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Non-destructive testing — Robotic ultrasonic test systems — General requirements

Essais non destructifs — Systèmes robotisés de contrôle par ultrasons — Exigences générales

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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.

Non-destructive testing — Robotic ultrasonic test systems — General requirements

1 Scope

This document specifies the necessary system hardware components, the characteristics, the component requirements and conditions for the application of robotic ultrasonic test systems.

This document specifies the general requirements and acceptance criteria for robotic ultrasonic test systems.

This document is applicable to robotic ultrasonic test systems composed of one or more robot(s). Some of the characteristics of a robot ultrasonic testing system can be application-specific.

This document is applicable to conventional straight-beam probes and immersion technique.

This document is also applicable for phased array equipment, but additional tests can be necessary.

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 230-1, *Test code for machine tools — Part 1: Geometric accuracy of machines operating under no-load or quasi-static conditions*

ISO 230-2, *Test code for machine tools — Part 2: Determination of accuracy and repeatability of positioning of numerically controlled axes*

ISO 5577, *Non-destructive testing — Ultrasonic testing — Vocabulary*

ISO 8373, *Robotics — Vocabulary*

ISO 9283, *Manipulating industrial robots — Performance criteria and related test methods*

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

ISO 22232 (all parts), *Non-destructive testing — Characterization and verification of ultrasonic test equipment*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5577, ISO 8373, ISO 9283, ISO 22232 (all parts) and the following 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
robotic ultrasonic test system
automatic scanning ultrasonic test system, controlled by computer program, with the scanning motion implemented by one or multiple robots

3.2
joint robot
robot fitted with rotary joints

Note 1 to entry: Rotary joints allow a full range of motion, as they rotate through multiple planes, and they increase the manipulating capabilities of the robot considerably. An articulated robot can have one or more rotary joints, and other types of joints may be used as well, depending on the design of the robot and its intended function.

3.3
scan path
motion trajectory of the probe relative to the test object when the robot is executing the ultrasonic scanning with the probe or the test object held by the *end effector* (3.5) of the robot

3.4
Cartesian robot
robot whose arm has three prismatic joints, whose axes are coincident with a Cartesian coordinate system

3.5
end effector
device specifically designed for attachment to the robot's mechanical interface to enable the robot to perform its task

3.6
tool coordinate system
coordinate system referenced to the tool (probe or test piece) or to the *end effector* (3.5) attached to the mechanical interface

4 Requirements for test personnel

a) Personnel to perform verification tests using this document shall be qualified in accordance with ISO 9712 or equivalent.

b) The personnel shall be familiar with the robotic ultrasonic scanning equipment and robot motion control technique.

c) The personnel shall be authorized by the employer or his/her agent.

5 Test system

5.1 General

Robotic ultrasonic test systems are automated high-performance ultrasonic test systems.

They are equipped with robotic manipulating technology and ultrasonic testing technology.

A robotic ultrasonic test system is mainly composed of one or more robot(s), with one or more ultrasonic probe(s), an ultrasonic instrument and a fluid, gas or contact coupling system.

Single-pulse excitation or tone burst excitation is used.

Ultrasonic reflection or through-transmission technique may be implemented.

Two-dimensional or three-dimensional images may be used to display the test results to show the shape and the position of the detected imperfections.

5.2 Design principles

a) The design of the test system shall meet the requirements of the application for the objects to be tested.

b) The ambient conditions and the requirements of the test method shall be taken into account.

c) The distance between the surface of the test objects and the probes shall be kept constant during ultrasonic scanning.

d) Electrical or mechanical interferences shall be reduced to a minimum by design.

5.3 Test equipment

5.3.1 Instrument

a) The ultrasonic instrument shall meet the requirements of ISO 22232-1 where applicable.

b) The ultrasonic instrument shall be selected according to the application.

c) The ultrasonic instrument shall support ultrasonic pulse-echo and/or ultrasonic through-transmission mode.

d) The ultrasonic instrument shall have signal conditioning circuits for the excitation and the reception of ultrasonic pulses.

e) The technical properties such as transmitter pulse voltage, transmitter pulse width, repetition frequency, gain range, filtering bandwidth, digitizing frequency, digitizing dynamic range (A/D converter bits) and crosstalk shall be specified in accordance with ISO 22232-1 and shall satisfy the requirements of the application.

f) The technical properties of the ultrasonic instrument shall be determined according to the application (e.g. material characteristics and the sensitivity requirements).

5.3.2 Probes

a) The ultrasonic probes shall be selected according to the test procedure.

b) The ultrasonic probes shall meet the requirements of ISO 22232-2.

c) The technical parameters of the ultrasonic probes, such as frequency, beam diameter, focal distance and relative bandwidth, shall be specified in accordance with ISO 22232-2 and shall satisfy the requirements of the application.

d) The cable length between the probes and the instrument shall be reduced to a minimum to reduce cable attenuation and electrical noise. The housing shall be electrically grounded.

5.3.3 Robots

a) The robots shall be selected according to the requirements of the test procedure.

b) The robots shall conform to the requirements for the scan pattern and the scan speed.

c) The robots may be joint robots or Cartesian robots.

d) The technical properties such as freedom of mechanical movement, range for manipulation, maximum moving speed, motion accuracy and positioning repetition accuracy shall be specified and shall satisfy the requirements of the application.

e) The end effector of the robots shall provide a flange for the attachment of an ultrasonic probe and/or the test object as well as a coupling supply squirter if necessary.

f) The position and orientation of the probe's coordinate system or the coordinate system of the test object relative to the coordinate system of the robots end effector flange or the coordinate system of the robot base shall be provided to express tested point position in different geometrical coordinate systems.

5.3.4 Couplant

a) Dependent on the application, gas or liquid may be used as couplant with a robotic ultrasonic test system.

b) For liquid coupling, a squirter or immersion device and a circulation system for the couplant shall be provided.

5.4 Typical test systems

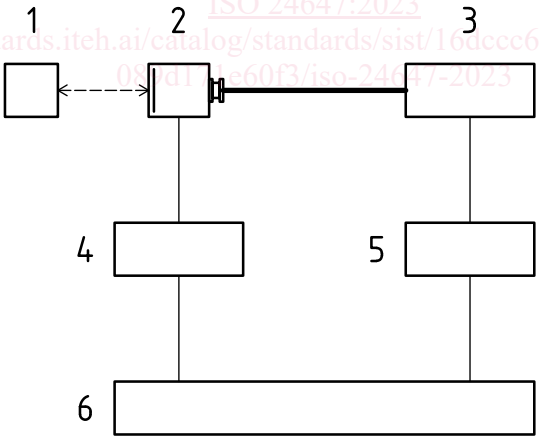
5.4.1 Single-robot test system

5.4.1.1 System components

Figure 1 shows the composition of a robotic ultrasonic test system based on one robot. The system setup is mainly composed of an ultrasonic instrument, an ultrasonic probe, a robot and its control system including software and a couplant circulation system. The system shall be arranged in a way that either the probe or the test object is moved by the robot.

a) Computer and robot controller shall be connected for control command and trajectory data transfer.

b) Computer and ultrasonic instrument shall be connected for control command and ultrasonic data transfer.



Key

1	test object
2	probe
3	robot
4	ultrasonic instrument
5	robot controller
6	computer and software
<----->	sound path
_____	electrical connection
▬▬▬▬	mechanical connection

Figure 1 — Single-robot ultrasonic test system

5.4.1.2 Scan modes

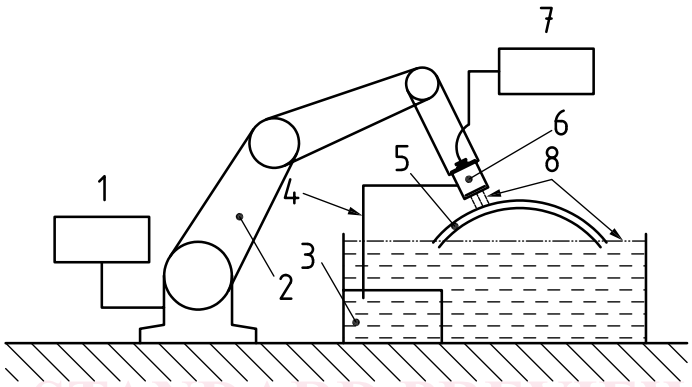
5.4.1.2.1 Scan mode with movement of the probe

The robot moves the probe while the test object is fixed, as shown in Figure 2.

This mode shall be used when the test object is too large or too heavy to be held by a robot.

It is suitable when the size of the test object is large and/or the acoustic attenuation is low so that the back-wall echo can be evaluated.

Usually, the ultrasonic probe is of little weight so that the robot can hold it without overload.



Key

1 robot controller
2 robot
3 circulatory system for couplant
4 couplant supply
5 test object
6 probe
7 ultrasonic instrument
8 couplant (e.g. water)

Figure 2 — Scan mode with movement of the probe (example for squirter technique)

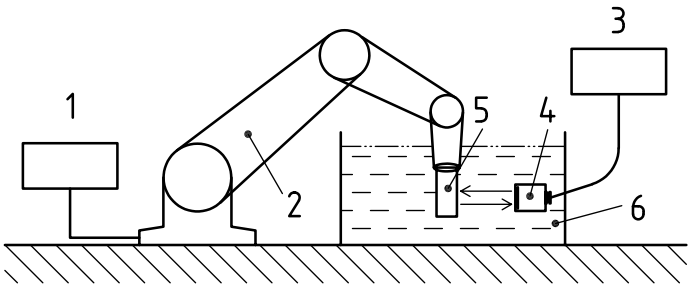
5.4.1.2.2 Scan mode with movement of the test object

The robot moves the test object while the probe is fixed, as shown in Figure 3.

This scan mode shall be used when the test object has a small size and complex profile.

It is suitable for the case when the size of the test object is small and the acoustic attenuation is low so that the back-wall echo can be received.

The weight of the test object is limited by the robot's load ability.



Key

1 robot controller
2 robot
3 ultrasonic instrument
4 probe
5 test object
6 couplant (e.g. water)

Figure 3 — Scan mode with movement of the test object (example for immersion technique)

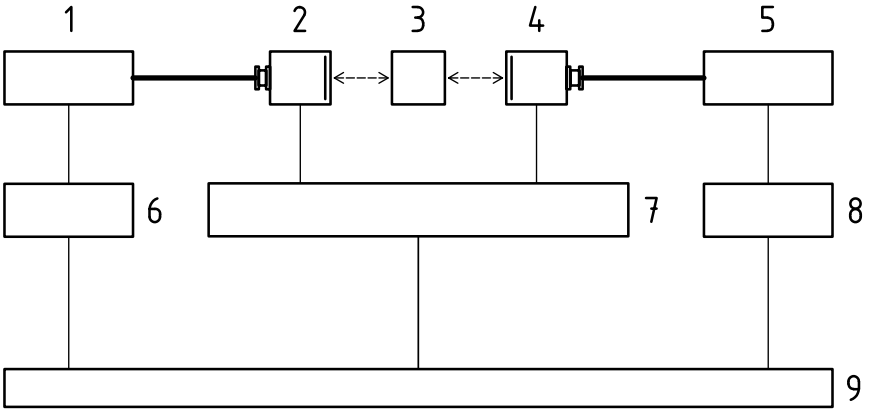
5.4.2 Twin-robot test system

5.4.2.1 System components

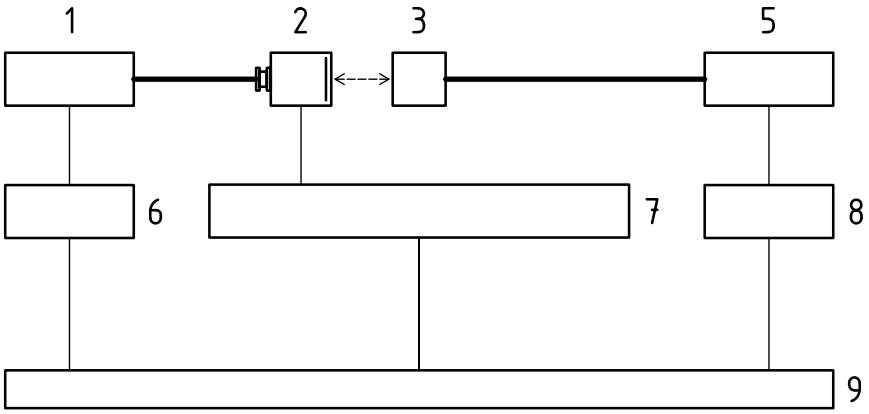
Figure 4 shows twin-robots ultrasonic test systems.

The system setup is mainly composed of one or two ultrasonic probes, one ultrasonic instrument, two robots and their control systems, including software and a couplant circulation system.

The software shall be able to send robot control commands, to transfer scan pattern data, to send commands to the ultrasonic instrument and to transfer ultrasonic signal data.



a) Setup with two robots and two probes



b) Setup with two robots and one single probe

Key

1	robot 1	7	ultrasonic instrument
2	probe 1	8	robot controller 2
3	test object	9	computer and software
4	probe 2	<---->	sound path
5	robot 2	———	electrical connection
6	robot controller 1	═══	mechanical connections

Figure 4 — Twin-robots ultrasonic test systems

5.4.2.2 Scan modes

5.4.2.2.1 Each robot moves a probe

Each robot moves a probe simultaneously while the test object is fixed, as shown in Figure 5.

This scan mode is suitable for the case when the size of the test object is large and/or the acoustic attenuation is high so that the back-wall echo cannot be received and evaluated by reflection method. Usually, the ultrasonic probes are of little weight so that the robot can hold them without overload.

The ultrasonic transmission technique requires that both beam axes be aligned to each other and be consistent with the normal vector to the surface of the test object at the test point.