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Non-destructive testing of welds — Ultrasonic testing — Testing of welds in austenitic steels and nickel-based alloys

Essais non destructifs des assemblages soudés — Contrôle par ultrasons — Contrôle des soudures en aciers austénitiques et en alliages à base nickel

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Contents

Page

Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 44, *Welding and allied processes*, Subcommittee SC 5, *Testing and inspection of welds*.

This third edition cancels and replaces the second edition (ISO 22825:2012), which has been technically revised.

The main changes compared to the previous edition are as follows:

— correction of an incorrect equation;

— update of the normative references and the bibliography;

— editorial modifications in the whole document;

— inclusion of the phased array technique.

Requests for official interpretations of any aspect of this document should be directed to the Secretariat of ISO/TC 44/SC 5 via your national standards body. A complete listing of these bodies can be found at www.iso.org.

Introduction

Welds in austenitic steel components and dissimilar metal welds are widely regarded as very difficult to test by ultrasound. The problems are mainly associated with unfavourable structure and grain size, as well as with different material properties which result in inhomogeneous and anisotropic mechanical and acoustic properties that contrast with the relatively homogeneous and isotropic behaviour in low-alloy steel welds.

Austenitic weld metal and other coarse-grained, anisotropic materials can significantly affect the propagation of ultrasound. In addition, beam distortion, unexpected reflections and wave mode conversions on the fusion line and/or columnar grains can occur. Therefore it can be difficult and sometimes impossible for ultrasonic waves to penetrate the weld metal.

Ultrasonic testing of these metals may require techniques that differ from conventional testing techniques. These special techniques often include the use of dual-element probes designed for refracted compression (longitudinal) waves or creeping waves rather than for conventional shear (transverse) waves.

In addition, it is necessary to produce representative reference blocks with welds in order to develop a testing procedure, set a preliminary sensitivity level, assess the procedure and demonstrate effectiveness before a definitive procedure is written. Material, weld preparation and welding procedure, as well as the geometry and surface condition of reference blocks are the same as for the component being tested.

Non-destructive testing of welds — Ultrasonic testing — Testing of welds in austenitic steels and nickel-based alloys

1 Scope

This document specifies the approach to be followed when developing procedures for the ultrasonic testing of the following welds:

— welds in stainless steels;

— welds in nickel-based alloys;

— welds in duplex steels;

— dissimilar metal welds;

— austenitic welds.

The purposes of the testing can be very different, for example:

— for the assessment of quality level (manufacturing);

— for the detection of specific discontinuities induced in service.

Acceptance levels are not included in this document, but can be applied in accordance with the scope of the testing (see 4.1).

The requirements of this document are applicable to both manual and mechanized testing.

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.

ISO 5577, *Non-destructive testing — Ultrasonic testing — Vocabulary*

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

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

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*

ISO 17635, *Non-destructive testing of welds — General rules for metallic materials*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5577, ISO 17635 and the following apply.

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

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

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

3.1
dual-element probe
ultrasonic probe in which the transmit and receive transducers are separate and are electrically and acoustically isolated from each other

3.2
focal distance
⟨dual-element probes⟩ distance between probe and focal point on the acoustical axis where the acoustic pressure is at its maximum

3.3
focal curve
⟨dual-element probes⟩ curve, representing the relationship between sound path and sensitivity of a probe on a specified material containing specified reflectors

4 Information required prior to testing

4.1 Items to be defined by specification

Information on the following items is required:

a) material type and grade;

b) purpose and extent of testing, including testing for transverse discontinuities, if required;

c) testing levels (see Clause 10);

d) manufacturing or operation stage at which the testing shall be carried out;

e) requirements for access, the surface condition (see 11.2) and temperature;

f) whether or not parent metal testing shall be carried out prior to and/or after welding (see 11.3);

g) reference blocks (see Clauses 6 and 7);

h) personnel qualifications (see Clause 5);

i) reporting requirements (see Clause 12);

j) acceptance criteria and/or recording level.

4.2 Specific information required by the operator prior to testing

Before any testing of a welded joint, the operator shall have access to all the information as specified in 4.1, together with the following additional information:

a) the written testing procedure (see Clause 9);

b) type(s) of parent material and product form (i.e. cast, forged, rolled);

c) the joint preparation and dimensions;

d) the welding procedure or relevant information on the welding process;

e) the time of the testing with regard to any post-weld heat treatment;

f) the result of any parent metal testing carried out prior to and/or after welding;

g) reference points and details of coordinate systems for the test object.

5 Personnel

Personnel performing testing in accordance with this document shall be qualified to an appropriate level in accordance with ISO 9712 or equivalent in the relevant industrial sector.

In addition to a general knowledge of ultrasonic weld testing, the operators shall be familiar with and have practical experience in testing problems specifically associated with the type of materials and weld joints to be tested. Specific training and examination of personnel should be performed on representative pieces (duplex, austenitic, stainless steel) containing welds and using dual-element longitudinal wave probes. This training and the examination results should be documented.

If this is not the case, specific training and examination should be performed with the finalized ultrasonic testing procedures and selected ultrasonic testing equipment on representative samples containing natural or artificial reflectors similar to those expected. This training and the examination results should be documented.

6 Test equipment

6.1 Conventional equipment

The equipment used for testing shall fulfil the requirements of EN 12668-1 and EN 12668-2. The verification of the combined equipment shall be done in accordance with EN 12668-3, with the exception of dual-element compression wave angle-beam probes, which may be verified on appropriate reference blocks other than the blocks mentioned in EN 12668-3.

Focal curves shall be available for the dual-element probes to be used, determined on a material representative of the material to be tested.

6.2 Phased array equipment

Phased array equipment may be used provided that:

— the combination of probe, wedge and focal laws is able to produce sound beams allowing the implementation of techniques defined in A.1 to A.6;

— the phased array equipment is compliant to the requirements of ISO 18563-1 and ISO 18563-2;

— the verification of the combined equipment shall be done in accordance with ISO 18563-3, with the exception of dual-element compression wave angle-beam probes, which may be verified on appropriate reference blocks other than the blocks mentioned in ISO 18563-3.

Focal curves shall be available for the phased array probes to be used, determined on a material representative of the material to be tested.

7 Range setting for compression waves

Range setting shall be carried out on appropriate calibration blocks, e.g. as shown in Annex B, which are designed to be similar in dimension to Block No. 2 in accordance with ISO 7963. The dimension of at least one of the radii of the block used shall be close to the focal distance of the probes.

The index point of each probe shall be marked on the probe's side, after having optimized the echo amplitude on the radius closest to its focal distance. Since echo optimization can be difficult for high-angle probes and creeping wave probes, the shear wave component may be used for optimization instead. In that case, the calibration methodology shall be included in the test procedure.

Optimization of the echoes shall be done on the two radii separately, and by iteration until the signals from the smaller and the larger radius are on their correct positions.

Alternatively, the time base may be set with the aid of a single-element straight-beam probe on the width of the calibration block, and subsequent zero point adjustment with the angle-beam probe placed on the calibration block, on the radius which is closest to the probe's focal distance.

For correct geometrical positioning of indications the influence of different sound velocities between base material and weld material may be taken into account, using the reflectors as used in 8.2 or 8.3. Range setting shall be carried out prior to each testing. Checks to confirm these settings shall be performed at least every 4 h and on completion of testing.

Checks shall also be carried out whenever a system parameter is changed or whenever changes in the equivalent settings are suspected.

If deviations are found during these checks, corrective actions shall be carried out as specified in Table 1.

Table 1 — Range deviations

1	Deviations ≤ 5 % of the range	No correction is needed, test can be continued
2	Deviations > 5 % of the range	The setting shall be corrected and all tests carried out over the previous period shall be repeated

8 Sensitivity setting

8.1 General

Sensitivity setting shall be performed on a reference block with a weld. Annex C shows examples for reference blocks. The wall thickness of the reference block shall be similar to the wall thickness of the object to be tested within 10 % or 3 mm, whichever is the larger.

Reference reflectors may be side-drilled holes in the weld centre and/or on the fusion line. Alternatively, flat-bottomed holes on the fusion line may be used, having the flat bottom in the plane of the fusion line (weld bevel). Surface notches shall be used as references for near-surface defects. See Figures C.1, C.2 and C.3.

Zone coverage related to wall thickness shall be established on the basis of the focal curves as shown in Figure A.6 when dual-element probes are used. Zone overlap shall be documented in the procedure.

Setting of sensitivity shall be carried out prior to each testing in accordance with this document.

The gap, g, between test surface and bottom of the probe shoe shall not be greater than 0,5 mm.

For cylindrical or spherical surfaces, this requirement can be checked with Formula (1):

$$g = \frac{a^2}{4D} \tag{1}$$

where

D is the diameter, in millimetres, of the test object;

a is the dimension, in millimetres, of the probe shoe in the direction of testing.

If a value for g larger than 0,5 mm results from Formula (1), the probe shoe shall be adapted to the surface, and the sensitivity and range shall be set accordingly.

Checks to confirm these settings shall be performed at least every 4 h and on completion of testing. Checks shall also be carried out if a system parameter is changed or if changes in the equivalent settings are suspected.

If deviations are found during these checks, corrective actions shall be carried out as specified in Table 2.

Table 2 — Sensitivity deviations

1	Deviations ≤ 2 dB	No correction is needed, test can be continued
2	Deviations between 2 dB and 4 dB	The setting shall be corrected before testing is continued
3	Reduction in sensitivity > 4 dB	The setting shall be corrected and all tests carried out since the last valid test shall be repeated
4	Increase in sensitivity > 4 dB	The setting shall be corrected and all indications recorded since the last valid test shall be re-evaluated

8.2 Use of side-drilled holes

If the reflectors in the fusion line are used, sensitivity settings shall be performed:

a) by establishing the echo height with the sound beam passing through the parent material only;

b) by establishing the echo height with the sound beam passing through the weld metal.

If the reflectors in the weld centre line are used, sensitivity setting may be performed from one side only, with the exception of dissimilar metal welds (where the acoustic properties of the parent metal are different on one side compared to the other).

A typical side-drilled hole has a diameter of 3 mm.

8.3 Use of other reference reflectors

Where specific discontinuities are to be detected and/or in a particular limited zone of the weld, other types and dimensions of reference reflectors may be used. In that case, specific conditions of sensitivity setting shall be defined.

In weld testing on pipes, flat-bottomed holes and notches are typically used as reference reflectors. An example for a pipeline girth weld is given in Figure C.2.

The position of the flat-bottomed hole shall be determined from a macro-section of the austenitic weld, positioned accordingly in the reference block and machined to position the flat bottom at the fusion line.

A typical flat-bottomed hole has a diameter between 2 mm and 5 mm.

9 Test procedure and ultrasonic techniques

9.1 Development of the test procedure

The development of a test procedure shall follow the main steps as mentioned in the flowchart shown in Figure 1.

9.2 Content of the test procedure

A test procedure shall be written and shall include the following information as a minimum:

a) the purpose and extent of testing;

b) the testing techniques;

c) the testing levels;

NOTE For the testing of austenitic steels, the testing levels are not defined in ISO 17640 as for ferritic steels. However, it is important to set them to take into account the required probability of detection in each area under consideration.

d) personnel qualification/training requirements;

e) the equipment requirements;

f) the probe for each zone or part of the bevel;

g) the reference blocks;

h) test blocks, if applicable;

i) the setting of test equipment;

j) available access and surface conditions;

k) the scanning directions and probe positions;

l) the testing of parent material;

m) the evaluation of indications;

n) the acceptance levels and/or recording levels;

o) the reporting requirements;

p) environmental and safety issues.

