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

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This draft International Standard is submitted to all ISO member bodies for voting, as a standard prepared by an international standardizing body in accordance with Council Resolution 42/1999. The proposer, the International Institute of Welding (IIW), has been recognized by the ISO Council as an international standardizing body for the purpose of Council Resolution 42/1999.

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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

ISO 18211 was prepared by IIW, *the International Institute of Welding*.

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) technique 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 can be applied to the following types of pipes:

a) above ground painted pipelines;

b) above ground insulated pipelines;

c) pipe sections within road crossings with external casing (without bitumen or plastic coating);

d) painted plant piping;

e) insulated plant piping.

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

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.

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

3 Terms and definitions

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

3.1
axial direction
the direction along the main axis of the pipe

3.2
circumferential direction
the direction around the circumference of the pipe

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

3.4
cross-section change
the 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 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 where reflectors of interest cannot be detected because they are covered by the transmitted pulse

3.7
flexural mode
a 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 (i.e. weld, support, flange, bend, etc.) causing the reflection of guided waves because of a cross section change or other acoustic impedance variation

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

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

3.12
primary mode
guided wave mode 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 which is different from the primary mode 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

3.16
test position
axial position on the pipe where the probe ring is place

3.17
test range
the distance between the test position 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
a symmetric twisting type mode of guided wave propagation in pipes, with particle displacements in the circumferential direction

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 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 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:

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 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 percent 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 percent 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 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 DN600 (24 inches 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 5 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/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 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 effects 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 cause 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:

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.

