Digital Radiography

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1 INTRODUCTION

X-ray radiography is useful for non-destructive inspections of the interior of objects. This technique can reveal internal components of assemblies and defects in materials for examination and assessment. Features are revealed based on differences in transmitted intensity of an X-ray beam through variations in thickness and material.

2 SCOPE

This document applies to case working personnel using the associated instruments in support of metallurgy, firearms/toolmarks, and anthropology examinations.

Radiography is a powerful imaging technique that can be applied to a wide variety of objects and assemblies. Because of this versatility, the conditions associated with imaging a particular object are optimized during the operation of the radiograph. The following procedure outlines the basic steps to acquire a digital radiograph (two-dimensional, 2-D) with the Faxitron CS-100AC and NSI X5000 radiography systems and a computed tomography (CT) (virtual three-dimensional, v3-D) scan with the NSI X5000 system. Under no circumstances should either X-ray system ever be independently operated by untrained personnel.

3 PRINCIPLE

Digital radiography utilizes the same operating principles as traditional film radiography. An object of interest is exposed to an intense source of X-rays. These are absorbed by the components comprising the object to a degree which depends on the atomic weight and thickness of the components. An electronic detector behind the object measures the spatial distribution of the transmitted X-rays and produces an electronic image whose brightness and contrast depend on the point-to-point variation of the X-ray intensity. This electronic image can then be used to visualize the internal structure of the object without opening it.

CT uses a series of acquired X-ray images to generate a virtual v3-D representation of the X-ray transparency variations throughout the object. Visualization software allows this v3-D volume to be examined from any angle and at any depth from the object's surface.

The Faxitron CS-100AC uses a micro-focus X-ray source with fixed spot size for high-resolution 2-D imaging. The distances of the source and detector from the sample are adjustable, allowing optimization of field of view (FOV), focus, and magnification. The maximum voltage of the X-ray tube is 90kV. Typically, this system can successfully image fine components within thin metal casings.

The NSI X5000 system provides capacity for both 2-D and v3-D X-ray imaging using either of two X-ray sources: a 225 kV micro-focus X-ray tube or a 450kV X-ray tube. The distances of the sample and the detector from the source are adjustable, allowing optimization of FOV, focus, and magnification. The detector and source height are also adjustable. Automated positioning software allows acquisition of mosaic images of large specimens in 2-D. Combined with automated sample rotation, helical image acquisition can be used for v3-D CT scans of large specimens.

4 SPECIMENS

Specimen size is limited by the X-ray system chamber size and the weight capacity of the sample platform. The material of construction is only important insofar as it affects the ability of the X-ray beam to penetrate the object. If the object construction is excessively thick-walled, a satisfactory image may not be obtained.

A. The CS-100AC accommodates samples up to 18” width x 24” length x 8 ½” height on a moveable stage and has a 90kV maximum X-ray energy with a very small focal spot (10 µm or less.)

B. The NSI X5000 can accommodate larger samples, up to 200 lbs. Stage, detector, and source(s) are all moveable to allow an area of interest in a large part to be imaged. The 225 kV microfocus tube has focal spot <6 µm at 320W and the 450 kV tube has a focal spot ~0.4 mm at 700W.

5 EQUIPMENT

- Digital X-ray radiography system (Faxitron CS-100AC, NSI X5000, or similar). Each unit consists of:
    - lead-lined chamber
    - X-ray tube(s)
    - power supply and controller
    - sample positioning table
    - digital X-ray detection panel
    - computer workstation for image file acquisition and, if applicable, component control
    - The NSI X5000 has an additional computer to construct v3-D CT images.
- X-ray filters (optional) – typically copper or aluminum sheets, but other materials may be used at the operator’s discretion. Optimum sheet thickness depends on imaging conditions.
- Tools for supporting specimen(s) on the sample table – these may include modeling clay, clamps, Styrofoam blocks, sandbags or other assorted objects as needed. Beeswax is a useful low atomic number mounting medium.
- For CT:
    - anti-vibration mat to place under specimen
    - alignment reference standard

6 STANDARDS AND CONTROLS

Although standards and controls are not required for basic operation and subsequent examination of 2-D digital radiographs, thickness and curvature standards of similar atomic number to the materials being examined can provide useful comparisons during analysis.

Computed tomography requires alignment using reference materials that are provided by the manufacturer and exclusive to the particular software used to generate the v3-D reconstruction.

7 PROCEDURE

7.1 Two-Dimensional Imaging, 2-D

A. Perform the instrument-specific X-ray tube warm up routine.

B. Power down the X-ray tube to insert or exchange samples in the chamber.

C. When inserting the sample(s), consider imaging orientation. For symmetrical objects, angle the planes of symmetry in the beam path (source-to-detector) in order to provide more information than parallel or perpendicular alignment.

D. Close the X-ray sample chamber in order to energize the X-ray tube.

E. Adjust the incident beam conditions to obtain a satisfactory image. The following adjustments can be repeated to optimize specific portions of the image.

    1. Adjust the tube voltage and current (amperage). In general, increasing the current will increase the image brightness, and increasing the X-ray source voltage will increase the radiation penetration through the object. The voltage should be increased if the object appears opaque.

    2. If needed, install a primary beam filter. Filtering the primary radiation source decreases the average X-ray wavelength reaching the sample and increases beam penetration through the sample. Filtering can be used in conjunction with voltage increases to improve object penetration.

F. Adjust the radiograph component positions (stage, detector, and source) to achieve desired FOV, magnification, and focus for the feature(s) of interest.

G. If applicable, (e.g., on the NSI X5000 system) use the instrument software to adjust the detector acquisition conditions:

    1. Run the routine to set detector gains.

    2. Run the routine to clamp dead pixels.

H. A .tif file format is recommended for image file saving to retain the most digital information.

I. Power off the system components when the imaging session is complete.

J. Record usage in the instrument logbook.

7.2 Computed Tomography, v3-D

In addition to the steps used for 2-D imaging, computed tomography requires the following processes:

A. Preview the 360° rotation of the image to assure the specimen orientation and X-ray tube conditions are satisfactory through the entire range of rotation.

    1. The region of interest of the specimen must be retained within the image margins throughout the entire rotation.

    2. No portion of the projection can be impenetrable to the X-rays throughout the entire rotation.

B. Collect an alignment scan on the suitably sized manufacturer-supplied reference material with the hardware in the same positions and the software at the same conditions as the scan conducted on the evidence.

C. Perform the reconstruction using the manufacturer-supplied, instrument-specific software.

8 ACCEPTANCE CRITERIA

8.1 Instrument Performance

The instrumental operating conditions are determined by the examiner in reference to the on-screen image. In general, any combination of operating parameters which produces a useful image is acceptable.

8.2 Image Quality

An X-ray radiograph is considered acceptable when the details of interest are visible in the image. This result is typically self-evident and is at the discretion of the operator. X-ray scattering effects must be considered when interpreting the shapes of edges and corners and as a source of artifacts within the detected image. Atomic number and consequent X-ray absorption must also be considered when comparing relative thickness of the separate parts of multi-component and/or multi-material assemblies. Appropriate interpretation may require additional background investigation, including radiography and/or disassembly of exemplar components for comparison.

9 LIMITATIONS

9.1 X-Ray Flux

An X-ray source is limited to a maximum operating voltage depending on the instrument in use. Thick metal sections may not permit sufficient flux of X-rays for useful imaging. The exact thickness limit will be a function of the object's geometry and its materials of construction.

9.2 X-Ray Absorption

Light items such as plastic and paper may not be visible due to poor X-ray absorption if they are inside a high atomic number material such as steel. However, it is usually possible to image plastics, tape, and other low atomic number materials if they are not otherwise shielded by higher atomic number materials.

10 SAFETY

A. Wear an X-ray film badge or dosimeter when operating instruments that generate X-rays. The instruments have protective enclosures and internal safety interlocks to prevent inadvertent X-ray radiation exposure. Never bypass or disable safety interlocks on instruments.

B. For the NSI X5000, never close a person inside the chamber. The door is mechanically driven and may not open in case of power loss.

11 REVISION HISTORY

Revision	Issued	Changes
06	09/30/2022	Revised to comply with new formatting requirements. Distributed information from previous Instrumental Conditions and Decision Criteria sections into Acceptance Criteria and Procedure sections. Removed informational references. Clarified 3-D as v3-D.