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Non-destructive testing — Ultrasonic guided-wave testing using the phased-array technique

Essais non destructifs — Essais par ondes ultrasonores guidées utilisant la technique multiélément

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Contents

Page

Foreword

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

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.

Introduction

To improve guided-wave tests, coverage will be extended from above-ground to underground facilities, and the technology will transition from single-element use to multi-element phased-array technology. Noticeable advantages in using the phased-array ultrasonic guided-wave technique over the conventional single-element technique are improvements in the signal-to-noise ratio (SN ratio) and in the testing reliability in harsh environments like buried or coated pipelines.

A low signal-to-noise ratio in buried or coated pipe reduces the sensitivity and the range of conventional guided-wave testing. The phased-array guided-wave focusing method presented in this document can overcome this issue. Beam focusing and steering with the proper mode selection is a key benefit.

Non-destructive testing — Ultrasonic guided-wave testing using the phased-array technique

1 Scope

This document specifies a concept of application of phased-array guided-wave testing for various types of inaccessible structures, including buried pipelines.

Materials considered are carbon steel and stainless steel. This document does not include principles and criteria for underground facilities and the phased-array ultrasonic guided-wave testing scheme.

Furthermore, this document consists of an optimized process to draw reliable test results on inaccessible pipe cases. This document provides guidance on the use of phased-array guided-wave testing for various types of inaccessible structures, including buried pipelines made of carbon steel and stainless steel. The methodology outlined in this document includes an optimized process for achieving reliable test results on inaccessible pipe cases, with adjustments made to the beam pattern of the GW's focus location based on the defect type, location, and frequency. The process also takes into consideration the distribution diagram of the guided waves and the characteristics of the selected mode, with optimal focusing and steering achieved by adjusting the excitation time delay for each transducer based on the number of circumferential arrangement intervals of a given array probe.

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

ISO 18211, *Non-destructive testing — Guided-wave testing of above-ground pipelines and plant piping using guided-wave testing with axial propagation*

ISO 23243, *Non-destructive testing — Ultrasonic testing with arrays — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5577, ISO 18211 and ISO 23243 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/

4 Personnel requirements

The personnel performing phased-array ultrasonic guided-wave testing shall be qualified in accordance with ISO 9712 (Level 1 with an additional 6-month training).

If ISO 9712 is not applicable to a specific situation, such as in cases where the relevant industrial sector has established other equivalent standards, those standards shall be used instead.

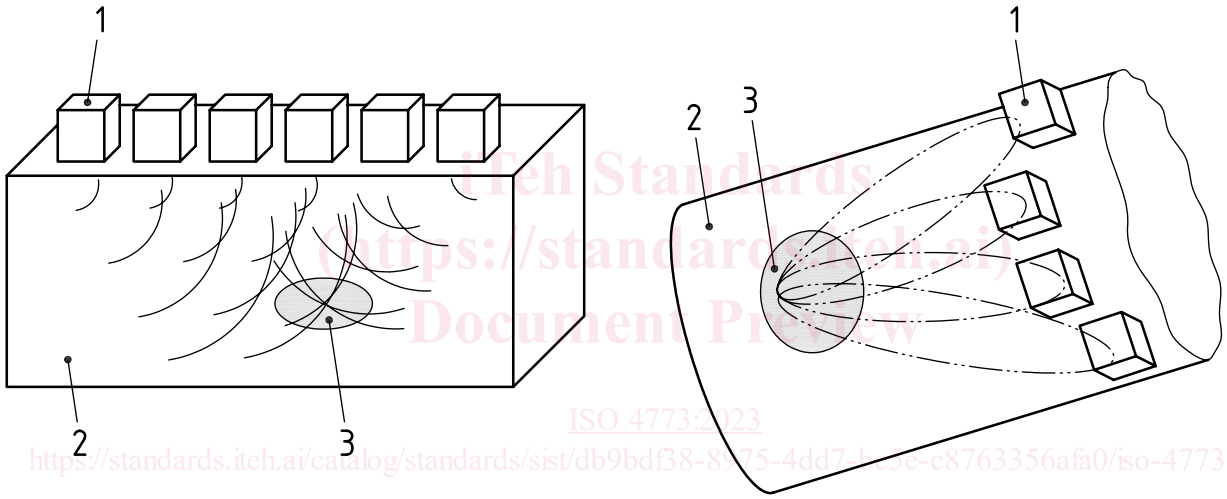
The personnel shall be trained on the use of the specific test equipment because there are significant differences between the available systems and diagnostic approaches.

5 Principles of phased-array guided-wave testing

The phased-array guided-wave testing is a technique that enables focusing and steering of ultrasonic waves by synthesizing a plurality of ultrasonic beams having a phase difference through a time delay between different ultrasonic probes. The phased-array guided-wave technique enables focusing and steering of ultrasonic beams.

Previously, as shown in Figure 1, only the synthesis of bulk wave signals was used. A similar principle can be applied to the signal synthesis of guided-waves; and this principle is applied to improve the reliability and test signals of guided-wave ultrasonic testing.

The phased-array probe is divided into torsional-mode and multi-mode modules (torsional, longitudinal), and each module is connected to a multi-channel instrument. The multi-channel modules are operated sequentially with time delay, focusing and steering the ultrasonic beam to the volume to be tested.



a) b)

Key

1 probe element
2 test object
3 imperfection

Figure 1 — Schematic showing the difference between the conventional phased-array ultrasonic testing (UT-PA) and the described guided-wave testing; a) Conventional UT-PA; b) Described guided-wave UT-PA.

6 Test equipment

6.1 General

The pulse-echo mode or pitch-catch mode technology shall be used.

The electronic system used for signal processing and analysis shall be capable of distinguishing the induced wave modes used in specific detection systems.

The instrument shall also have a device to display and record data.

For covered test objects, the following procedure shall be applied:

a) determine the maximum possible distance for testing according to the covering environment;

b) dismantle the covering material and remove the buried soil to install the guided-wave array module;

c) secure access space for the operator;

d) secure access space for equipment, equipment installation and initial software operation checks;

e) prevent interference of the initial diffusely reflected signal in the sound field near the guided-waves.

6.2 Test instrument

The test instrument shall be able to perform the following functions:

a) to generate and receive pulses in a frequency range of 20 kHz to 1 000 kHz;

b) one or more of the following guided-wave modes:

— longitudinal guided-wave mode;

— torsional guided-wave mode;

c) a focusing function to allow specific testing of suspected areas;

d) synthetic focusing:

e) focusing:

1) deliberate concentration of guided-wave modes at a single circumferential and axial position.

2) controlling a multi-mode probe module to function differently at different positions on the surface of an object enables the possibility of focusing the testing at a specific axial and lateral position on the object. This enhances sensitivity and spatial selectivity. To achieve this, the data collection process needs to be repeated for each axial and lateral position of interest.

6.3 Probe

a) Probes for transmitting and receiving signals shall be able to tune proper guided-wave modes in a pipe.

b) When using more than two guided-wave modes, the wave modes shall be applied to test object separately, not simultaneously.

c) Probe element with a frequency range of 20 kHz to 1 000 kHz shall be used; either one continuous ring or an individual probe may form a ring, resulting in axial symmetrical waves.

d) Other frequencies may be used for specialized tests specified in the test procedure.

6.4 Environmental requirements

The following environments shall be considered:

a) in the case of cladding or coating, the coating material, the bonding strength of the coating to the pipe surface, the area and volume of the coated area, the installation period of the coating material;

b) for buried test objects, soil quality, earth pressure (depth of burial, compressive strength of soil and pipes, buried period), moisture content, length and area of buried site;

c) other criteria, e.g. whether straight pipe or curved pipe, number of elbow positions, position of welds, support positions and their shape.

7 Periodical check of the test equipment

7.1 Periodical check of the instrument

The instrument shall be checked every 12 months by the manufacturer or a qualified test laboratory. After repairs and when a new software version is loaded, a check shall also be performed on the following:

a) power capacity;

b) pulser frequency and amplitude;

c) receiver input impedance;

d) DAC (distance amplitude curve);

e) linearity of TCG (time-corrected gain).

7.2 Periodical check of probe

Perform a visual check of the probe. If there is a damage, replace the probe. A visual and functional check of testing hardware system is required.

The periodical checks shall be performed according to ISO 18563-3.

7.3 Check of the complete system setting

The setting of the system shall be performed by default using pipes in service. Based on the checklist in Annex A, it shall be checked before and after the test.

The following processes shall be performed.

a) The integrity of a probe shall be verified.

b) The checks shall take into consideration the positions of the weldment, branch and coupling zone of the test object.

c) System configuration and setting are required for each testing (including a series of similar tests) and for system alterations.

7.4 Recording level

The recording level shall always be more than 6 dB above the noise level.

8 Test procedure

8.1 General

The test procedure includes the following steps:

a) preparation of testing;

b) probe test position;

c) data collection;