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Non-destructive testing — Automated ultrasonic testing — Selection and application of systems

Essais non destructifs — Contrôle automatisé par ultrasons — Sélection et application des systèmes

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Contents

Page

Foreword

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Non-destructive testing — Automated ultrasonic testing — Selection and application of systems

1 Scope

The information in this document covers all kinds of ultrasonic testing on components or complete manufactured structures for either correctness of geometry, for material properties (quality or defects), and for fabrication methodology (e.g. weld testing).

This document enables the user, along with a customer specification, or a given test procedure or any standard or regulation to select:

— ultrasonic probes, probe systems and controlling sensors;

— manipulation systems including controls;

— electronic sub-systems for the transmission and reception of ultrasound;

— systems for data storage and display;

— systems and methods for evaluation and assessment of test results.

With regard to their performance, this document also describes procedures for the verification of the performance of the selected test system.

This includes

— tests during the manufacturing process of products (stationary testing systems), and

— tests with mobile systems.

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*

3 Terms and definitions

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

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

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

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

4 Basic system description

4.1 Systems

There are two major applications for automated ultrasonic testing systems:

a) detection and evaluation of material defects (e.g. cracks, porosity, geometry);

b) measurement and evaluation of material properties (e.g. sound velocity, scattering).

Essential components of an automated test system are:

a) mechanically positioned and controlled ultrasonic probes and/or test objects;

b) automatic data acquisition for the ultrasonic signals;

c) acquisition and storage of probe positions in relation to the ultrasonic signals;

d) storage of test results.

A test system usually consists of several individually identifiable components. These are:

a) manipulators for probes or test objects;

b) probes and cables;

c) supply (pre-wetting), application and removal of the couplant;

d) electronic ultrasonic sub-systems;

e) data acquisition and processing devices;

f) data evaluation and display devices;

g) system controls;

h) sorting and marking of tested objects.

The complexity of a test system depends on the scope of the test and application of the system.

Test systems may be divided into stationary and mobile devices.

Examples of stationary test systems are testing machines:

— for the continuous testing of steel products, e.g. billets, plates, tubes, rails;

— for the testing of components, e.g. steering knuckles, rollers, balls, bolts, pressure cylinders;

— for the testing of composite materials, such as aerospace structures, e.g. complete wings made of composite materials, CRFP and GFRP components;

— for the testing of random samples (batch test) in a process accompanying production checks, e.g. testing for hydrogen induced cracking in steel samples.

Examples of mobile test systems are test rigs:

— for pre-service and in-service testing of components, e.g. valves, vessels, bolts, turbine parts;

— for pre-service and in-service inspection of vehicles;

— for pre-service and in-service testing of pipelines, e.g. oil or gas pipelines;

— ultrasonic testing of rails in railway tracks.

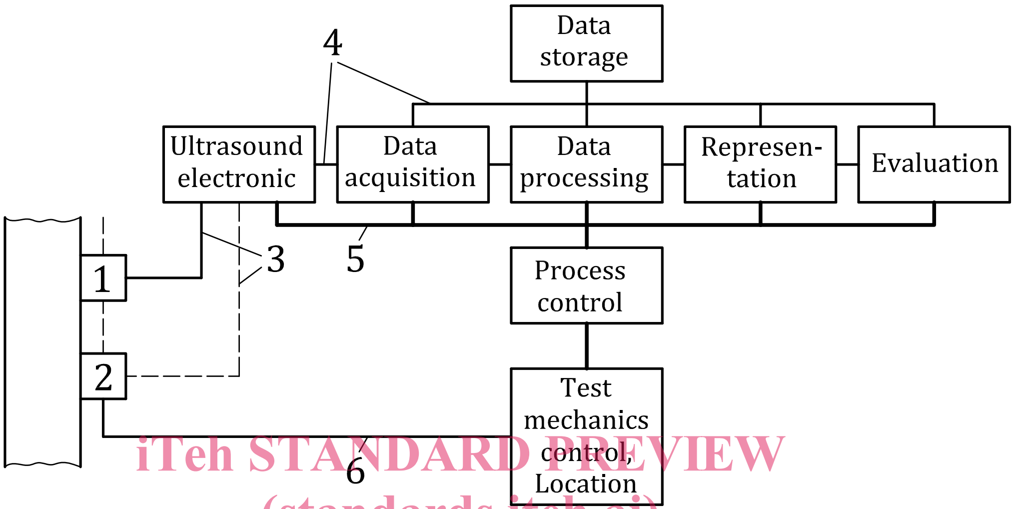
The test systems can be single or multichannel systems.

The complexity of the manipulator of the system depends on the examination task.

The complexity of the data acquisition and evaluation system depends on the number of test channels, on the required test speed, and on other test requirements.

4.2 System schematic

The essential components of an automated ultrasonic scanning system are shown in Figure 1. More detailed descriptions can be found elsewhere in this document. A detailed description of the individual functions is given in Clause 5.



Key

1 probe no 1
2 probe no 2
3 signal lines
4 data lines
5 control line
6 control line/position data

Figure 1 — System schematic

The probe position shall be determined and be recorded together with the ultrasonic data. This can be achieved by using encoders, ultrasound, or video techniques.

The most simple ultrasonic system uses only one probe (Figure 2).

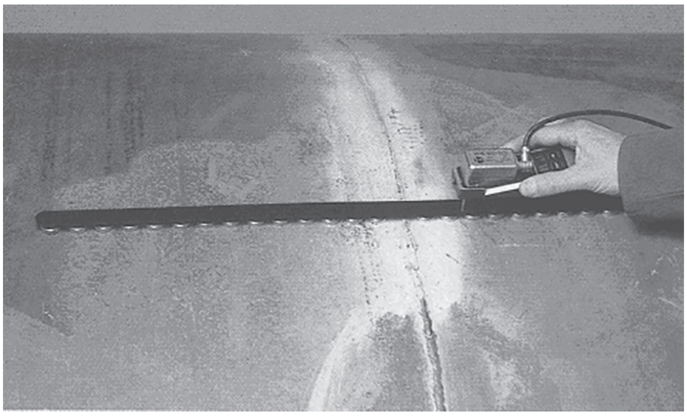


Figure 2 — Simple system with one probe

In order to fulfil more complex test requirement, the system can include several hundred probes, e.g. in a pig for pipeline testing, see Figure 3.

The ultrasonic sub-system is the main component of the complete test system. Figure 4 shows a block diagram of the basic electronic components of the ultrasonic sub-system. Depending on the required complexity, the ultrasonic sub-system can be made from one module for a single-channel system or multiple modules for multi-channel systems. These can be self-contained modules, computer plug-in cards, or rack mounted electronic systems.

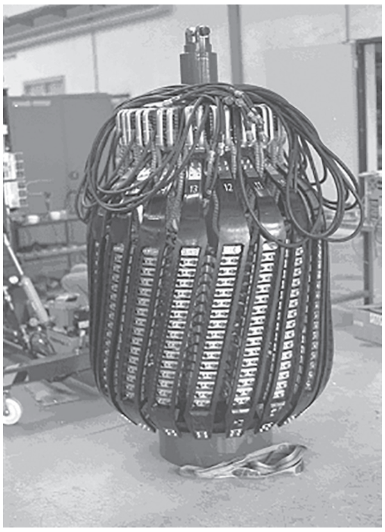


Figure 3 — Probe assembly of an intelligent pig for use on a 40-inch-diameter pipeline

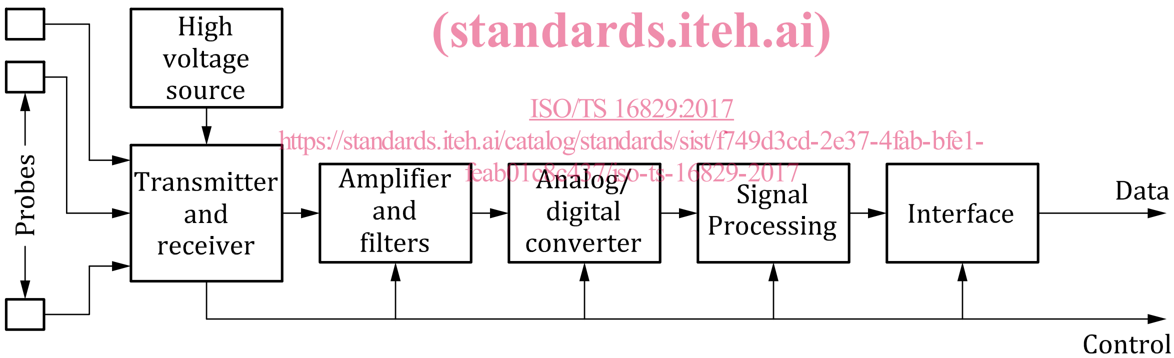


Figure 4 — Block diagram of the electronics of the ultrasonic sub-system

Some digital systems used for testing provide acquisition and storage of full RF ultrasonic signals. This mode offers the most information compared to other acquisition methods.

In order to reduce the time for testing, data processing and storage, other methods use data reduction techniques such as signal peak evaluation. For many applications, this provides a perfectly adequate level of data for the purposes of the testing.

Methods for data reduction are described in 6.6.5.2.

The data, which are transferred from the ultrasonic unit to the data acquisition unit, are referred to as test data.

In the data processing unit, the test data are processed in a way which enables them to be visualized on a display for the interpreter (user) performing the evaluation.

The data can be assessed and the test verified automatically during automated testing of objects.

In certain industrial sectors, the evaluation has to be performed by experienced test personnel, e.g. for welds on vessels and pipelines, or for safety-critical components in the aerospace industry. In these cases, the data processing unit has to provide images from the test data as a projection or sectional image. Other tasks are possible by filtering of the data to remove unwanted information. This can be achieved by software in a computer or by special hardware.

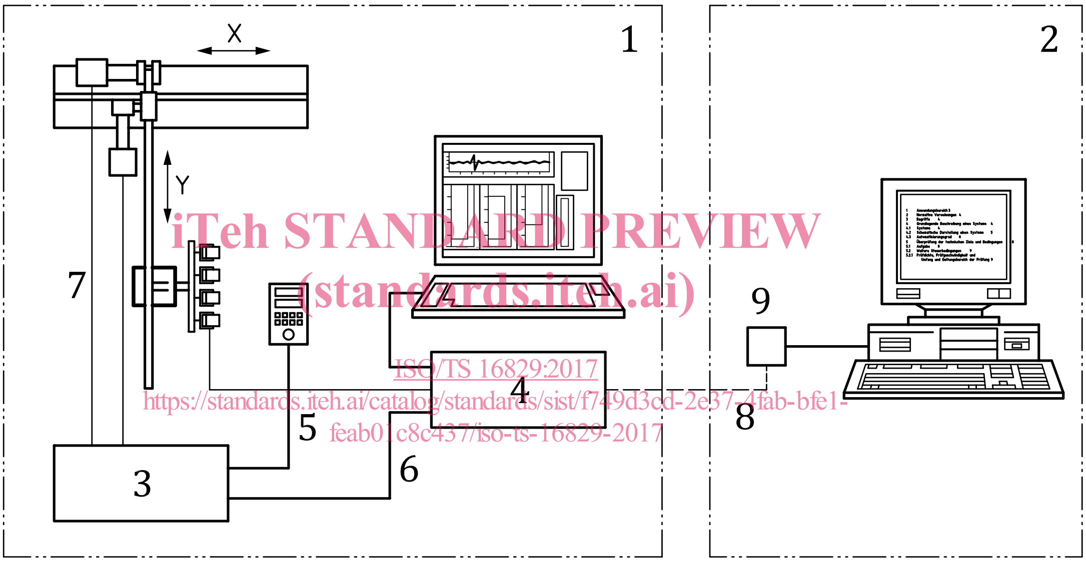
Data can be stored at different moments during the signal processing, as shown in Figure 1. If this is a simple go/no go test, only the final test result needs be recorded. In contrast, during testing of safety-critical components, the test data are stored together with any assessment result.

The control and synchronization of the individual system components is achieved by the system control. This ensures that the proper test sequence is performed.

The system control also synchronizes the storage of the probe positioning data and the ultrasonic data.

In-process testing can provide automated sorting or marking of unacceptable test objects.

A practical example of a basic system for automated scanning is shown in Figure 1. The set-up of a multi-channel test system is shown in Figure 5. This system has an XY-manipulator, and can be used for testing of vessels and pipes.



Key

1 sector of testing
- online survey
- data acquisition

2 sector of evaluation
- test planning
- data acquisition
- display
- assessment
- documentation

3 manipulator control

4 ultrasonic electronics

5 probe cable

6 position data

7 motor control, encoder signals

8 optional network link to ultrasonic electronics

9 network interface

Figure 5 — Set-up of a multi-channel test system

4.3 Levels of automation

Various levels of automated testing are possible, ranging from simple probe movement assisted by mechanical means through to fully automated acquisition and assessment of test data, and marking or sorting of test objects.

5 Examination of technical objectives and conditions of the testing

5.1 Test task

The test task specifies the discontinuities or material properties that the test is intended to detect or to measure.

The specification for the test system shall be designed within practical and economical viable limits, with due consideration to the properties of the test object.

Any existing relevant normative documents shall be taken into consideration.

The technical limits of the test system are governed, by amongst other things, the following parameters:

a) overall signal-to-noise ratio of the ultrasonic sub-system;

b) bandwidth of the probe(s) and the ultrasonic sub-system;

c) spatial resolution of the sound beam(s).

The most important factor in all methods of automated scanning is the system's dynamic lateral resolution. The scanning pattern and the scanning speed shall be specified in accordance with the sound beam dimensions as determined by a relevant reflector.

5.2 Other important conditions

5.2.1 General

The following conditions shall be considered for the specification of the test system:

a) requirements governed by the material properties, e.g. surface conditions and coupling requirements;

b) standards, guidelines and other specifications;

c) limitations to perform the testing, e.g. by test environment, accessibility, weather conditions, and power restrictions.

5.2.2 Scanning density, test speed, extent and coverage of testing

High speed testing is typical in automated scanning. This generates large amounts of data. If this is to be automatically assessed, processing speed is a key issue.

There is a relationship between the gap between points of testing, speed of probe motion, pulse repetition frequency, and speed of data acquisition. This relationship shall also consider the number of channels.

If the probe is moved in a direction x and test data have to be taken equidistantly (either amplitude or time-of-flight), the following condition shall be satisfied:

$$v < \left(\Delta x * f_r \right) / n \quad (1)$$