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Thermoplastic pipes for the conveyance of fluids — Inspection of polyethylene butt fusion joints using time of flight diffraction testing

Tubes en matières thermoplastiques pour le transport des fluides - Contrôle des assemblages par soudage bout à bout en polyéthylène au moyen de la technique par diffraction des temps de vol

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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).

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This document was prepared by Technical Committee ISO/TC 138, *Plastics pipes, fittings and valves for the transport of fluids*, Subcommittee SC 5, *General properties of pipes, fittings and valves of plastic materials and their accessories — Test methods and basic specifications*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Thermoplastic pipes for the conveyance of fluids — Inspection of polyethylene butt fusion joints using time of flight diffraction testing

1 Scope

This document describes the time of flight diffraction (TOFD) testing of polyethylene butt fusion (BF) joints, including pipe-to-pipe, pipe-to-fitting and fitting-to-fitting joints, used for the conveyance of fluids. This document provides a test, whereby the presence of imperfections such as voids, inclusions, lack of fusions, misalignment and particulate contamination in the BF joints can be detected. The document is only applicable to polyethylene pipes and fittings without a barrier to ultrasonic waves.

This document also provides requirement for procedure qualification and guidance for personnel qualifications which are essential for the application of this test method.

This document also covers the equipment, the preparation and performance of the test, the indication assessment and the reporting for polyethylene BF joints. The acceptance criteria are not covered in this document.

NOTE 1 At the present time laboratory experiences exist on the use of TOFD for polyethylene butt fusion joints and/or reference blocks of wall thickness between 8 mm to 100 mm[1][2][3][4][5][6]. Recently field experience on butt fusion joints in HDPE pipes has been reported[7].

NOTE 2 Round robin testing has shown that TOFD is a viable method for enhancing the integrity assessment of butt-fusion joints[14].

NOTE 3 TOFD techniques for cold fusion detection are known to be available. However further research, verification and experience are needed to transfer the technique into an ISO Standard. This document does not provide any information regarding the detection of cold fusions[14].

2 Normative references

The following referenced standards 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 5577, *Non-destructive testing — Ultrasonic testing — Vocabulary*

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

ISO 13953, *Polyethylene (PE) pipes and fittings — Determination of the tensile strength and failure mode of test pieces from a butt-fused joint*

3 Terms and definitions

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

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

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

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

3.1
cold fusion
incomplete intermolecular diffusion of polymer chains for proper molecular entanglement at the joint interface due to reasons other than contamination

Note 1 to entry: Cold fusion results in insufficient joint integrity including significant reduction of joint ductility.

3.2
inclusion
foreign material trapped in the fusion joint

3.3
lack of fusion
absence of intermolecular diffusion of polymer chains for molecular entanglement at the interface

Note 1 to entry: A lack of fusion flaw results in complete separation at the flaw location.

3.4
melt fusion zone
MFZ
zone containing the fusion interface and having boundaries on either side of the interface which reflect the limits of crystalline melting during the butt fusion jointing process

Note 1 to entry: The MFZ is shown in Figure 1.

3.5
misalignment
offset between the axis of the pipes/fittings to be jointed

3.6
particulate contamination
fine particles (e.g. airborne dust) or coarse particles (e.g. sand and grit) that are present at the fusion interface

3.7
surface imperfection
imperfection on the ID or OD surface of the butt fusion joint

3.8
void
empty space (or air pocket) in a butt fusion joint

3.9
time-of-flight diffraction image / TOFD image
two-dimensional image, constructed by collecting adjacent A-scans while moving the time-of-flight diffraction setup

Note 1 to entry: The signal amplitude of the A-scan is typically represented by grey-scale values

3.10
time-of flight diffraction set-up/ TOFD setup
probe arrangement defined by probe characteristics (e.g. frequency, probe element size, beam angle, wave mode), probe position, *probe centre separation* (3.11) and the number of probe pairs

3.11
probe centre separation
distance between the index points of the two probes

Note 1 to entry: The probe centre separation for two probes located on a curved surface is the straight-line, geometric separation between the two probe indexes and not distance measured along the surface.

3.12
scan increment
distance between successive data collection points in the direction of scanning

3.13
false call
reporting an imperfection when none exists

4 General

This document covers the TOFD equipment, the preparation and performance of the test, the indication assessment and the reporting for polyethylene butt fusion joints. The acceptance criteria are not covered in this document.

This document may be used to draft a detailed procedure for TOFD testing of polyethylene butt fusion joints.

Characterisation of imperfections in the parent material adjacent to the butt fusion joint is also possible.

5 Information required prior to testing

5.1 Items required for test procedure development

Information on the following items is required:

— purpose and extent of testing;

— reference sample;

— requirements for getting access to the butt fusion joints, the surface condition of the pipe; and the temperature range

— personnel qualifications;

— reporting requirements;

— manufacturing or operation stage of butt fusion joints at which the testing is to be carried out.

5.2 Specific information required by the operator before testing

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

a) written test procedure, qualified in accordance with Clause 10;

b) all relevant joint dimensions.

5.3 Written qualified test procedure

For all testing a written qualified test procedure is required. This test procedure shall include at least the following information:

a) purpose and extent of testing;

b) reference sample;

c) requirements for access to the butt fusion joints and surface conditions and temperature;

d) personnel qualifications;

e) reporting requirements;

f) equipment requirements and settings (including but not limited to frequency, sampling rate and element size, probe centre separation);

g) evaluation of indications;

h) environmental and safety issues;

i) documented testing strategy or scan plan.

NOTE The testing strategy gives information on the probe placement, movement, and component coverage that provides a standardized and repeatable methodology for fusion joint testing. The scan plan gives information on the volume tested for each butt fusion joint.

6 Personnel qualifications

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

In addition to a general knowledge of ultrasonic testing, the operator shall be familiar with and have practical experience in the use of TOFD systems on polyethylene butt fusion joints. Specific theoretical and practical training and examination of personnel shall be performed on representative polyethylene butt fusion joints containing natural or artificial reflectors similar to those expected. These training and examination results shall be documented.

7 Equipment

7.1 General

The complete equipment, i.e. ultrasonic instrument, probe, cables and display monitor shall be capable of the repetition of test results.

NOTE 1 In selecting the system components (hardware and software) ISO TS 16829[8] give useful information.

NOTE 2 Ultrasonic equipment used for TOFD testing should comply with the requirements of ISO 15626[9] EN-12668 [10] when applicable.

7.2 Ultrasonic instrument and display

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 should be at least six times the nominal probe frequency.

7.3 Ultrasonic probes

Only longitudinal wave mode can be used.

7.3.1 Probe selection

Any type of ultrasonic TOFD probe can be used if it satisfies the requirement of Clause 8 (Range and sensitivity settings) with the ultrasonic equipment.

The most suitable ultrasonic probe frequency shall be selected in accordance with the pipe wall thickness. Table 1 shows the recommended frequencies for each thickness range. However, the optimal frequency can deviate from these values depending on the attenuation and thickness of the sample to be tested.

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

For thicknesses greater than 30 mm the wall thickness shall be divided into more than one inspection zone, each zone covering a different depth region. Probe angle and frequencies shall be chosen to cover full volume. These zones can be inspected simultaneously or separately. Table 2 shows the examples of single and multiple inspection zone probe setup.

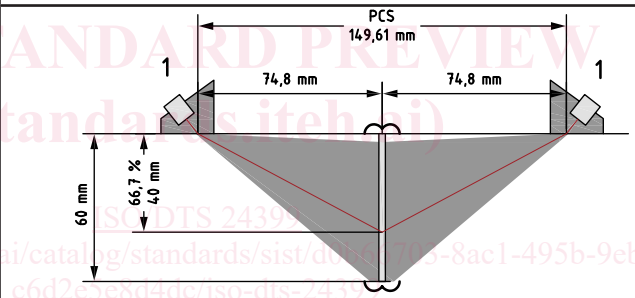
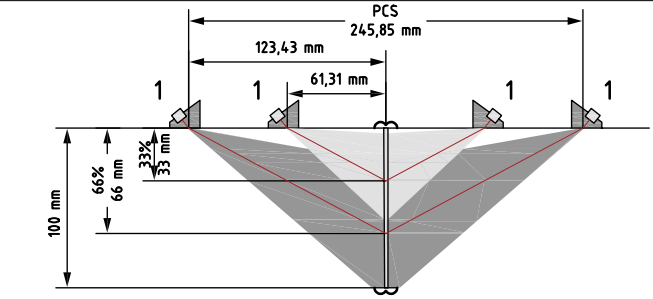
Table 1 — Selection of probe frequency

Wall Thickness (t) mm	**Number of TOFD setups**	**Centre Frequency** MHz	**Recommended Beam angle** (longitudinal waves)	**Element size** mm
8 ≤t< 30	1 or 2	5 to ≤ 10	60 to ≤ 70	3 to ≤ 6
30 ≤t< 60	2	2,25 to ≤ 5	60 to ≤ 70	6 to ≤ 11
60 ≤t≤ 100	3	1 to ≤ 5	45 to ≤ 70	6 to ≤ 11

NOTE 1 For multiple TOFD setups the deeper the range the lower the frequency and the smaller the beam angle.

NOTE 2 In general higher frequencies provide better resolution and lower frequencies provide better penetration.

Table 2 — Description of TOFD technique for testing butt fusion joints

TOFD set-up	**Example**
Single zone	
Multi-zone	

7.3.2 Probe separation

The maximum diffraction efficiency occurs when the included angle is about 120 degrees.

The probes should be arranged such that the (imagined) beam centre lines intersect at about this angle in the depth region where discontinuities are anticipated/sought.

Deviations of more than -35º or +45º from this value may cause the diffracted echoes to be weak and should not be used unless detection capabilities can be demonstrated.

Probes shall not touch the bead.

7.4 Scanning mechanisms

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

7.5 Couplant

In order to generate proper images, a couplant should be used which provides a constant transmission of ultrasound between the probe and the material. The same couplant used for calibration shall be used for the testing.

Any couplant used should be cleaned off after testing.

8 Range and sensitivity settings

8.1 Settings

8.1.1 General

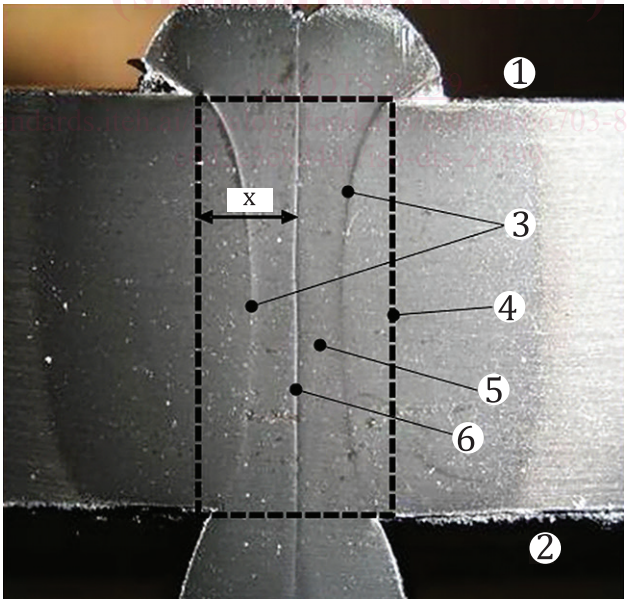
Setting of range and sensitivity shall be carried out prior to each testing period in accordance with this document. Any change of the TOFD set-up, e.g. probe centre separation, will require a new setting.

8.1.2 Range setting - test volume

The range in the depth direction shall cover the full joint thickness in the fusion zone.

The range in the axial direction shall cover the melt fusion zone on both sides of the butt fusion centre line. As a general guidance, for wall thicknesses up to 100 mm, the test area width is 10 mm or 1/5 of the wall thickness from either side of the fusion zone, whichever is smaller (see Figure 1).

The range in the circumferential direction shall include the full circumference.



Key

x width of test area
1 outside of joint
2 inside of joint
3 MFZ boundary
4 test area
5 melt fusion zone (MFZ)
6 fusion interface

Figure 1 — Test area