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Non-destructive testing — Long-range inspection of above-ground pipelines and plant piping using guided wave testing with axial propagation

Essais non destructifs — Vérification à large échelle des réseaux de canalisations hors sol et de la tuyauterie d'usine utilisant un essai d'onde guidée à propagation axiale

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Foreword

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The committee responsible for this document is IIW, *International Institute of Welding*, Commission V.

Requests for official interpretations of any aspect of this International Standard should be directed to the ISO Central Secretariat, who will forward them to the IIW Secretariat for an official response.

Non-destructive testing — Long-range inspection of above-ground pipelines and plant piping using guided wave testing with axial propagation

1 Scope

This International Standard specifies a method for long-range testing of carbon and low-alloy steel above-ground pipelines and plant piping using guided ultrasonic waves with axial propagation applied on the entire circumferential pipe section, in order to detect corrosion or erosion damage.

The guided wave testing (GWT) method allows for fast inspection of above-ground pipelines, plant piping and cased road crossings, giving a qualitative screening and localization of probable corroded and eroded areas. GWT is typically performed on operating piping systems.

This International Standard is applicable to the following types of pipes:

a) above-ground painted pipelines;

b) above-ground insulated pipelines;

c) painted plant piping;

d) insulated plant piping.

NOTE Pipe sections within road crossings with external casings (without bitumen or plastic coating) are a special case of buried pipe where there is no soil pressure on the OD of the pipe. This International Standard applies to these cased road crossings.

Other types of pipes not included in the above list need dedicated approaches due to increased complexity.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
axial direction
direction along the main axis of the pipe

3.2
circumferential direction
direction around the circumference of the pipe

3.3
total pipe wall cross-section
TCS
area between the inner and outer diameters of the pipe in a plane perpendicular to the pipe axis

3.4
cross-section change
equivalent cross-section change calculated assuming that an indication is purely caused by a change in the cross-section of the pipe wall

3.5
datum point
reference point for reporting a *test position* (3.16) and for correlating test results with the corresponding position on the test object

3.6
dead zone
length of pipe on either side of the *test position* (3.16) where reflectors of interest cannot be detected because they are covered by the transmitted pulse

3.7
flexural mode
non-symmetric bending type mode of guided wave propagation in pipes, with particle displacements in axial, circumferential and radial directions

3.8
focus
concentration of guided waves at a single axial and circumferential position, achieved either by hardware settings or by post-processing of a recorded set of signals (synthetic focus)

3.9
geometric feature
pipeline feature (e.g. weld, support, flange, bend, etc.) causing the reflection of guided waves because of a *cross-section change* (3.4) or other acoustic impedance variation

3.10
guided wave mode
distinct type of guided wave with a specific vibration pattern

3.11
longitudinal mode
symmetric compression type mode of guided wave propagation in pipes, with particle displacements predominantly in the *axial direction* (3.1)

3.12
primary mode
guided wave mode (3.10) which is chosen for the incident wave

3.13
probe ring
circumferential component, containing transducer elements with direct contact to the pipe

3.14
secondary mode
guided wave mode (3.10) which is different from the *primary mode* (3.12) and is generated by mode conversion at pipe features or discontinuities

3.15
test frequency
centre frequency of the pulses transmitted by the *probe ring* (3.13)

3.16
test position
axial position on the pipe where the *probe ring* (3.13) is placed

3.17
test range
distance between the *test position* (3.16) and the furthest position for which the minimum acceptable sensitivity of the reference signal is achieved, in each direction (positive or negative)

3.18
torsional mode
symmetric twisting type mode of guided wave propagation in pipes, with particle displacements in the *circumferential direction* (3.2)

4 Test personnel

The personnel performing ultrasonic guided wave testing shall be qualified in accordance with ISO 9712 or with any another equivalent standard of the relevant industrial sector.

Training in the use of the specific equipment is required because there are significant differences between the available systems and diagnostic approaches.

5 General

Ultrasonic guided wave testing (GWT) uses elastic waves which are guided along the pipe wall and can travel long distances, thus providing rapid near complete coverage of the volume of the pipe wall.

The typical test setup is comparable to conventional ultrasonic pulse-echo testing: an ultrasonic instrument forces transducers in the probe ring to generate ultrasonic waves in the pipe wall which are reflected by discontinuities and received by the same probe ring. The time-of-flight of the received signal indicates the distance between the discontinuities and the probe ring. A single test with guided waves can cover a length of pipe of tens of meters.

Within this International Standard, GWT is performed as a screening method. The reflections returning from discontinuities and received by the ultrasonic instrument indicate the position of the discontinuity. However, they do not give detailed quantitative information about its morphology. Therefore, GWT is used to indicate any locations which need to be followed up with complementary detailed inspection. More information on the nature of guided waves is given in Annex A.

Within this International Standard, GWT typically uses a frequency range between 20 kHz and 500 kHz. If the performance of the test has been shown to have equal or better sensitivity to that obtained with the frequency range specified above, a frequency lower than 20 kHz can be used for GWT.

The successful application of guided ultrasonic waves requires the following:

a) selective pure mode transmission and reception;

b) wave modes which are non-dispersive in the frequency range used;

c) coverage of the full cross section of the pipe wall;

d) signals coming from each direction shall be distinguished.

The amplitude of a reflected ultrasonic guided wave signal from a discontinuity varies in a complex manner that depends on many factors such as test frequency, guided wave mode and the specific morphology of the discontinuity. It is often possible to correlate the size of the reflected signal with the overall cross-section change in the pipe wall resulting from wall loss, meaning that GWT can qualitatively group discontinuities into different severity groups such as indications of low, medium and high concern. However, usually the parameter of interest when testing piping systems with wall loss is the remaining wall thickness in areas with discontinuities, which GWT cannot accurately provide (see Annex A for more information).

It is recommended to perform ultrasonic guided wave testing using a range of frequencies to improve the accuracy of the test. Also, GWT ultrasonic instruments often employ advanced approaches like focusing or synthetic focusing to improve the sensitivity and discontinuity sizing ability of GWT. The use of these is not specified in this International Standard, but background information is provided in Annex A.

6 Factors influencing GWT performance

6.1 External diameter

The sensitivity of GWT depends on the cross-section change. The absolute cross-section change in a pipe due to corrosion or erosion loss is measured in the units of area and depends on both the depth and the circumferential extent of the discontinuity. GWT is sensitive to a minimum per cent of cross-sectional loss, which is a function of both the absolute cross-section change and the pipe geometry. As an example, a discontinuity in a small diameter pipe may represent a large per cent change in cross section that is easily detectable using GWT, but the same discontinuity in a large diameter pipe may represent a small cross-section change that cannot be detected using GWT. Because of this effective decrease in sensitivity as pipe diameter increases, testing of pipes larger than DN 600 (24 inches in diameter) can miss significant isolated corrosion pits, so it is recommended that complementary NDT methods are used. When testing pipes where the known damage mechanisms result in larger cross-section changes rather than isolated pitting, GWT is still recommended for rapid testing of pipes with diameters larger than DN 600 (24 inches in diameter).

6.2 Pipeline geometry

The complexity of the pipe geometry can limit guided wave propagation. Below are summarized the effects of some common pipe features which can be present in the pipes listed in Clause 1.

a) It is not possible to test beyond flanged joints or any breaks of the pipe because the guided waves cannot propagate across them.

b) It is not permitted to test beyond an elbow fitting; instead, the tool shall be moved to a test position on the other side of the bend. Testing beyond "pulled" bends, where a straight length of pipe is formed into a curve of radius equal to five or more times the pipe diameter is permitted.

c) It is permitted to test beyond a branch or a tee only if the diameter of the branch is no greater than ½ the diameter of the pipe being tested. This restriction is to avoid problems with distortion of the forward travelling guided wave by interactions with the branch.

d) It is not permitted to test beyond a support if the amplitude of reflection from it is higher than 6 dB below the weld DAC curve. This restriction is to avoid problems of the distortion of the forward travelling guided wave by interactions with the support.

6.3 Test range

The test range depends on many factors which are summarized below. In general, the test range is limited by the signal-to-noise ratio (SNR) of the test data (see Clause 9, item e).

a) Geometrical features on the pipe attenuate and/or distort guided wave modes reducing test range.

b) The type of coating on the pipe can have a large effect on test range. Typically, insulation materials like calcium silicate do not affect test range appreciably, but coatings like bitumen drastically reduce test range by attenuating guided wave signals.

c) This International Standard only applies to above-ground pipe, but buried pipe where there is soil in contact with the pipe surface or pipe coating is a more difficult GWT application due to high attenuation and low signal to noise.

d) The substance contained in the pipe affects test range and it is a complex function depending on the specific substance, ID corrosion products and the specific guided wave mode being used.

e) The presence of welds in the pipe causes reflections thereby attenuating the guided wave signal.

6.4 Road crossing

If performing GWT on a pipe passing through a road crossing with an external casing, achievement of the test for the length of the crossing shall be proven by the test range including a reflection from a geometrical feature (normally a weld) beyond the crossing or a reflection from a geometrical feature (normally a weld) inside the crossing that is identifiable from both sides of the crossing.

7 Test equipment

7.1 General

The test equipment consists of the following:

a) an ultrasonic instrument to generate and receive pulses in the frequency range from 20 kHz to 500 kHz;

b) a probe ring carrying transducers for the generation of guided wave modes;

c) a probe ring carrying transducers for the reception of reflected guided waves; it can be the same probe ring used for generating guided wave modes;

d) an electronic system for recording, processing and analysing the reflected signals.

7.2 Probe ring

The transmitting probe ring shall be capable of generating the primary guided wave mode in isolation from other possible modes of the pipe. If more than one wave mode is used, they should be used separately to improve the reliability of the inspection.

The receiving probe ring shall be capable of separating the individual guided wave modes which are of interest for the analysis and to suppress the undesired modes (see Annex A for more information).

There are three different types of transducers currently available to generate and receive guided ultrasonic waves in pipes:

— piezoelectric transducers;

— electromagnetic acoustic transducers (EMAT);

— magnetostrictive transducers.

These types of transducers are deployed on a probe ring which is placed around the pipe.

7.3 Signal processing and analysis system

The signal processing and analysis system shall produce its results in a form which can be recorded reliably on a computer storage medium.

The results which are recorded shall be in a form such that the features in the results can be correlated to physical locations on the piping system.

7.4 Periodic verification of equipment performance

The equipment shall be verified periodically, at intervals of no more than 12 months, to check its proper functioning and performance, and any faults found shall be corrected.

This verification shall be performed in accordance with a dedicated written procedure following the manufacturer's instructions.

7.5 Instrument settings

If no relevant standards for instrument settings are available, the following minimum requirements shall be met.

a) **Frequency and signal settings**

The settings which control the frequency and bandwidth of the signal shall be chosen to be appropriate for specific relevant guided wave modes which have been selected according to the inspection procedure to be used for the pipe under test.

b) **Pulse repetition frequency**

The pulse repetition frequency shall be set sufficiently low as to allow all signals to attenuate completely between subsequent pulses.

8 Test procedure

GWT shall be performed according to a written test procedure, which shall include at least the following:

a) a reference to this International Standard, i.e. ISO 18211;

b) background information (including standards, restrictions, safety requirements, etc.);

c) personnel qualification;

d) a description of the pipe to be tested;

e) range of the test;

f) access and environmental conditions;

g) surface preparation;

h) equipment used;

i) equipment parameters and functional testing;

j) parameters for data collection;

k) parameters for evaluation of results;

l) complementary non-destructive testing;

m) reporting requirements;

n) recording of deviations from the procedure.

9 Requirements for test data quality

The minimum requirements to assure the quality of the test data are as follows.

a) Before testing, the whole combined test system shall be checked according to the specifications provided by the manufacturer. If the GWT instrument performs self-checks, then the results of these shall be stored with the recorded data. Any equipment deviations from allowed specification shall be rectified before starting the test.

b) The tolerance of range setting shall be agreed upon between the parties (due to the long wavelength used for GWT the tolerance on distance measurement is not likely to be better than ±100 mm).

c) The probe ring coupling to the pipe surface shall be checked according to the procedures and thresholds provided by the manufacturer. If the coupling is found not to meet the required specification, then the surface preparation shall be improved, the probe ring re-applied and the data re-sampled.

d) If the equipment permits an absolute amplitude calibration, then it shall be used. Otherwise, calibration of sensitivity, using knowledge of a well-characterized reflector, such as a girth weld, shall be used. The calibration shall also include distance amplitude correction (DAC) or time corrected gain (TCG), in order to compensate the calibration for axial position within the range of the test. DAC and TCG are to be understood conceptually in the same manner as is established for conventional UT testing; a DAC provides a constant level of sensitivity as a function of range, allowing reflections at varying ranges to be compared in a consistent manner to a known reference level. The calibration shall be set according to the instructions provided by the manufacturer of the GWT equipment.

e) The signal-to-noise ratio shall be estimated according to the procedure provided by the manufacturer. For adequate interpretation of the test data, the signal-to-noise ratio shall be greater than 6 dB; small amplitude signals below this value cannot be interpreted reliably and will lead to noise signals being reported as discontinuities. The signal-to-noise ratio is used to determine the range of the test (see 6.3 for more information on test range).

10 Testing

10.1 Preparation of the test object

10.1.1 Surface temperature

The surface temperature of the pipe shall be within the operating range of the test equipment used.

10.1.2 Removal of insulation

Testing on insulated pipes requires the removal of circular bands of insulation at all the points where the probe ring shall be positioned and for a length that is sufficient to allow the fixing of the probe ring directly on to the pipe surface.

10.1.3 Wall thickness assessment

Metal loss at the probe ring location affects the test performance of GWT. Visual testing and ultrasonic testing shall be performed to assess the presence of external or internal metal loss. If metal loss is detected, it is recommended that the probe ring is attached to an alternative location. The wall thickness values shall be recorded.

GWT does not provide inspection coverage in the dead zone. One way of providing 100 % pipe inspection coverage is to perform more than one guided wave test on a piping system where there is sufficient overlap between tests to provide inspection coverage in all dead zones. If the dead zone is not inspected with GWT using another test location and if the dead zone is to be tested, ultrasonic testing (or an alternative method) shall be used.

10.1.4 Surface preparation

Testing on well-adhered painted surfaces is normally satisfactory. Loose or flaking paint, superficial corrosion products and other coatings shall be removed at the test location prior to attaching the probe ring if required to achieve the data quality set out in Clause 9, item e).