SLOVENSKI STANDARD
SIST-TS CEN/TS 14751:2005

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Varjenje ï Uporaba tehnike zvoļ ne poti (TOFD) za preiskavo zvarov

Welding - Use of time-of-flight diffraction technique (TOFD) for examination of welds

Schweißverbindungen - Anwendung der Beugungslaufzeittechnik (TOFD) für die Prüfung von Schweißverbindungen

Soudage - Utilisation de la technique de diffraction des temps de vol (méthode TOFD) pour le contrôle des soudures

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English version

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Foreword

This document (CEN/TS 14751:2004) has been prepared by Technical Committee CEN/TC 121 “Welding”, the secretariat of which is held by DIN.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to announce this Technical Specification: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom.

1 Scope

This document specifies the application of the time-of-flight diffraction (TOFD) technique for the semi-, or fully-automated ultrasonic testing of fusion welded joints in metallic materials equal to and above 6 mm thickness. It is primarily intended for use on full penetration welded joints of simple geometry in plates, pipes, and vessels, where both the weld and parent material are low alloyed carbon steel. Where specified and appropriate, TOFD may also be used on other types of materials that exhibit low ultrasonic attenuation (especially that due to scatter).

Where material dependent ultrasonic parameters are specified in this document, they are based on steels having a sound velocity of (5920 ± 50) m/s for longitudinal waves, and (3255 ± 30) m/s for transverse waves. This has to be taken into account when examining materials with a different velocity.

This document makes reference to the basic pre-standard ENV 583-6 and provides guidance on the specific capabilities and limitations of TOFD for the detection, location, sizing and characterisation of discontinuities in fusion welded joints. TOFD may be used as a stand-alone method or in combination with other NDT methods or techniques, both for manufacturing inspection (pre-service) and for in-service inspection.

This document specifies four examination levels (A, B, C, D) corresponding to an increasing level of inspection reliability. Guidance on the selection of examination levels is provided.

This document permits assessment of indications for acceptance purposes. This assessment is based on the evaluation of transmitted, reflected and diffracted ultrasonic signals within a generated TOFD image.

This document does not include acceptance levels for discontinuities.

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.

EN 473, *Non destructive testing — Qualification and certification of NDT personnel — General principles.*

EN 583-1, *Non-destructive testing — Ultrasonic examination — Part 1: General principles.*

ENV 583-6, *Non-destructive testing — Ultrasonic examination — Part 6: Time-of-flight diffraction technique as a method for detection and sizing of discontinuities.*

EN 1330-4:2000, *Non-destructive testing — Terminology — Part 4: Terms used in ultrasonic testing.*

EN 1714, *Non destructive examination of welds — Ultrasonic examination of welded joints.*

EN 12062, *Non destructive examination of welds — General rules for metallic materials.*

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 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 1330-4:2000 and the following apply:

3.1
TOFD set-up
probe arrangement defined by probe characteristics (e.g. frequency, probe element-size, beam-angle, wave mode) and probe centre separation (PCS)

3.2
probe centre separation (PCS)
distance between the index-points of the two probes. For curved surfaces it is the shortest distance between the index-points

3.3
beam intersection point
point of intersection of the two main beam-axes

3.4
indication
pattern or disturbance, in the TOFD image which may need further evaluation

3.5
TOFD image
two-dimensional image, constructed by collecting adjacent A-scans while moving the TOFD set-up. The signal-amplitude of the A-scans is typically represented by grey-scale values

3.6
offset-scan
scan parallel to the weld-axis, where the beam intersection point is not on the centre-line of the weld

4 General remarks on the capabilities of the technique

General principles of the TOFD-technique are described in ENV 583-6. For the testing of fusion welded joints some specific capabilities and limitations of the technique have to be considered.

The TOFD technique is an ultrasonic image-generating technique, which offers the capability of detection, location and sizing. To a certain extent characterisation of discontinuities in the weld material as well as in the adjacent parent material is also possible.

Compared with purely reflection-based techniques, the TOFD technique, which is based upon diffraction as well as reflection, is less sensitive to the orientation of the discontinuity. Discontinuities oriented perpendicular to the surface, and at intermediate angles of tilt, are detectable as well as discontinuities in the weld fusion faces.

In certain circumstances (thickness, weld preparation, scope of testing etc) more than one single TOFD set-up is required.

A typical TOFD image is linear in time (vertical axis) and probe movement (horizontal axis). Because of the V-geometry of the ultrasound paths, the location of a possible discontinuity is then non-linear. Similar to the generation of radiographic images, a TOFD testing has to be carried out in a correct and consistent way, such that valid images are generated which can be evaluated correctly. For example coupling losses and data acquisition errors have to be avoided, see 12.2.

The interpretation of TOFD-images requires skilled and experienced operators. Some typical TOFD-images of discontinuities in fusion welded joints are provided in Annex B.

There is a reduced capability for the detection of discontinuities close to or connected with the scanning surface or with the opposite surface. This has to be considered especially for crack-sensitive steels or at in-service inspections. In cases where full coverage of these zones is required, additional measures shall be taken. By example, TOFD can be accompanied by other NDT-methods or -techniques, e.g. conventional pulse-echo testing, see EN 1714.

Diffracted signals from weld-discontinuities have small amplitudes comparable to grain-scatter signals from coarse-grained materials which may hinder the detection and evaluation of discontinuities.

5 Examination levels

This document specifies four examination levels (A, B, C and D). From examination level A to examination level C an increasing reliability will be achieved.

Table 1 — Examination levels

examination level	TOFD set-up	reference block for set-up verification (see 8.2)	reference block for sensitivity settings (see 10.1.4)	offset-scan	Written test instruction
A	acc. to Table 2	no	No	no	this TS
B	acc. to Table 2	no	Yes	no	this TS
C	acc. to Table 2	yes	Yes	[a]	yes
D	as specified	yes	Yes	[a]	yes

[a] the necessity, number of and position of offset scans has to be determined

For pre-service inspections (see also EN 12062) all examination levels are applicable. Level A is only applicable for wall-thickness up to 50 mm. For in-service inspections only examination level D shall be applied.

If the specified acceptance criteria require detection of a certain size of discontinuities at both or one surface of the weld (see Clause 4) this may necessitate the use of techniques or methods outside the scope of this document.

6 Information required prior to testing

6.1 Items to be defined by specification

Information on the following items is required:

a) purpose and extent of TOFD testing (see Clauses 5 and 8);

b) examination levels (see Clause 5), e.g.
   — whether or not a written test instruction is required;
   — whether or not reference blocks are required;

c) specification of reference blocks, if required (see 10.3);

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

e) requirements for access and surface conditions (see Clause 8) and temperature;

f) reporting requirements (see Clause 13);

g) acceptance criteria;

h) personnel qualifications (see 7.1).

6.2 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 Clause 6.1 together with the following additional information:

a) written test instruction (see 6.3), if required;

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 inspection relative to any post-weld heat treatment;

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

6.3 Written test instruction

For examination levels A and B, this document satisfies the need for a written test instruction.

Where this is not the case, or where the techniques described in this document are not applicable to the welded joint to be tested, specific written test instructions shall be used.

7 Requirements for personnel and equipment

7.1 Personnel qualifications

In addition to a general knowledge of ultrasonic weld inspection, all personnel shall be competent in TOFD inspections. Documented evidence of their competence (training, experience) is required.

Preparation of written test instruction, final off-line analysis of data, and acceptance of the report shall be performed by personnel certified as a minimum to level 2 in accordance with EN 473 or equivalent in ultrasonic testing in the relevant industrial sector.

Equipment set-up, data acquisition, data storage, and report preparation shall be performed by personnel certified as a minimum to level 1 in accordance with EN 473 or equivalent in ultrasonic testing in the relevant industrial sector.

For data acquisition the level-1 person may be supported by an assistant technician.

In cases where the above minimum qualifications are not considered adequate, job-specific training shall be carried out.

7.2 Equipment

7.2.1 Ultrasonic equipment and display

Ultrasonic equipment used for the TOFD technique shall, where applicable, comply with the requirements of EN 12668-1, EN 12668-2 and EN 12668-3.

In addition, the requirements of ENV 583-6 shall apply taking into account the following:

— The equipment shall be able to select an appropriate portion of the time base within which A-scans are digitised;

— It is recommended to use a sampling rate of the A-scan of at least 6 times the nominal probe frequency.

7.2.2 Ultrasonic probes

Ultrasonic probes used for the TOFD technique on welds shall comply with ENV 583-6.

Adaptation of probes to curved scanning surfaces shall comply with EN 1714.

A recommendation for the selection of probes is given in Table 2.

7.2.3 Scanning mechanisms

The requirements of ENV 583-6 shall apply. To achieve consistency of the images (collected data), guiding mechanisms may be used.

8 Preparation for testing

8.1 Volume to be inspected

Testing shall be performed in accordance with ENV 583-6. The purpose of the testing shall be defined by specification. Based on this the volume to be inspected shall be determined.

The volume to be inspected is located between the probes. For examination levels A and B the probes shall be placed symmetrically to the weld centre line. For examination levels C and D additional offset-scans may be required.

For manufacturing examinations (pre-service inspection) the examination volume is defined as the zone which includes weld and parent material for at least 10 mm on each side of the weld, or the width of the heat affected zone, whichever is greater. In all cases the whole examination volume shall be covered.

Normally these examinations are carried out according to recognised standards applying acceptance levels for quality assurance. If fitness-for-purpose methods are applied, then corresponding acceptance criteria shall be specified.

For in-service inspections, the examination volume may be targeted to specify areas of interest, e.g. the inner 1/3 of the weld body. The acceptance criteria and minimum size discontinuity to be detected in the area of interest shall be specified.

8.2 Set up of probes

The probes shall be set up to ensure adequate coverage and optimum conditions for the initiation and detection of diffracted signals in the area of interest. For butt welds of simple geometry and with narrow weld crowns at the opposite surface the testing shall be performed in one or more set-ups (scans) dependent upon the wall thickness (see Table 2). For other configurations, e.g. X-shaped welds, different base metal thickness at either side of the weld, or tapering, Table 2 may be used as guidance. In this case, effectiveness and coverage shall be verified by the use of reference blocks.

Selection of probes for full coverage of the complete weld thickness (typically pre-service inspection) should follow Table 2. Care should be taken to choose appropriate combinations of parameters. For example, in the thickness range 15 mm to 35 mm a frequency of 10 MHz, a beam-angle of 70° and an element-size of 3 mm may be appropriate for a thickness of 16 mm but not for 32 mm.

If set-up parameters are not in accordance with Table 2, the capability shall be verified by the use of reference blocks.

For examination levels C and D, all the set-ups chosen for the test object shall be verified by use of reference blocks.

For in-service inspection the intersection point of the beam centre lines should be optimised for the specified examination volume.

Table 2 — Recommended TOFD set-ups for simple butt-welds dependent on wall-thickness

Thickness t / mm	Number of TOFD set-ups	Depth-range Δt / mm	Centre-frequency f / MHz	Beam-angle α / ° (long.-waves)	Element – size / mm	Beam intersection
6-10	1	0-t	15	70	2-3	2/3 of t
10-15	1	0-t	15-10	70	2-3	2/3 of t
15-35	1	0-t	10-5	70-60	2-6	2/3 of t
35-50	1	0-t	5-3	70-60	3-6	2/3 of t
50-100	2	0-t/2	5-3	70-60	3-6	1/3 of t
		t/2-t	5-3	60-45	6-12	5/6 of t; or t for $\alpha \leq 45°$
100-200	3	0-t/3	5-3	70-60	3-6	2/9 of t
		t/3-2t/3	5-3	60-45	6-12	5/9 of t
		2/3t-t	5-2	60-45	6-20	8/9 of t; or t for $\alpha \leq 45°$
200-300	4	0-t/4	5-3	70-60	3-6	1/12 of t
		t/4-t/2	5-3	60-45	6-12	5/12 of t
		t/2-3t/4	5-2	60-45	6-20	8/12 of t
		3t/4-t	3-1	50-40	10-20	11/12 of t; or t for $\alpha \leq 45°$

8.3 Scan increment setting

The scan increment setting is dependent upon the wall thickness to be examined. For thickness up to 10 mm the scan increment shall be no more than 0,5 mm. For thickness between 10 mm and 150 mm the scan increment shall be no more than 1 mm. Above 150 mm a scan increment of 2 mm can be used.

8.4 Geometry considerations

Care should be taken when examining welds of complex geometry, e.g. welds joining materials of unequal thickness, materials that are joined at an angle, or nozzles. As TOFD is based upon the measurement of time intervals of sound waves taking the shortest path between the point of emission and the point of reception via points of reflection or diffraction, some areas of interest may be obscured. Additional scans may in many cases overcome this problem. Planning examinations of complex geometries requires in depth knowledge of sound propagation, representative reference blocks and sophisticated software and is beyond the scope of this document.