applications.

The choice of wave mode and direction of propagation will depend on the purpose of the examination, and should take into account the specular nature of reflection from planar reflectors. Except when using Lamb waves, the direction of sound propagation, for single probe pulse echo scanning, should be as nearly perpendicular to the plane of the reflector as possible.

5.3 Transmission technique

This technique is based on measuring the signal attenuation after the passage of an ultrasonic wave through the examination object.

The signal used for measurement can be either:

a) a backwall echo, or;

b) any other signal transmitted either directly, or after intermediate reflection from the surfaces of the object.

Further details of this technique are contained in ISO 16823.

5.4 Pulse echo technique

This technique utilizes the reflected or diffracted signal from any interface of interest within the object under examination. This signal is characterized by its amplitude and position along the timebase; the latter related to the distance between the reflector and the probe. The location of the reflector is determined from the knowledge of its distance, the direction of sound propagation, and the position of the probe.

It is recommended that the signal amplitude be measured by comparison with either:

a) a distance amplitude correction (DAC) curve, or a series of DAC curves, obtained by using artificial reflectors (sidedrilled holes, flat-bottomed holes or notches etc.) within one or more reference blocks;

b) an equivalent reflector diagram (DGS system);

c) echoes from suitable notches; or

d) echoes from large planar reflectors perpendicular to the acoustic axis (e.g. back wall echo).

These techniques are described in ISO 16811.

In order to obtain further information about the shape and size of reflectors, other techniques may be used. Such techniques are based, for example on variations in signal amplitude with movement of the probe, measurement of sound path or frequency analysis.

6 Equipment

6.1 Ultrasonic instrument

The ultrasonic instrument shall fulfil the requirements of EN 12668-1.

6.2 Ultrasonic probes

The probe(s) shall fulfil the requirements of EN 12668-2.

6.2.1 Probe selection

The choice of the probe depends on the purpose of the examination and the requirements of the referencing standard or specification. It depends on:

- the material thickness, shape and surface condition;
- the type and metallurgical condition of the examined material;
- the type, position and orientation of imperfections to be identified.

The probe parameters listed in clauses 6.2.2, 6.2.3 and 6.2.4 shall be considered in relation to the characteristics of the examination object stated above.

6.2.2 Frequency and dimensions of transducer

The frequency and dimensions of a transducer determine the shape of the beam (near field and beam divergence). The selection shall assure that the characteristics of the beam are the optimum for the examination by a compromise between the following:

- the near field length which shall remain, whenever possible, smaller than the thickness of the object under examination;

NOTE: It is possible to detect imperfections in the near field, but their characterization is less accurate and less reproducible.

- the beam width, which shall be sufficiently small within the examination zone furthest from the probe to maintain an adequate detection level;
- the beam divergence, which shall be sufficiently large to detect planar imperfections that are unfavourably orientated.

Apart from the above considerations the selection of frequency shall take into account the sound attenuation in the material and the reflectivity of imperfections. The higher this frequency, the greater the examination resolution, but the sound waves are more attenuated (or the spurious signals due to the structure are greater). The choice of frequency thus represents a compromise between these two factors. Most examinations are performed at frequencies between 1 MHz and 10 MHz.

6.2.3 Dead zone

The choice of the probe shall take into account the dead zone in relation to the examination volume.

6.2.4 Damping

The selection of probe shall also include consideration of the damping which influences the resolution as well as the frequency spectrum.

6.2.5 Focusing probes

Focusing probes are mainly used for the detection of small defects and for sizing reflectors. Their sound fields should be described by focal zone and focal diameter. Their advantages in relation to unfocused single crystal probes are an increased lateral resolution and a higher signal to noise ratio. Sensitivity setting has to be carried out by using reference reflectors.

6.3 Coupling media

Different coupling media can be used, but their type shall be compatible with the materials to be examined. Examples are:

- water, possibly containing an agent e.g. wetting, anti-freeze, corrosion inhibitor;
- contact paste;
- oil;
- grease;
- cellulose paste containing water, etc.

The characteristics of the coupling medium shall remain constant throughout the verification, calibration operations and the examination. It shall be suitable for the temperature range in which it will be used.

If the constancy of the characteristics cannot be guaranteed between calibration and examination, a transfer correction may be applied. One method for determining the necessary correction is described in ISO 16811.

After the examination is completed, the coupling medium shall be removed if its presence is liable to hinder subsequent operations, inspection or use of the object.

6.4 Calibration blocks

The calibration blocks used are defined in ISO 2400 and ISO 7963.

The stability of calibration can be verified using the blocks above.

6.5 Reference blocks

When amplitudes of echoes from the object are compared with echoes from a reference block, certain requirements relating to the material, surface condition, geometry and temperature of the block shall be observed.

Where possible, the reference block shall be made from a material with acoustic properties which are within a specified range with respect to the material to be examined, and shall have a surface condition comparable to that of the object to be examined. If these characteristics are not the same, a transfer correction shall be applied. A method for determining the necessary correction is described in ISO 16811.

The geometrical conditions of the reference block and the object under examination shall be considered. For further details, see ISO 16811.

The geometry of the reference block, its dimensions, and the position of any reflectors, should be indicated on a case by case basis in the specific standards and codes. The position and number of reflectors should relate to the scanning of the entire examination zone.

The most commonly used reflectors are:

a) large planar reflectors, compared to the beam width, perpendicular to the acoustic axis (e.g. backwall);

b) flat-bottomed holes;

c) side-drilled holes;

d) grooves or notches of various cross-sections.

When reference blocks are used for immersion examination the influence of water in the holes shall be considered or the ends of the holes shall be plugged.

The consequences of temperature differences between examination object, probes, and reference blocks, shall be considered and compared to the requirements for the accuracy of the examination. If necessary the reference blocks shall be maintained within the specified temperature range during the examination.

6.6 Specific blocks

In certain cases, specific blocks e.g. with identified natural defects can be used to finalize the examination method and to check the stability of the sensitivity.

7 Settings

7.1 General settings

In the absence of defined instructions in the standards or detailed specifications, it is essential to ensure that:

— suppression shall not be used unless specifically called for by the referencing documents;

— the amplifier is used in an appropriate frequency band;

— filtering is set to give optimum resolution;

— the impedance matching of the examination system is adjusted, if necessary, to obtain a maximum echo height while preserving resolution;

— the pulse energy setting is as low as possible taking the amplification reserve into consideration.

These settings shall be maintained throughout the examination.

The settings shall be made at the start of each examination sequence and then checked periodically at established time intervals and whenever a system parameter is changed or the operator suspects a drift (see EN 12668-3).

A maximum drift of amplitude and range shall be established. If such maxima are exceeded new settings are required or agreed actions are necessary.

7.2 Range settings

Each range shall be selected to cover the examination zone defined in the relevant standard, procedure or detailed specification.

The time base and delay settings shall be made using a calibration block or by calculation. They shall be verified by ultrasonically checking the location of the reflectors in the reference block.

7.3 Amplification

The amplification and pulse energy settings shall be made using the echoes from artificial reflectors, or from the opposite surface of the reference block or the examination object. They shall be adequate to:

— detect all the imperfections from which the signal exceeds the recording level or other signals of interest defined in the referencing documents;

— evaluate all the imperfection indications, or other signals of interest, by one of the methods described in the relevant standard or by any other methods described in detail specifications associated with the product to be examined.

The amplification settings can be different during the examination for detection, and during evaluation.

For the detection of imperfections by manual examination, the setting shall be such that all signals above the evaluation level, up to the maximum range under examination, are displayed at a minimum of 20 % full screen height or as specified in the reference documents. Methods of setting sensitivity are described in ISO 16811.

7.4 Pulse repetition frequency

When adjustable, the pulse repetition frequency should be sufficiently high to ensure adequate screen brightness and to detect all relevant signals, whilst being sufficiently low to avoid the production of ghost echoes when working on long path lengths particular in low attenuation materials. See also 9.2.2.

8 Preparation for examination

8.1 Surface preparation

All scanning surfaces shall be free from dirt, loose scale, weld spatter etc., and shall be of sufficiently uniform contour and smoothness that satisfactory acoustic coupling can be maintained. In addition, such features of the surface of the object that may give rise to errors of interpretation shall be removed prior to examination. See ISO 16811.

8.2 Identification and datum points

Where the reporting of imperfections or other local features is a requirement of the referencing document(s), each object to be examined shall be uniquely identified and an agreed method of referencing shall be used to clearly locate the position of any reportable imperfection. This method can be based on the provision of suitably permanent datum points, or on the use of suitable geometrical features.

8.3 Application of transfer correction

During the evaluation of signals by means of reference blocks, these shall display an ultrasonic wave attenuation, and surface losses, equivalent to that of the examination object.

If not, a transfer correction shall be applied to compensate for differences in the surface losses and material attenuation. Simple methods are proposed in ISO 16811.

For certain objects of complex shape, coated objects, austenitic steel objects, etc., it can be difficult, or even impossible, to develop an industrial method of equivalence verification. If so, a specific procedure shall be implemented.

For the examination of specific products of relatively low thickness, or whose attenuation is known to be negligible, transfer correction is possibly not necessary.

9 Examination

9.1 Examination coverage

Scanning shall be carried out in accordance with the requirements of the referencing document(s). These requirements shall include the area to be scanned and the scanning direction(s), and can include the type, size, frequency and beam angle of the probe(s) to be used.

9.2 Overlap and scanning speed

9.2.1 Overlap

For a 100 % examination, the interval between two successive scan lines shall not be greater than the –6 dB beam width at any depth within the examination volume.

9.2.2 Scanning speed

The choice of scanning speed shall take into consideration the pulse repetition frequency and the ability of the operator to recognize or of the instrument to record signals.

In semi-automatic or automatic examination, the maximum scanning speed (V_{max}) is determined by the passage of a reference block beneath the probe, or is calculated from the following equation (1):

$$V_{max} = \frac{d \times f_{rep}}{n} (mm/s) \quad (1)$$

where :

d is the minimum beam width at –6dB, in millimetres as applicable for the examination;

f_{rep} is the pulse repetition frequency in Hz;

n is the number of consecutive signals of an indication before alarm.

9.3 Evaluation and recording levels

The evaluation and recording levels are defined in relevant standards. When these levels are not defined, the values applied during the examination shall be included in the examination report.

9.3.1 Pulse echo technique

If the amplitude of an echo exceeds the evaluation level, the signal shall be evaluated against the acceptance criteria.

9.3.2 Transmission technique

If the amplitude of the transmitted signal is below the evaluation level, the signal shall be evaluated against the acceptance criteria.

10 Characterization of imperfections

10.1 Pulse echo technique

The imperfections are characterized by at least:

— their location in the object (x-, y- and z-coordinates);