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Badania nieniszczące spoin

Badanie ultradźwiękowe

Stosowanie zautomatyzowanej techniki głowicy mozaikowej

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EN ISO 13588

March 2019

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English Version

Non-destructive testing of welds - Ultrasonic testing - Use of automated phased array technology (ISO 13588:2019)

Contrôle non destructif des assemblages soudés - Contrôle par ultrasons - Utilisation de la technique multi-éléments automatisés (ISO 13588:2019)

Zerstörungsfreie Prüfung von Schweißverbindungen - Ultraschallprüfung - Anwendung von automatisierter phasengesteuerter Array-Technologie (ISO 13588:2019)

This European Standard was approved by CEN on 9 February 2019.

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European foreword

This document (EN ISO 13588:2019) has been prepared by Technical Committee ISO/TC 44 "Welding and allied processes" in collaboration with Technical Committee CEN/TC 121 “Welding and allied processes” the secretariat of which is held by DIN.

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of an identical text or by endorsement, at the latest by September 2019, and conflicting national standards shall be withdrawn at the latest by September 2019.

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

This document supersedes EN ISO 13588:2012.

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Endorsement notice

The text of ISO 13588:2019 has been approved by CEN as EN ISO 13588:2019 without any modification.

INTERNATIONAL STANDARD

ISO 13588

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2019-02

Non-destructive testing of welds — Ultrasonic testing — Use of automated phased array technology

Essais non destructifs des assemblages soudés — Contrôle par ultrasons — Utilisation de la technique multi-éléments automatisés

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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.

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).

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

For an explanation of 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 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*.

Any feedback, question or request for official interpretation related to 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/members.html. Official interpretations, where they exist, are available from this page: https://committee.iso.org/sites/tc44/home/interpretation.html.

This second edition cancels and replaces the first edition (ISO 13588:2012), which has been technically revised. The main changes compared to the previous edition are as follows:

— Clauses 2 and 3 have been updated;

— a method of length and height measurement has been added;

— new Annex B has been added;

— the document has been editorially updated.

Non-destructive testing of welds — Ultrasonic testing — Use of automated phased array technology

1 Scope

This document specifies the application of the phased array technology for the semi- or fully automated ultrasonic testing of fusion-welded joints in metallic materials of minimum thickness 6 mm. It applies to full penetration welded joints of simple geometry in plates, pipes, and vessels, where both the weld and the parent material are low-alloy and/or fine grained steel. For the testing of welds in other steel materials this document gives guidance. For coarse-grained or austenitic steels, ISO 22825 applies in addition to this document.

This document provides guidance on the specific capabilities and limitations of the phased array technology for the detection, location, sizing and characterization of discontinuities in fusion-welded joints. Phased array technology can be used as a stand-alone technology or in combination with other non-destructive testing (NDT) methods or techniques, for manufacturing inspection, pre-service and for in-service inspection.

This document specifies four testing levels, each corresponding to a different probability of detection of imperfections.

This document permits assessment of discontinuities for acceptance purposes based either on amplitude (equivalent reflector size) and length, or on height and length.

This document does not include acceptance levels for discontinuities.

This document is not applicable for automated testing of welds during the production of steel products covered by ISO 10893-8, ISO 10893-11 and ISO 3183.

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 5817, *Welding — Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) — Quality levels for imperfections*

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

ISO 17640, *Non-destructive testing of welds — Ultrasonic testing — Techniques, testing levels, and assessment*

ISO 10863, *Non-destructive testing of welds — Ultrasonic testing — Use of time-of-flight diffraction technique (TOFD)*

ISO 18563-1, *Non-destructive testing — Characterization and verification of ultrasonic phased array equipment – Part 1: Instruments*

ISO 18563-2, *Non-destructive testing — Characterization and verification of ultrasonic phased array equipment — Part 2: Probes*

ISO 18563-3, *Non-destructive testing — Characterization and verification of ultrasonic phased array equipment — Part 3: Combined systems*

ISO 19285, *Non-destructive testing of welds — Phased array ultrasonic testing (PAUT) — Acceptance levels*

ISO 22825, *Non-destructive testing of welds — Ultrasonic testing — Testing of welds in austenitic steels and nickel-based alloys*

EN 16018, *Non-destructive testing — Terminology — Terms used in ultrasonic testing with phased arrays*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5577, EN 16018 and the following 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/

3.1
phased array image
one- or two-dimensional display, constructed from the collected information of phased array operation

3.2
indication
phased array indication
pattern or disturbance in the *phased array image* (3.1) which can need further evaluation

3.3
phased array setup
probe arrangement defined by probe characteristics (e.g. frequency, probe element size, beam angle, wave mode), *probe position* (3.4), and the number of probes

3.4
probe position
PP
distance between the front of the wedge and the weld centre line

3.5
scan increment
distance between successive data collection points in the direction of scanning (mechanically or electronically)

3.6
skewed scan
scan performed with a skewed angle

Note 1 to entry: The skewed angle can be achieved electronically or by means of probe orientation.

3.7
mode
phased array mode
combination of ultrasonic beams created by phased array technology, e.g. fixed angle, E-scan, S-scan

4 Testing levels

Quality requirements for welded joints are mainly associated with the material, welding process and service conditions. To comply with all of these requirements, this document specifies four testing levels (A, B, C and D).

From testing level A to testing level C, an increasing probability of detection is achieved by an increasing testing coverage, e.g. number of incidences, combining techniques.

Testing level D may be agreed for special applications using a written procedure which shall take into account the general requirements of this document. This includes tests of metals other than ferritic steel, tests on partial penetration welds, tests with automated equipment and tests at object temperatures outside the range. For coarse-grained or austenitic steels, ISO 22825 shall also be used.

In general, the testing levels are related to quality levels (e.g. according to ISO 5817). The appropriate testing level can be specified by standards for the testing of welds (e.g. ISO 17635), by product standards or by other documents. When ISO 17635 is specified, the testing levels in relation to ISO 5817 as given in Table 1 shall be used.

Table 1 — Quality levels of ISO 5817 and corresponding testing levels

Testing level	Quality level in ISO 5817
A	C, D
B	B
C	by agreement
D	special application

Table 2 shows the minimum requirements and in all cases, as described in 7.2, the setup shall be verified with a reference block. In cases where scanning is performed from one face (excluding TOFD), half and full skip shall be used and stored; if scanning is performed from both faces, half skip is sufficient.

If diffraction signals are detected they may be used for sizing.

If the evaluation of the discontinuities is based on amplitude only, the deviation of the beam direction from the normal to the weld bevel shall not exceed 6°. If this is not possible because of the geometry of the test object (e.g. weld cap, narrow gap weld), the scan plan shall describe the corrective measures and explain how these areas to be tested shall be covered with enough sensitivity

Table 2 — Description of testing levels

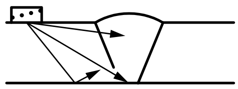
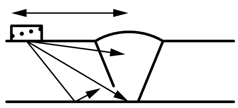
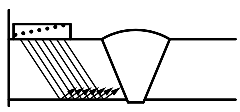
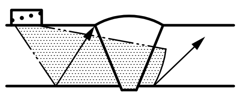
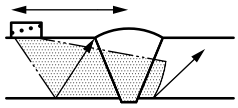
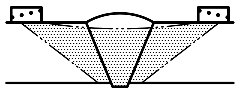
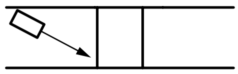
Mode	Testing levels			Example of sketches
	A	B	C	
	Reference blocks (see Annex A)			
	Block A	Block B	Block C	
Test set-up				
Fixed angles at fixed probe position to weld (line scans)[a]	Two sides	Not suitable as single technique	Two sides	
Fixed angles with raster scanning[a]	One side	One side	One side	
E-scan at fixed probe position (line scan)[a]	One side	Two sides with two angles [c]	Two sides	
S-scan at fixed probe position to weld (line scan)[a]	One side	Two sides or two probe positions	Two sides or two probe positions	

Table 2 *(continued)*

Mode	Testing levels			Example of sketches
	A	B	C	
	Reference blocks (see Annex A)			
	Block A	Block B	Block C	
S-scan raster	Not recommended		One side	
TOFD generated with phased array[a]	Not recommended, TOFD testing in accordance with ISO 10863		One setup	
Skewed scan[b]	If required by specification			

[a] For testing level C, at least two different test setups from this table shall be combined; at least one of them shall be S-scan or TOFD.

[b] If detection of transverse discontinuities is required by specification, a suitable additional test setup shall be applied. Skewed probe or electronically skewed beam can be used.

[c] At least 10° difference between angles.

5 Information required prior to testing

5.1 Items to be defined prior to procedure development

Information on the following items is required:

a) purpose and extent of testing;

b) testing levels;

c) acceptance criteria;

d) specification of reference blocks;

e) manufacturing or operation stage at which the testing is to be carried out;

f) weld details and information on the size of the heat-affected zone;

g) requirements for access and surface conditions and temperature;

h) personnel qualifications;

i) reporting requirements.

5.2 Specific information required by the operator before testing

Before any testing of a welded joint can begin, the operator shall have access to all the information as specified in 5.1 together with the following additional information:

a) written test procedure;

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

c) joint preparation and dimensions;

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

e) time of testing relative to any post-weld heat treatment;

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

5.3 Written test procedure

For all testing levels, a written test procedure is required.

The procedure shall include the following information as a minimum:

a) purpose and extent of testing;

b) testing techniques;

c) testing levels;

d) personnel qualification/training requirements;

e) equipment requirements (including but not limited to frequency, sampling rate, pitch between elements, element size);

f) reference and/or test blocks;

g) setting of equipment;

h) available access and surface conditions;

i) testing of parent material;

j) evaluation of indications;

k) acceptance levels and/or recording levels;

l) reporting requirements;

m) environmental and safety issues.

The procedure shall include a documented testing strategy or scan plan showing probe position, probe movement, and component coverage that provides a standardized and repeatable methodology for weld testing. The scan plan shall also include ultrasonic beam angles used, beam directions with respect to the weld centre line, and the volume to be tested for each weld.

6 Requirements for personnel and test equipment

6.1 Personnel qualifications

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 general knowledge of ultrasonic weld testing, the operators shall be familiar with, and have practical experience in, the use of ultrasonic phased arrays. Specific training and examination of personnel should be performed on representative pieces. These training and 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 test equipment on representative samples containing natural or artificial reflectors similar to those expected. These training and examination results should be documented.

6.2 Test equipment

6.2.1 General

In selecting the system components (hardware and software), ISO/TS 16829 gives useful information.

Ultrasonic equipment used for phased array testing shall be in accordance with the requirements of ISO 18563-1, ISO 18563-2, and ISO 18563-3 when applicable.

6.2.2 Ultrasonic instrument

The instrument shall be able to select an appropriate portion of the time base within which A-scans are digitized.

It is recommended that a sampling rate of the A-scan be used of at least six times the nominal probe frequency.

6.2.3 Ultrasonic probes

Both longitudinal and shear waves may be used.

Adaptation of probes to curved scanning surfaces shall comply with ISO 17640. When adapted probes are used, the influence on the sound beam shall be taken into account.

The number of dead elements on each active aperture shall be a maximum of 1 out of 16 and dead elements are not allowed to be adjacent. For active apertures using less than 16 elements, no dead element is allowed, unless adequate performance is demonstrated.

6.2.4 Scanning mechanisms

To achieve consistency of the images (collected data), guiding mechanisms and scan encoder(s) shall be used.

7 Preparation for testing

7.1 Volume to be tested

The purpose of the testing shall be defined by specification. Based on this, the volume to be tested shall be determined.

For tests at the manufacturing stage, the testing volume shall include the weld and the parent material for at least 10 mm on each side of the weld (5 mm for laser welds and for electron beam welds), or the width of the heat-affected zone (based on the manufacturer's information), whichever is greater.

A scan plan should be provided. The scan plan should show the beam coverage, the weld thickness and the weld geometry.

It shall be ensured that the sound beam(s) cover(s) the volume to be tested.

7.2 Verification of the test setup

The capability of the test setup shall be verified by the use of reference blocks (see 9.3).

7.3 Scan increment setting

The scan increment setting along the weld is dependent upon the wall thickness to be tested. For thicknesses up to 10 mm, the scan increment shall be no more than 1 mm. For thicknesses between

10 mm and 150 mm, the scan increment shall be no more than 2 mm. Above 150 mm, a scan increment of no more than 3 mm is recommended.

The scan increment setting perpendicular to the weld when applicable shall be chosen in order to ensure the coverage of the test volume.

When TOFD is used, the scan increment shall be in accordance with ISO 10863.

7.4 Geometry considerations

Care should be taken when testing welds of complex geometry, e.g. welds joining materials of unequal thickness, materials that are joined at an angle or nozzles. These tests should be planned carefully and require in-depth knowledge of sound propagation. These tests shall always be carried out under testing level D, unless single-sided testing is allowed according to Table 2.

For level D tests scan plan(s), representative reference block(s), and a performance demonstration are mandatory (see Annex A).

NOTE In some cases, the number of reference blocks can be reduced by the use of simulation programs.

7.5 Preparation of scanning surfaces

Scanning surfaces shall be clean in an area wide enough to permit the test volume to be fully covered.

Scanning surfaces shall be even and free from foreign matter likely to interfere with probe coupling (e.g. rust, loose scale, weld spatter, notches, grooves). Waviness of the test surface shall not result in a gap between a probe and the test surface greater than 0,5 mm. These requirements shall be ensured by dressing the scanning surface, if necessary.

Scanning surfaces may be assumed to be satisfactory if the surface roughness, *Ra*, is not greater than 6,3 µm for machined surfaces, or not greater than 12,5 µm for shot-blasted surfaces.

When a layer of different material, e.g. coating, paint, cladding, is present on the scanning surface and is not to be removed, testing level D is applicable.

7.6 Temperature

When not using special high-temperature phased array probes and couplants, the surface temperature of the object to be tested shall be in the range 0 °C to 50 °C.

For temperatures outside this range, the suitability of the test equipment shall be verified.

7.7 Couplant

In order to generate proper images, a couplant shall be used which provides a constant transmission of ultrasound between the probes and the test object.

The couplant used for the calibration shall be the same as that used in subsequent testing and post-calibrations.

8 Testing of base material

When the test is performed according to this document, a test for the detection of laminations shall be performed. This may be carried out as part of the test or independently of it.

9 Range and sensitivity settings

9.1 Settings

9.1.1 General

Setting of range and sensitivity shall be carried out prior to each test in accordance with this document. Any change of the phased array setup, e.g. probe position (PP) and steering parameters, requires a new setting.

Signal-to-noise ratio should be optimized with a minimum of 12 dB for the reference signals, when using A-scans, or with a minimum of 6 dB when using phased-array images.

9.1.2 Pulse-echo time window

If applicable, the time window used for pulse-echo signals shall include the volume of interest and be described in the written test procedure.

Ensure that the combination of beams covers the area of interest.

9.1.3 Pulse-echo sensitivity settings

9.1.3.1 General

After selection of the mode (fixed angle, E-scan, S-scan) the following shall be carried out:

a) the test sensitivity shall be set for each beam generated (e.g. beam angle, focal point) by the phased array probe;

b) when a probe with wedge is used, the sensitivity shall be set with the wedge in place.

9.1.3.2 Focusing

Different modes of focusing can be applied with phased array probes, e.g. static and dynamic depth focusing (DDF).

When focusing is used, the sensitivity shall be set for each focused beam.

9.1.3.3 Gain corrections

The use of angle-corrected gain (ACG) and time-corrected gain (TCG) enables the display of signals for all beam angles and all distances with the same amplitude.

9.1.3.4 Sensitivity settings for different modes of phased array testing

For weld testing, different modes can be applied, e.g. fixed angles, E-scans, S-scans. After the previous steps, the reference sensitivity for each beam generated shall be set according to ISO 17640, including transfer correction if applicable.

9.1.4 TOFD settings

If TOFD testing is performed, all settings shall comply with the requirements specified in ISO 10863.

9.2 Checking of the settings

Settings shall be checked at least every 4 h and after completion of the testing. If the single test takes more than 4 h, the settings shall be checked after completion of the test.

If a reference block was used for initial setting, the same reference block shall be used for checking. Alternatively, a smaller block with known transfer properties may be used.

If deviations from the initial settings, in accordance with 9.1, are found during these checks the corrections given in Table 3 shall be carried out.

Table 3 — Sensitivity and range corrections

Sensitivity	
Deviations ≤4 dB	No action required; data may be corrected by software.
Deviations >4 dB	The complete chain of measurement shall be checked. If no defective components are identified, settings shall be corrected and all tests carried out since the last valid check shall be repeated.
The required signal-to-noise ratio has to be achieved. The deviation 4 dB applies for pulse-echo testing. For TOFD, testing a 6 dB deviation is allowed.	
Range	
Deviations ≤0,5 mm or 2 % of depth-range, whichever is greater	No action required.
Deviations >0,5 mm or 2 % of depth-range, whichever is greater	Settings shall be corrected and all tests carried out since the last valid check shall be repeated.

9.3 Reference blocks

9.3.1 General

Depending on the testing level, reference blocks shall be used to determine the adequacy of the testing (e.g. coverage, sensitivity setting). Recommendations for reference blocks are shown in Annex A.

9.3.2 Material

The reference block shall be made of similar material to the test object (e.g. with regard to sound velocity, grain structure, and surface condition).

9.3.3 Dimensions and shape

The thickness of the reference blocks is recommended to be between 0,8 times and 1,5 times the thickness of the test object, with a maximum difference in thickness of 20 mm compared to the test object. The length and width of the reference block should be chosen such that all the artificial discontinuities can be properly scanned. For testing of longitudinal welds in cylindrical test objects, curved reference blocks shall be used having diameters from 0,9 times to 1,5 times the test object diameter. For test objects having a diameter greater than or equal to 300 mm, a flat reference block may be used.

In all cases, with regard to the diameter or curvature, the requirements mentioned in 6.2.3 and 7.5 are mandatory. The maximum allowed gap between probe shoe and reference block is 0,5 mm.

9.3.4 Reference reflectors

For a thickness, t, between 6 mm and 25 mm, at least three reflectors are required. For a thickness $t > 25$ mm, at least five reflectors are required. Typical reference reflectors are side-drilled holes, notches and flat-bottomed holes.

Examples of reference blocks according to the testing levels are given in Annex A, see Table 4.

Table 4 — Testing levels and reference blocks

Testing level	Reference block
A	see Figure A.1
B	see Figure A.2
C	see Figure A.3
D	as specified

10 Equipment checks

It shall be checked that all relevant channels, probes, and cables of the ultrasonic phased array system are functional. This check shall be performed daily before and after testing. If any item of the system fails, corrective action shall be taken and the system shall be retested.

11 Procedure qualification

A procedure qualification is required for testing levels B, C, and D. The test procedure shall have been demonstrated to perform acceptably on reference block(s). Examples of reference blocks are described in Annex A.

A satisfactory procedure qualification shall take place prior to the first testing.

A satisfactory procedure qualification includes:

a) detection of all required reflectors;

b) sizing capability as required by specification;

c) proof of coverage in depth and width.

12 Weld testing

Before initial testing, the coverage shall be verified with the scan plan and demonstrated on a suitable reference block.

Acceptable deviations of the probe position relative to the weld centre line shall be documented in the test procedure, and shall be covered in the scan plan and shown on a reference block.

Some discontinuities detected during the initial scanning can require additional evaluation, e.g. offset scans, scans perpendicular to the discontinuity, complementary phased array setups.

The scanning speed shall be chosen such that satisfactory images are generated (see 14.1). The scanning speed shall be selected dependent on factors such as number of delay laws, scan resolution, signal averaging, pulse-repetition frequency, data acquisition frequency, and volume to be tested. Missing scan lines indicate that the scanning speed used was too high. A maximum of 5 % of the total number of lines collected in one single scan may be missed but no adjacent lines shall be missed.

If the length of a weld is scanned in more than one section, an overlap of at least 20 mm between the adjacent scans is required. When scanning circumferential welds, the same overlap is required for the end of the last scan with the start of the first scan.

If applicable, a control function for the coupling efficiency is recommended.

13 Data storage

The ultrasonic testing shall be performed using a device employing computer-based data acquisition. All A-scan data covering the test area shall be stored and all data sets with setup parameters shall be included in the data record.

All data shall be stored for a period as specified.

14 Interpretation and analysis of phased array data

14.1 General

Interpretation and analysis of phased array data are typically performed as follows:

a) assess the quality of the phased array data;

b) identify relevant indications;

c) classify relevant discontinuities as specified;

d) determine location and size of the discontinuities as specified;

e) evaluate the data against acceptance criteria.

14.2 Assessing the quality of the phased array data

A phased array test shall be carried out such that satisfactory images are generated which can be evaluated with confidence. Satisfactory images are defined by appropriate:

a) coupling;

b) time-base setting;

c) sensitivity setting;

d) signal-to-noise ratio;

e) indication of saturation;

f) data acquisition.

Assessing the quality of phased array images requires skilled and experienced operators (see 6.1). The operator shall decide whether non-satisfactory images require new data acquisition (re-scanning).

14.3 Identification of relevant indications

The phased array technique images both discontinuities in the weld and geometric features of the test object.

In order to distinguish between indications and geometric features, detailed knowledge of the test object is necessary.

To decide whether an indication is relevant (caused by a discontinuity), patterns or disturbances in the phased array image shall be evaluated considering shape and signal amplitude relative to general noise level.

14.4 Classification of relevant indications

Amplitude, location and pattern of relevant indications can contain information on the type of the discontinuity.

Relevant indications shall be classified as specified.

14.5 Determination of location

The location of a discontinuity parallel to the weld axis, perpendicular to the weld axis and in the through-wall direction shall be determined from the related indication.

14.6 Determination of length and height

14.6.1 General

The length and height of a discontinuity are determined by the length and height of its indication.

14.6.2 Determination of length

The length is defined by the difference of the x-coordinates of the indication. The length of an indication shall be measured as described in ISO 11666. If TOFD is used the length of an indication shall be measured as described in ISO 15626.

Alternative techniques for measuring indication length may be used when specified.

14.6.3 Determination of height

14.6.3.1 General

The height is defined as the maximum difference of the z-coordinates. For indications displaying varying height along their length, the height shall be determined at the scan position of maximum extent. Examples are given in Figures B.1 to B.4.

14.6.3.2 Using diffracted signals

If diffracted signals are identified they shall be used to determine height. The height is determined using:

— 2 diffracted signals identified from the same discontinuity (upper and lower tip);

— 1 diffracted signal and a surface signal identified from the same discontinuity;

— 1 diffracted signal and the known wall thickness for root connected indications; or

— 1 diffracted signal in relation to the surface for surface breaking discontinuity.

Annex B shows illustrations of these 4 cases of possible diffracted signals to be used.

If TOFD is used, the height shall be measured as described in ISO 15626.

14.6.3.3 Using amplitude-based and other signals

The determination can be based on:

— amplitudes using the reference levels as described in ISO 11666. Other sizing techniques may be used (TCG, DGS, 6 dB drop);

— the time of flight of reflections (e.g. hollow root, mismatch);

— time of flight of mode converted signals.

14.7 Evaluation against acceptance criteria

After classification of all relevant indications, determination of their location and length, and after assessment, the discontinuities shall be evaluated against the acceptance criteria of ISO 19285, if not specified differently by the contracting parties.

The discontinuities can then be categorized as "acceptable" or "not acceptable".

15 Test report

The test report shall include at least the following information:

a) a reference to this document, i.e. ISO 13588;

b) information relating to the object under test:

   1) identification of the test object;

   2) dimensions including wall thickness;

   3) material type and product form;

   4) geometrical configuration;

   5) location of the tested welded joint(s);

   6) reference to welding process and heat treatment;

   7) surface condition and temperature of the test object;

   8) stage of manufacture of the test object;

c) information relating to the test equipment:

   1) manufacturer and type of the phased array instrument including scanning mechanisms with identification numbers if required;

   2) manufacturer, type, frequency of the phased array probes including number and size of elements, material and angle(s) of wedges with identification numbers if required;

   3) details of the reference block(s) with identification numbers if required;

   4) type of couplant used;

d) information relating to the test technology:

   1) testing level and reference to a written test procedure;

   2) purpose and extent of test;

   3) details of datum and coordinate systems;

   4) method and values used for range and sensitivity settings;

   5) details of signal processing and scan increment setting;

   6) scan plan;

   7) access limitations and deviations from this document; if any;

e) information relating to the phased array setting:

   1) increment (E-scans) or angular increment (S-scans);

2) element pitch and gap dimensions;

3) focus (calibration should be the same as for scanning);

4) virtual aperture size, i.e. number of elements and element width;

5) element numbers used for focal laws;

6) maximum deviation of the beam direction from the normal to the weld bevel;

7) documentation on permitted wedge angular range, specified by the manufacturer;

8) documented calibration, time-corrected gain (TCG) and angle-corrected gain (ACG);

f) information relating to the test results:

1) reference to the phased array raw data file(s),

2) phased array images of at least those locations where relevant discontinuities have been detected on hard copy, all images or data available in soft format;

3) acceptance criteria applied;

4) tabulated data recording the classification, location and size of relevant discontinuities and the results of evaluation;

5) reference points and details of the coordinate system;

6) date of test;

7) names, signatures and qualification of the test personnel.

Annex A
(informative)

Typical reference blocks and reference reflectors

A.1 Reference reflectors

For a thickness between 6 mm and 25 mm, at least three reference reflectors are recommended, covering the thickness of the block (see Figure A.1). The reflectors may be machined in one or more blocks.

For a thickness above 25 mm, at least five reference reflectors are recommended, covering the thickness of the block (see Figure A.2). The reflectors may be machined in one or more blocks.

The tolerances for all the dimensions of the reference reflectors are as follows:

— diameter: ±0,2 mm;

— length: ±2 mm;

— angle: ±2°;

— Tables A.1, A.2, and A.3 describe the reference reflectors for different wall thicknesses. If TOFD is used, then refer to ISO 10863 for details of reference notches.

Table A.1 — Length and depth of surface notches in the reference block

Dimensions in millimetres

Thickness t	Length l	Height h	Width b
$6 < t \leq 40$	t	1 ± 0,2	0,2 ± 0,05
$40 < t \leq 60$	40 ± 2	2 ± 0,2	0,2 ± 0,05
$60 < t \leq 100$	50 ± 2	2 ± 0,2	0,2 ± 0,05
$t > 100$	60 ± 2	3 ± 0,2	0,2 ± 0,05

Table A.2 — Diameter, D_d, of side-drilled holes

Dimensions in millimetres

Thickness t	Diameter D_d
$6 < t \leq 25$	2,5 ± 0,2
$25 < t \leq 50$	3,0 ± 0,2
$50 < t \leq 100$	4,5 ± 0,2
$t > 100$	6,0 ± 0,2
NOTE Length of side drilled holes $L \geq 25$ mm.	

If near-side surface holes are required, they shall have a diameter of 2 mm; see Figure A.2.

Table A.3 — Length of side-drilled holes and notches for thickness t > 25 mm

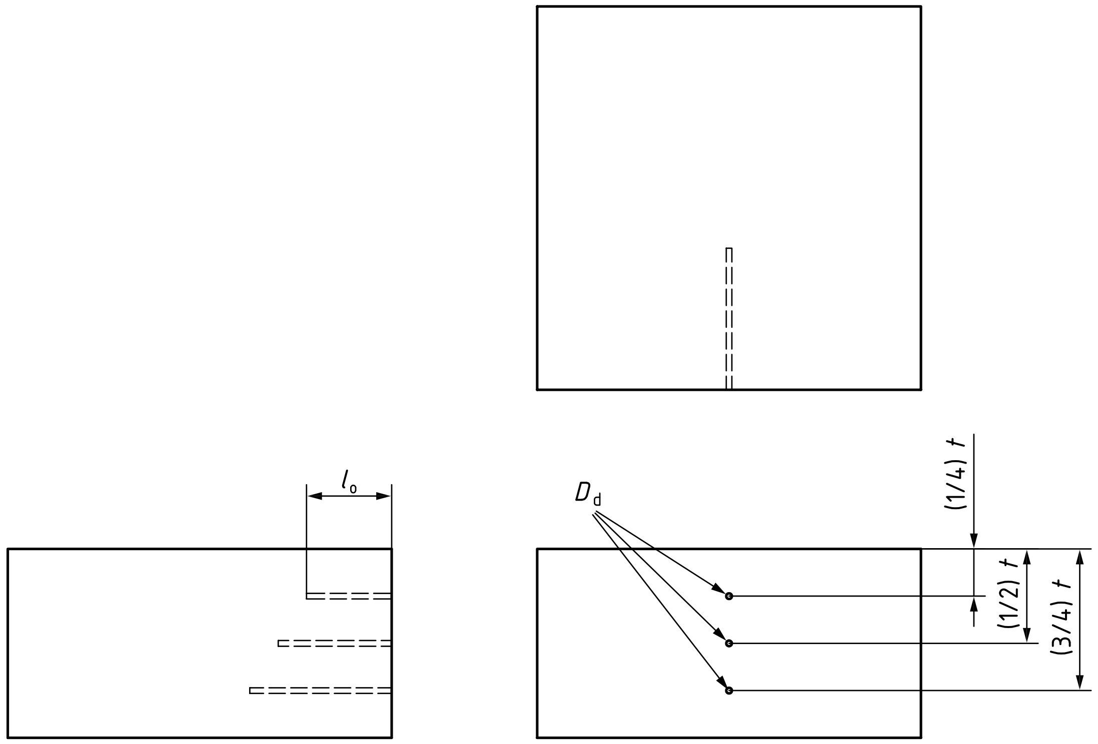
Dimensions in millimetres

Depth	Minimum length			
	Three holes in the same block	Three separate blocks, one hole per block	Three notches in the same block	Three separate blocks, one notch per block
(1/4)t	l_0 = 45	45	40	40
(1/2)t	l_0 + 15	45	40	40
(3/4)t	l_0 + 30	45	40	40

A.2 Typical reference blocks

A.2.1 Testing level A (Figure A.1)

Dimensions in millimetres



Key

D_d diameter of side-drilled hole

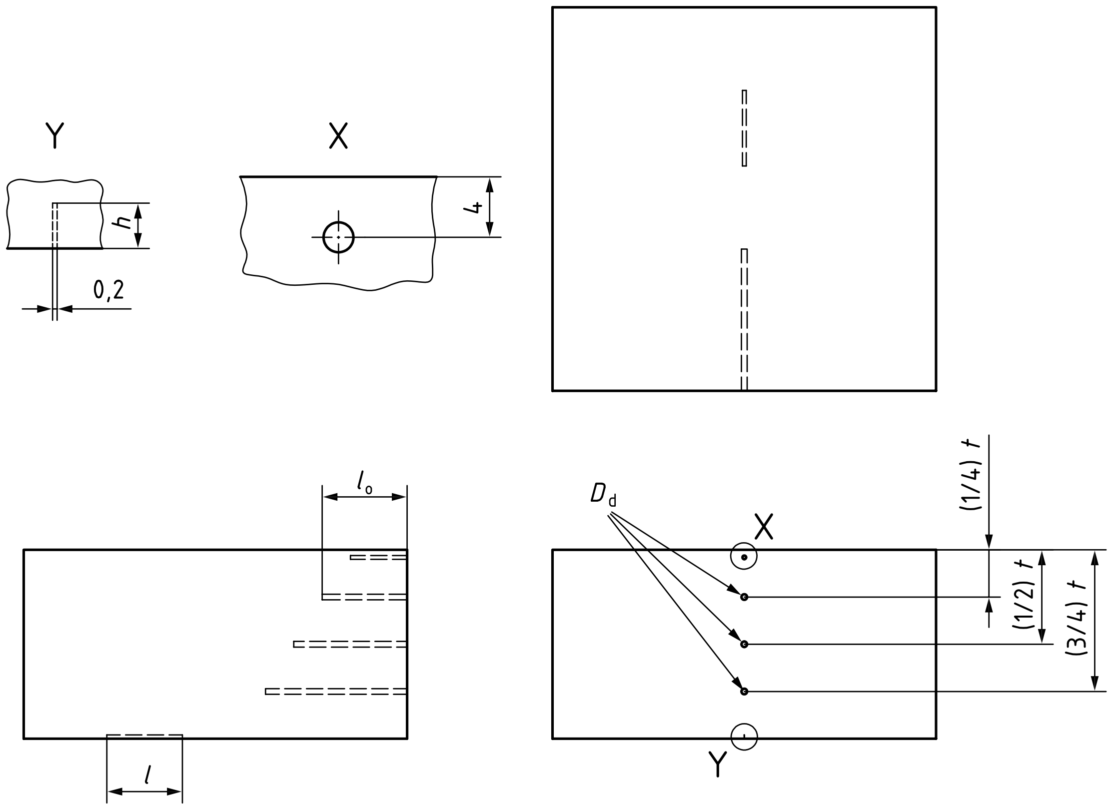
l_0 length of side-drilled hole

t thickness of block

Figure A.1 — Recommended reference block for testing level A

A.2.2 Testing level B (Figure A.2)

Dimensions in millimetres



Key

D_d diameter of side-drilled hole

h depth of notch at the bottom

l length of notch

l_0 length of side-drilled hole

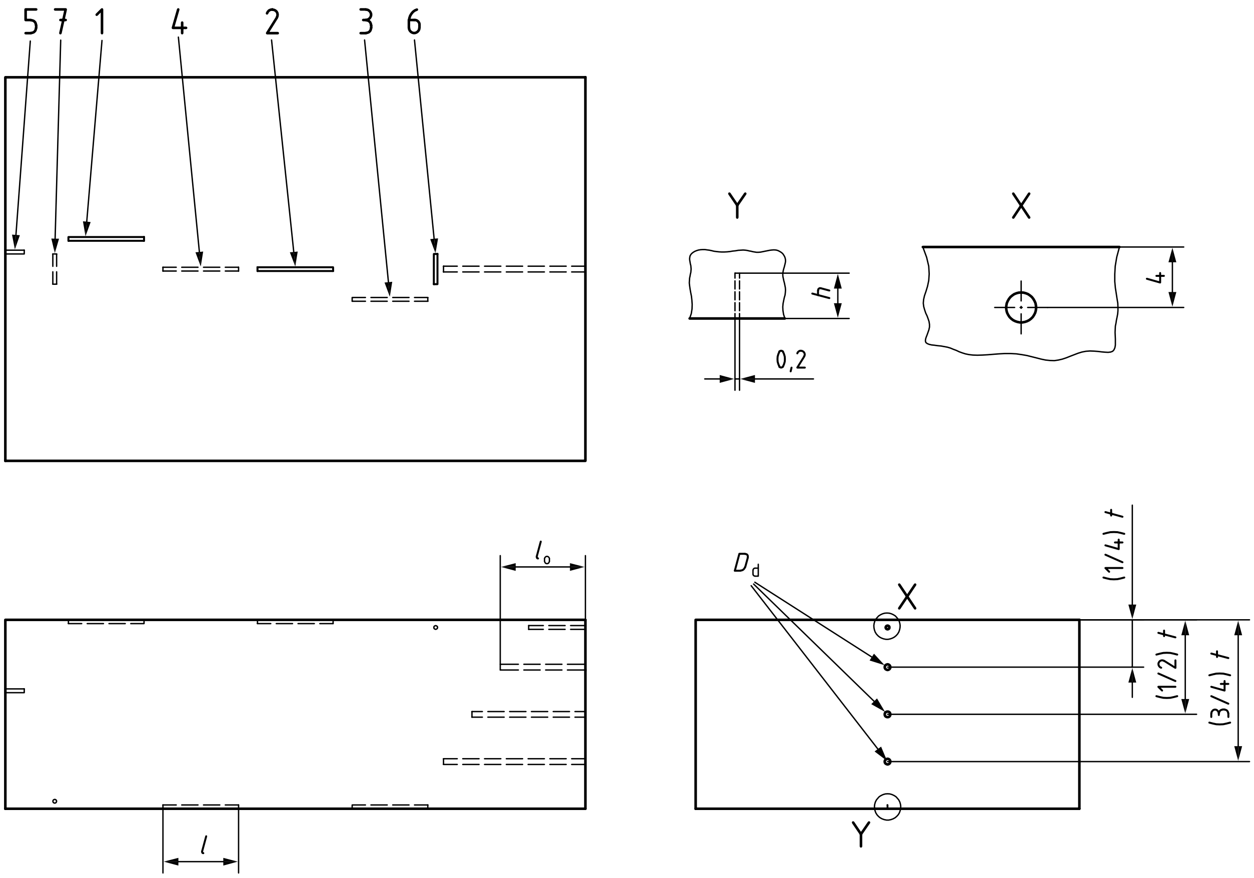
t thickness of block

Figure A.2 — Recommended reference block for testing level B

Detail X shows a side-drilled hole located at 4 mm below the surface, with a diameter of 2 mm and a minimum length of 30 mm. Alternatively, a surface notch can be used with the same dimensions as described in Table A.1.

A.2.3 Testing level C (Figure A.3)

Dimensions in millimetres



Key

D_d diameter of side-drilled hole

h depth of the notch at the bottom

l length of notch

l_0 length of side-drilled hole

t thickness of block

1, 2 near-side surface notches

3, 4 far-side surface notches

5 notch on imaginary weld bevel

If required by specification:

6 near-side surface transverse notch

7 far-side surface transverse notch

Figure A.3 — Recommended reference block for testing level C

Detail X shows a side-drilled hole located at 4 mm below the surface, of diameter 2 mm and minimum length 30 mm. Alternatively, a surface notch can be used with the same dimensions as described in Table A.1.

The notches 2 and 4 are positioned at the imaginary weld centre line. The notches 1 and 3 are positioned at the edges of the volume to be tested. Notch 5 is positioned on the imaginary weld bevel with an orientation of ±5° to the weld bevel. The dimensions and the location of notch 5 shall be as specified.

There should be a volume in the reference block which is kept free from artificial reflectors. The extent of this volume should exceed the sound beam width. This volume should be symmetrical about the weld centre line.

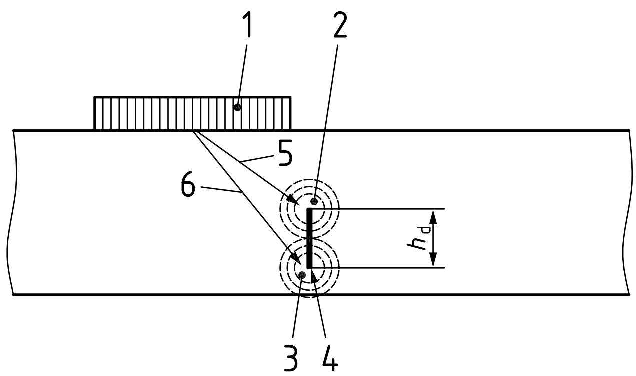
A.2.4 Testing level D

For testing level D special blocks containing additional reflectors shall be used with the same configuration, same base material properties, same weld material properties and same weld process as the object to be tested. These special blocks shall be used in addition to the test blocks described for testing levels B and C.

Annex B
(informative)

Illustrations of possible signals to be used

B.1 2 diffracted signals from the same discontinuity (upper and lower tip)



Key

1 phased array probe

2 diffracted signal from the upper tip

3 diffracted signal from the lower tip

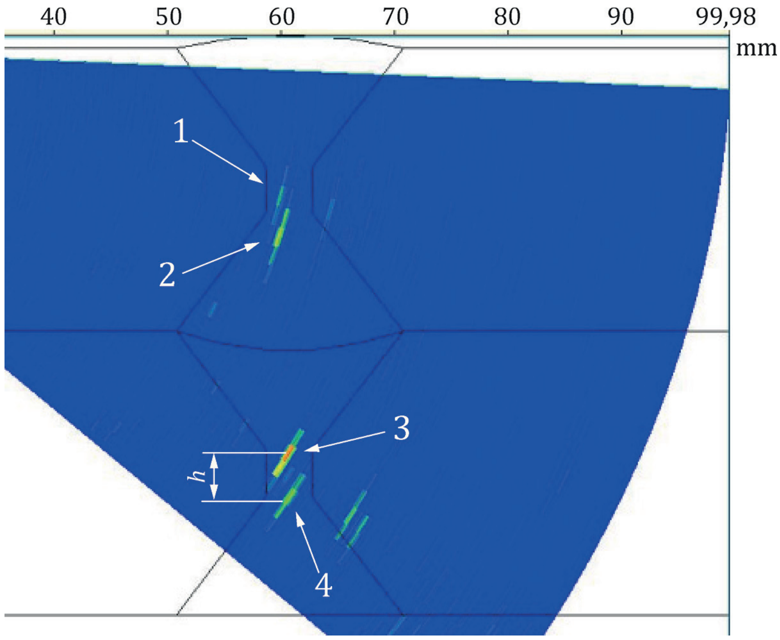
4 discontinuity

5 path (within half skip) to the upper tip considered for sizing

6 path (within half skip) to the lower tip considered for sizing

h_d height of the discontinuity

Figure B.1 — Diffracted signals used for height determination (E-Scan or/and S-Scan may be used)



Key

1 display of the diffracted signals of the upper tip within half skip

2 display of the diffracted signals of the lower tip within half skip

3 display of the diffracted signals of the lower tip within full skip

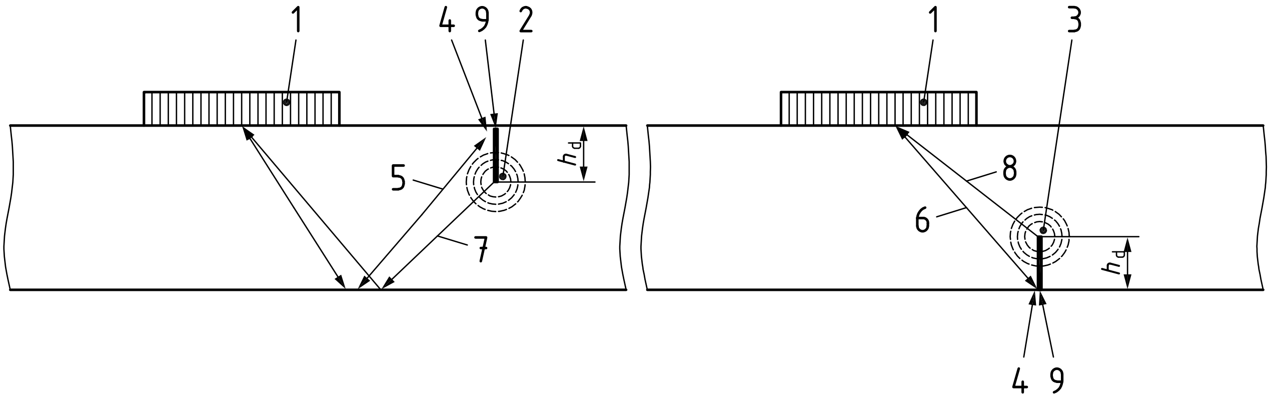
4 display of the diffracted signals of the upper tip within full skip

h measured height

Figure B.2 — Sectorial scan image of an embedded discontinuity

The identified diffracted signals are selected (3 and 4). The cursors are set at the maximum amplitude corresponding to the diffracted signals. The measured height, *h*, is determined as the difference of the z-coordinates.

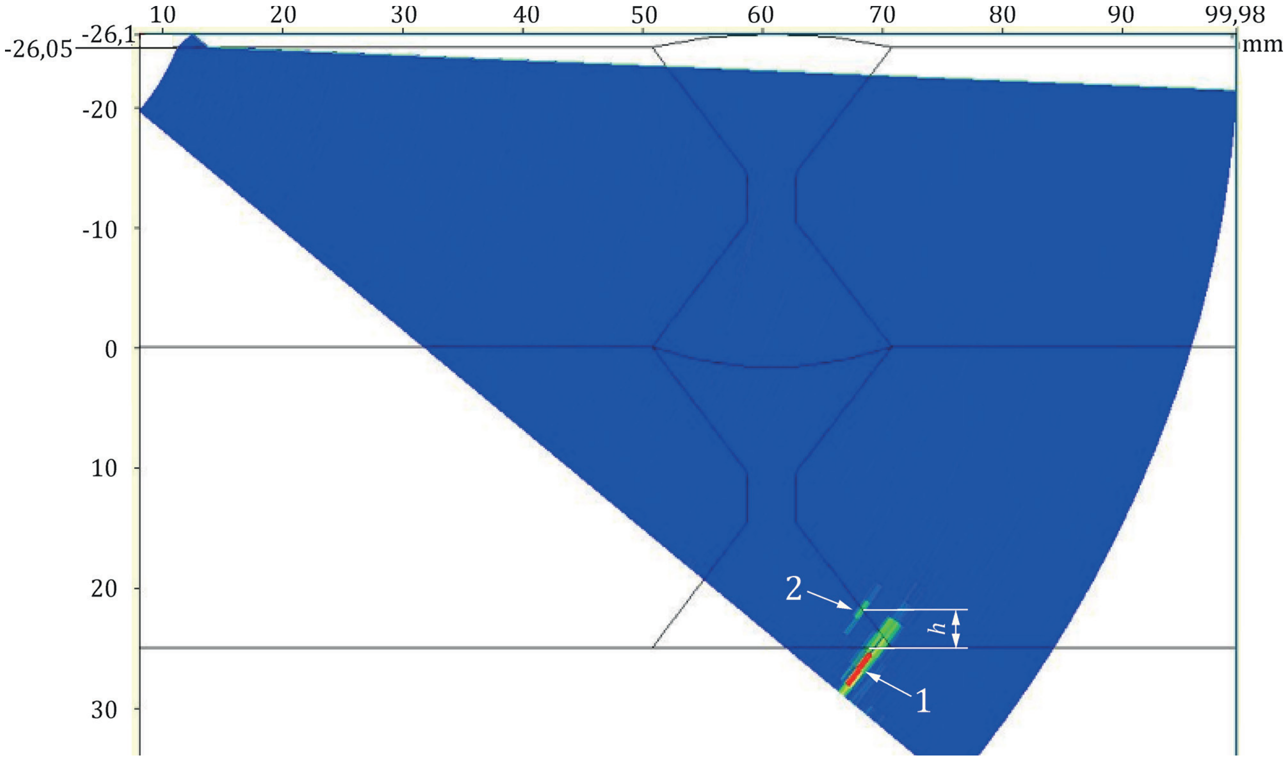
B.2 Diffracted signal and reflected signal from the same discontinuity



Key

1 phased array probe
2 diffracted signal from the lower tip
3 diffracted signal from the upper tip
4 corner reflection
5 path (within full skip) of the corner reflection signal considered for sizing
6 path (within half skip) of the corner reflection signal considered for sizing
7 path (within full skip) to the lower tip considered for sizing
8 path (within half skip) to the upper tip considered for sizing
9 discontinuity
h_d height of the discontinuity

Figure B.3 — Signals used for height determination of surface-breaking discontinuities



Key

1 display of the reflected signals of the corner at full skip

2 display of the diffracted signals of the lower tip within full skip

h measured height

Figure B.4 — Sectorial scan image of a surface-breaking discontinuity

The cursors are set at the maximum amplitude corresponding to each signal. The height of the discontinuity, *h*, is determined from the difference of the z-coordinates.

Bibliography

[1] ISO 3183, *Petroleum and natural gas industries — Steel pipe for pipeline transportation systems*

[2] ISO 10893-8, *Non-destructive testing of steel tubes — Part 8: Automated ultrasonic testing of seamless and welded steel tubes for the detection of laminar imperfections*

[3] ISO 10893-11, *Non-destructive testing of steel tubes — Part 11: Automated ultrasonic testing of the weld seam of welded steel tubes for the detection of longitudinal and/or transverse imperfections*

[4] ISO 11666, *Non-destructive testing of welds — Ultrasonic testing — Acceptance levels*

[5] ISO 15626, *Non-destructive testing of welds — Time-of-flight diffraction technique (TOFD) — Acceptance levels*

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

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

[8] ISO/TS 16829, *Non-destructive testing — Automated ultrasonic testing — Selection and application of systems*

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

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