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Non-destructive testing — Radiation methods — Computed tomography —

Part 2:
Examination practices

Essais non destructifs — Moyens utilisant les rayonnements — Tomographie informatisée —

Partie 2: Pratiques d'examen

Reference number
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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 3.

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 part of ISO 15708 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 15708-2 was prepared by Technical Committee ISO/TC 135, *Non-destructive testing*, Subcommittee SC 5, *Radiation methods*.

ISO 15708 consists of the following parts, under the general title *Non-destructive testing — Radiation methods — Computed tomography*:

— *Part 1: Principles*

— *Part 2: Examination practices*

Introduction

Computed tomography (CT), as with conventional radiography and radioscopic examination, is broadly applicable to any material or test object through which a beam of penetrating radiation passes, including metals, plastics, ceramics, metallic/non-metallic composite material and assemblies. The principal advantage of CT is that it provides densitometric (i.e., radiological density and geometry) images of thin cross sections — "slices" — through an object. Because of the absence of structural superposition, images are much easier to interpret than conventional radiological images. CT images correspond closely to the way the human mind visualizes 3D structures than conventional projection radiology. Because CT images are digital, the images may be enhanced, analysed, compressed, archived, input as data into performance calculations, and compared with digital data from other non-destructive evaluation (NDE) modalities. CT images can also be transmitted to other locations for remote viewing.

This part of ISO 15708 describes CT procedures that can provide for non-destructive testing and evaluation. Requirements in this part of ISO 15708 are intended to control the reliability and quality of the CT images. This part of ISO 15708 is applicable for the systematic assessment of the internal structure of a material or assembly and may be used to prescribe operating CT procedures. It also provides a basis for the formation of a programme for quality control and its continuation through calibration, standardization, reference samples, inspection plans and procedures.

Non-destructive testing — Radiation methods — Computed tomography —

Part 2: Examination practices

1 Scope

This part of ISO 15708 gives guidelines for procedures for performing CT examinations. It is intended to address the general use of CT technology and thereby facilitate its use. This part of ISO 15708 implicitly assumes the use of penetrating radiation, specifically X-ray and γ-ray.

2 Normative reference

The following normative document contains provisions which, through reference in this text, constitute provisions of this part of ISO 15708. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 15708 are encouraged to investigate the possibility of applying the most recent edition of the normative document indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 15708-1:2002, *Non-destructive testing — Radiation Methods — Computed tomography — Part 1: Principles*

3 Terms and definitions

For the purposes of this part of ISO 15708 the terms and definitions listed in annex A of ISO 15708-1:2002 apply.

4 Summary

This part of ISO 15708 describes CT procedures which can provide for non-destructive testing and evaluation. Requirements in this part of ISO 15708 are intended to control the reliability and quality of the CT images.

CT systems are made up of a number of subsystems; the function served by each subsystem is common in almost all CT scanners. Clause 5 describes the following subsystems:

a) source of penetrating radiation;

b) radiation detector or an array of detectors;

c) mechanical scanning assembly;

d) computer system including:

   1) image reconstruction software/hardware;

2) image display/analysis system;

3) data storage system;

4) operator interface.

Clause 6 describes and defines the procedures for establishing and maintaining quality control of CT examination services.

The extent to which a CT image reproduces an object or a feature within an object is influenced by spatial resolution, statistical noise, slice plane thickness and artifacts of the imaging system. Operating parameters shall strike an overall balance between image quality, inspection time and cost. These parameters shall be considered for CT system configurations, components and procedures. The setting and optimization of CT system parameters are discussed in clause 7.

Methods for the measurement of CT system performance are provided in clause 8.

5 System configuration

5.1 CT System configurations

Many different CT examination system configurations are possible and it is important to understand the advantages and limitations of each. It is important that the optimum system parameters be selected for each examination requirement, through careful analysis of the benefits and limitations of the available system components and the chosen system configuration.

5.2 Radiation sources

5.2.1 General

Whilst the CT examination systems may utilize either gamma-ray or X-ray generators, the latter is used for most applications. For a given focal spot size, X-ray generators [i.e., X-ray tubes and linear accelerators (linacs)] are several orders of magnitude more intense than isotope sources. Most X-ray generators are adjustable in peak energy and intensity and have the added safety feature of discontinued radiation production when switched off. However, polychromaticity of the energy spectrum causes artifacts such as “cupping” (the anomalous decreasing attenuation toward the centre of a homogeneous object) in the image, if left uncorrected.

5.2.2 Electrical radiation generators

X-rays produced from electrical radiation generators have focal spot sizes ranging from a few millimetres down to a few micrometres. Reducing the focal spot size reduces geometric unsharpness, thereby enhancing detail sensitivity. Smaller focal spots permit higher spatial resolution, but at the expense of reduced X-ray beam intensity.

5.2.3 Radioisotope sources

A radioisotope source can have the advantages of small physical size, portability, low power requirements, simplicity and stability of output. The disadvantages are limited intensity and limited peak energy, primarily due to inefficiency in the process whereby continuous X-rays are generated. Radioisotope sources are typically several orders of magnitude less intense that X-ray generators

5.2.4 Synchrotron radiation (SR) sources

SR sources produce very intense, naturally collimated, narrow bandwidth, tunable radiation. Thus, CT systems using SR sources can employ essentially monochromatic radiation. With current technology however, practical SR energies are restricted to less than approximately 20 keV to 30 keV. Since any CT system is limited to the inspection of samples with radio-opacities consistent with the penetrating power of the X-ray used, SR systems can, in general, image only small (about 1 mm) objects.

5.3 Detection system

The detection system is a transducer that converts the transmitted radiation-containing information about the test object into an electronic signal suitable for processing. The detection system may consist of a single sensing element, a linear array of sensing elements or an area array of sensing elements. The more detectors used, the faster the required scan data can be collected; but there are important tradeoffs to be considered.

A single detector provides the least efficient method of collecting data but entails minimal complexity, eliminates cross talk and detector matching, and allows an arbitrary degree of collimation and shielding to be implemented.

Linear arrays have reasonable scan times at moderate complexity, acceptable cross talk and detector matching, and a flexible architecture that typically accommodates good collimation and shielding. Most commercially available CT systems employ a linear array of detectors.

An area detector provides a fast method of collecting data but entails the transfer and storage of large amounts of information, forces tradeoffs between cross talk and detector efficiency, and creates serious collimation and shielding challenges.

5.4 Manipulation System

5.4.1 General

The test part manipulation system has the function of holding the test object and providing the necessary range of motions to position the volume of interest between the radiation source and detector. Two types of scan motion geometries are most common.

5.4.2 Translate-rotate motion

With translate-rotate motion, the test object is translated in a direction perpendicular to the direction of and in the plane of the X-ray beam. Full data sets are obtained by rotating the test article between translations by the fan angle of the beam and again translating the part until a minimum of 180° of data have been acquired. The advantage of this design is simplicity, good view-to-view detector matching, flexibility in the choice of scan parameters and ability to accommodate a wide range of different object sizes including objects too big to be subtended by the X-ray fan. The disadvantage is a longer scan time.

5.4.3 Rotate-only motion

With rotate-only motion, a complete view is collected by the detector array during each sampling interval. A rotate-only scan has a lower motion penalty than a translate-rotate scan and is attractive for industrial applications where the part to be examined fits within the fan beam and the scan speed is important.

5.5 Computer system

CT requires substantial computational resources such as a large capacity for image storage and archival and the ability to perform numerous mathematical computations swiftly and efficiently, especially for the back-projection operation. Computational speed can be augmented by either generalized array processors or specialized back-projection hardware or both. The particular implementations will change as computer hardware evolves, but high computational power will remain a fundamental requirement for efficient CT examination. A separate workstation for image analysis and display and archiving is often appropriate.

5.6 Image reconstruction software

The aim of CT is to obtain information regarding the nature of material occupying exact positions in a test object. In current CT scanners, this information is obtained by “reconstructing” individual cross-sections (i.e., slices) of the test object from the measured intensity of X-ray beams transmitted through that cross section. An exact mathematical theory of image reconstruction exists for idealized data. This theory is applied although the physical measurements do not fully meet the requirements of the theory. When applied to actual measurements, algorithms based on this theory produce images with blurring and noise, the extent of which depends on the quantity and quality of the measurements.

The simplifying assumptions made in setting up the theory of reconstruction algorithms are:

a) cross sections are infinitely thin (i.e., they are planes);

b) both the focal spot or source and the detector elements are infinitely small (i.e., they are points);

c) the physical measurements correspond to total attenuation along the line between the source and detector;

d) the radiation is, or can be treated as, effectively monoenergetic.

A reconstruction algorithm is a collection of step-by-step instructions that define how to convert the measurements of total attenuation to a map of linear attenuation coefficients over the field of view.

A number of methods for recovering an estimate of the cross section of an object have evolved. They can be broadly grouped into three classes of algorithms: matrix inversion methods, finite series-expansion methods and transform methods. See ISO 15708-1 for a treatment of reconstruction algorithms.

If the test object is larger than the prescribed field of view (FOV), either by necessity or by accident, unexpected and unpredictable artifacts or a measurable degradation of image quality can result. Many methods have been devised to scan objects larger than the largest FOV for which an instrument has been designed. One technique, which also provides improved spatial resolution in specific regions of larger objects is known as region-of-interest (ROI) tomography. ROI tomography reconstructs a convex region within an object, utilizing a projection subset, on a specified sampling grid, providing higher resolution in this reduced area.

5.7 Image display

The function of the image display is to convey derived information (i.e., an image) of the test object to the system operator. For manual evaluation systems, the displayed image is used as the basis for accepting or rejecting the test object, subject to the operator's interpretation of the CT data.

Generally, CT image display requires a special graphics monitor. Television image presentation is of lower quality but may be acceptable. Most industrial systems utilize colour displays. These units can be switched between colour and grey-scale presentation to suit the preference of the viewer, but it should be noted that grey-scale images presented on a colour monitor are not as sharp as those on a grey-scale monitor. The use of colour permits the viewer to distinguish a greater range of variations in an image than grey-scale does. Depending on the application, this may be an advantage or a disadvantage. Sharply contrasting colours may introduce false, distinct definition between boundaries. While at times advantageous, unwanted instances can be corrected through the choice of colour (or monochrome) scales.

5.8 Data storage medium

Many CT examination applications require an archival-quality record of the CT examination. This could be in the form of raw data or reconstructed data. Therefore, formats and headers of digital data need to be specified so information can be retrieved at a later date. Each archiving system has its own specifics as to image quality, archival storage properties, equipment and media cost. Computer systems are designed to interface to a wide variety of peripherals. As technology advances or needs change, or both, equipment can be easily and affordably upgraded. The examination record archiving system shall be chosen on the basis of these and other pertinent parameters, as agreed upon by the supplier and purchaser of CT examination services. The reproduction quality of the archival method shall be sufficient to demonstrate the same image quality as was used to qualify the CT examination system.

5.9 Operator interface

5.9.1 General

The operator interface determines much of the function of the rest of the CT system. The control panel and image display system are the two significant subsystems affected. The control software, hardware mechanisms and interface to a remote data workstation if applicable, are amongst those controlled by this interface. Override logic, emergency shutdown and safety interlocks are also controlled at this point. There are three types of operator interfaces.

5.9.2 Simple programming console interface

Here the operator types in commands on a keyboard. Whilst being less “user friendly,” this type can offer the greatest range of flexibility and versatility.

5.9.3 Dedicated console

This has specific function buttons and relatively rigid data and processing features. These systems are usually developed explicitly for standardized, non-varying inspection tasks. They are designed to be “functionally hardwired” for efficient throughput for that programme. Medical CT equipment is often of this type.

5.9.4 Graphical user interface

This uses a software display of the menu or windowing type with means such as a pointing device for entering responses and interacting with the system. This approach has the advantage of being able to combine the best features of the other two types of operator interface.

5.10 Automation

A variation among CT systems is the extent to which users can create, modify or elaborate image enhancement or automated evaluation processes. The level of sophistication and versatility of a user command language or a “learning mode” is an important consideration for purchasers and suppliers who expect to scan a variety of test objects or to improve their processes as they gain experience with CT.

6 Documentation

6.1 General

The examination protocol shall cover the areas listed in 6.2 to 6.5.

6.2 Equipment qualifications

These comprise a listing of the basic system features that shall be qualified to ensure that the system is capable of performing the desired examination task.

6.3 Test object scan plan

6.3.1 General

There shall be a listing of test object scan parameters and performance measurements to be extracted from the image(s).