Digital Radiography in Industry

Wafik HARARA

Atomic Energy Commission; Damascus, Syria

Phone:00963-11-6111926, Fax:00963-11-6112289

E-mail: wharara@aec.org.sy, web:http://www.aec.org.sy

Abstract:

Digital radiography is a powerful technique that can be used in Non-destructive examination of internal features of an object to obtain two-dimensional or three dimensional computed tomography(CT) images depending to the testing needs.

New generation of digital detectors become more and more competitive to film detectors, however the transition from film to digital radiography is not always the best choice for every NDT organization especially from the point of view of investments.

This paper explains the difference between the types of digital radiography detectors used to replace films and when transition from analogue film radiography to digital radiograph can be a practical technique for the NDT organization.

Keywords: Computed radiography, Digital radiography, Digital detectors. Resolution, Imaging plate, Scintillator.

1 Introduction

Digital radiography is a powerful technique that can be used in Non-destructive examination of internal features of an object to obtain two-dimensional computed tomography (CT) images needed to characterize material properties, identify defects and measure part geometry.

Multiple CT slices can also be assembled to create accurate three-dimensional CT that can be used for a variety of different purposes as viewing the shape of defects.

The earliest and simplest CT digital radiography scanner was for medical purposes it was consisted of a single source and detector that rotate about the object (a human head), then a more advanced tomographic scanner was made which consisted of a single source and multiple detectors in a fan beam, both source and detectors rotate about the object. Another arrangement consisted of a rotating source and a fixed array of detectors arranged in a circle about the object[1].

In digital industrial radiography scanner and the object, positioned on the turntable, can be both translated and rotated.

Figure 1 shows fan beam or 2D –CT system. This system allows to reconstruct one object layer by one fan beam x-ray scan. The attenuated X-ray data are collected at brief time intervals. The X-ray measurements are then digitized and the image is reconstructed and displayed as a 2-D image on the computer screen.

To test the whole object, several scans of different layers have to be carried out and that can be done by moving the x-ray source and linear detector array along the entire length of the object or moving the object through the stationary X-ray source and linear detector.

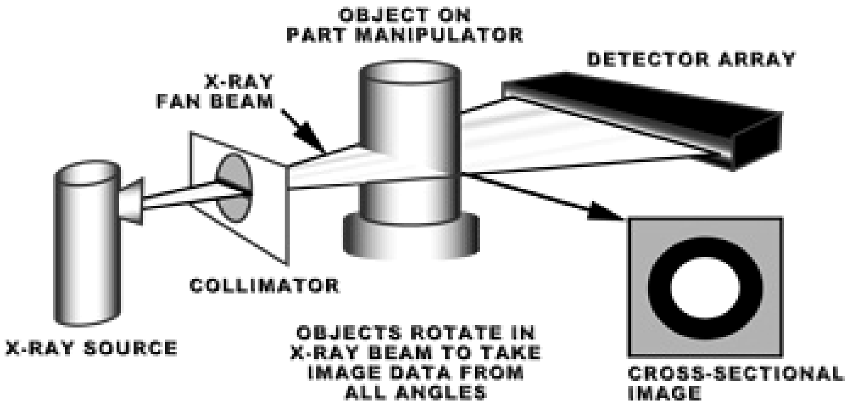

Fig.1 Fan beam or 2D-CT imaging system

Figure 2 shows cone beam or 3D-CT imaging system. This system using flat panel detector. In order to irradiate the object from all side, the object rotates in the X-ray cone. During rotation a set of projections is then applied to reconstruct the 3D structure of the object.

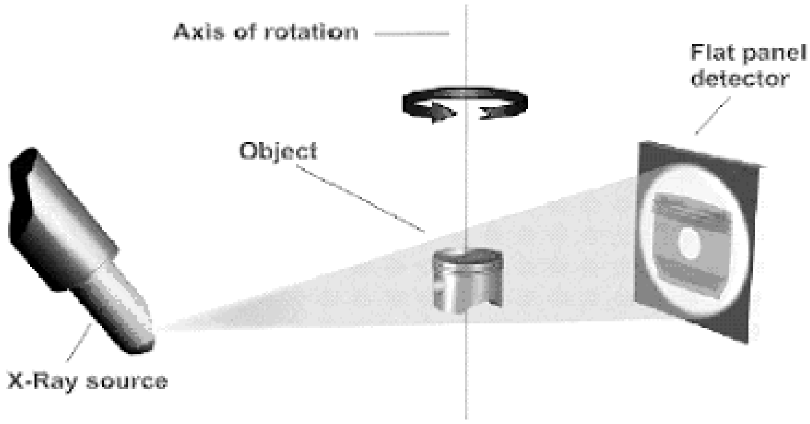

Fig.2 Cone beam or 3D-CT imaging system

The data collected from the detectors eventually ends up as a digital data stored in a mass memory in a computer. The computer controls the movement of the scanner, collects the data, applies the reconstruction algorithm and finally display the results.

The industrial tomographic scanners are quite different from those on a medical scanner due to diversity of industrial problems. Also it is unlikely to build a general purposes industrial scanner to give a good result but every industrial application needs a properly designed equipment for better results[2-5].

Table 1 shows the relative comparison between medical tomography and industrial tomography.

Table 1 Comparison between medical tomography and industrial tomography

Consideration	Medical tomography	Industrial tomography
Relative motion	Patient is translated, X-ray source/detector combination rotates.	Object can be both translated and rotated and X-ray source/detector combination may be moved
Subject	Tissue, blood and bone	Polymers, wood, concrete, ceramics, metals, composites.
Requirement	Visualization of small changes in density is required.	High special resolution is required.
Energy	Normally < 200 kev	Up to 9 Mev available (9 Mev real time radiography at Ford Motor Company)
Dosage level	Limited for subject safety	As much as needed
Complex 3D visualization capabilities and software development	Good advancement during the last two years. Many commercial SW packages available	Good advancement during the last two years. Several commercial SW packages available.
Nominal resolution	1 – 2 mm for human subjects	< 0.3 mm for engineering–scale object (mini-tomography) and 10 to 20 μm for small object (micro-tomography)
Scan modes	Use 2nd, 3rd or 4th generation which called the spiral scan CT system	Use 2nd (translate-rotate scan) or 3rd (rotate scan) generation CT system.
Education and training	Medical schools and radiological training courses	University and industrial facilities
Facility availability	Available at most hospitals	Low power facilities available. Large high–power are scarce
Facility costs	Expensive	Very expensive for high power

2 Computed and Digital radiography detectors

Computed radiography (CR) is a filmless radiography using imaging plates. Imaging plates are exposed as film and scanned by a laser scanner to obtain a digital radiograph without any developing process. After erasing the remaining latent image with a bright light source, the same imaging plate can be reused more than 1000 times.

Imaging plates are an excellent tool for computed radiography. They are suitable for stationary and mobile inspection under almost any weather condition. There exist no limitation of the radiation energy and dose.

Digital radiography (DR) is also a film less radiography using digital detectors. Digital detectors can be classify into:

(1) Indirect conversion charge–coupled devices (CCDs) Camera:

The CCDs are used as the image-acquisition component of cameras in video and digital photography. This detector is composed from x-ray scintillator (Gadolinium oxysulfide), lens and CCDs to image the light emitted by the scintillator.

(2) Indirect conversion flat panel detector:

This detector is composed from X-ray scintillator, photodiode and thin film transistors (TFT). The TFT is an electronic switch made from amorphous silicon on flat-panel detector, it allows the charge collected at each pixel to be independently transferred to electronic circuit where it is amplified by photomultiplier to be then converted from analog to digital into 512 gray shades in order to produce the digital image data. The digital image will be processed to produce the suitable image for display and diagnosis.

The image processing consists of contrast enhancement, gradient removal, smoothing and thresholding the enhanced image into a binary image where the void is shown as all white and the reminder as all black. The binary image is important for defect measurement by the operator.

(3) Direct Conversion flat panel detector:

Flat panel detector also known as digital detector array (DDA) is in the way to become an alternative technology for both computed radiography and image intensifier based real time radiography. This detectors are characterized by a higher spatial resolution than the systems using fluorescence screens, (indirect conversion flat panel detector).

Flat panel detector is composed from X-ray photoconductor (amorphous Selenium) and TFT so that it is the most efficient detector because it doesn't require an intermediate steps or additional conversion processes for producing the suitable image for display and diagnosis.

Digital detector arrays are suitable for in-house inspection, because they need stabilized temperature and moisture conditions. They are an excellent tool for serial part inspection.

For service providers a combination of high resolution, high accuracy, high scanning speed with the capability to scan a large range of applications are important. This situation can be best realized by a cone beam digital radiography system using micro focus X-ray tube and DDA. By means of cone beam digital radiography with DDA, the volume of the component can be scanned with only one rotation, the reconstruction can be performed in parallel to the scan. A magnification technique utilizing a micro focus tube that allows to adjust the focal spot size leads to high resolution and short scan times.

In fact cone beam reconstruction delivers poorer image quality compared to fan beam CT due to scattered radiation. Scattered radiation can be efficiently reduced by collimating the X-ray cone beam to a fan beam but that increases the scan time.

Depending on the test objectives, it is advisable to apply cone beam CT for defect analysis and fan beam CT for metrology applications[6-7].

3 Application of DR and CR in industry

Computed and digital radiography can be applied in advantage to inspect composite materials and casting.

In composite materials inspection, where speed of inspection is a driving factor. A wing of an airplane is not limited to (35×43) cm areas, the application has a need for larger detectors. Up to 130 cm long storage phosphor plates are produced to cover the need of the airplane aileron inspection application, as the inspection of the honeycomb and the glue between the honeycomb and the aluminum sheets.

Figure 3 represent a computed radiograph showing the existence of water in honeycomb structure.

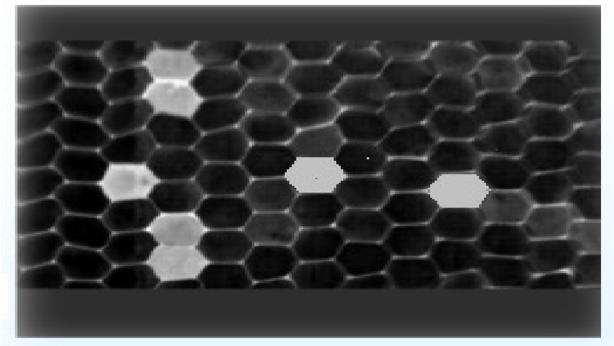

Fig.3 computed radiograph of water in honeycomb structure

In metal casting inspection, conventional radiography inspection of a single safety critical casting during production is expensive and time consuming. A premium quality aluminum casting buyer estimated that 5% of the casting cost is in film costs. Digital radiography can be applied to detect flaws in casting during production, and to reduce the production cost by replacing the films with digital detector and saving the inspection time[8-9].

Figure 4 shows an aluminum casting and a slice of the 450 KV cone beam CT scan reveals the presence of flaws inside it.

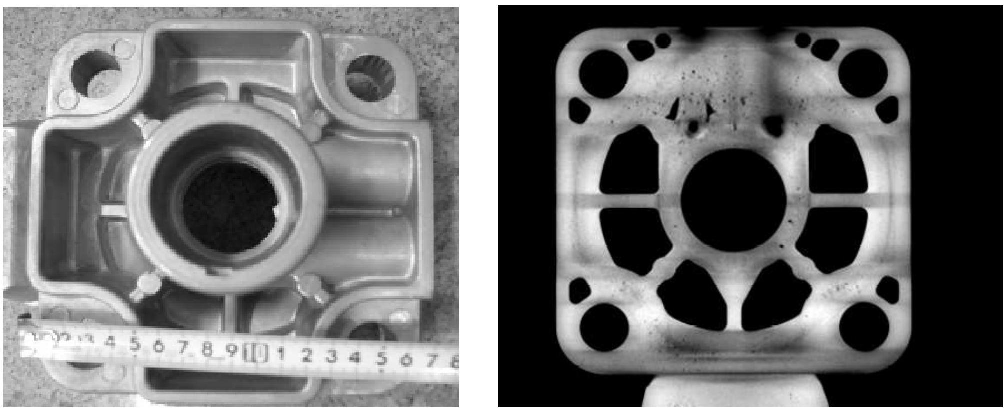

Fig. 4 aluminum casting and a slice of the 450 KV cone beam CT scan

4 Transition from analogue film radiography to digital radiography

Almost anything can be tomographically inspected, the transition from film to digital radiography is not always smooth and successful. The transition must be done after learning lessons from the NDT organization using digital radiography equipments, because the transition to digital radiography is not always the best choice in every case especially from the point of view investment. In general, tomography can be a practical NDT technique if:

(1) The consequences of material failure are disastrous (economically or in loss of life).
(2) There are very large number of identical inspections to be made.
(3) The data cannot be obtained by any other way.
(4) the management of information and images are required.

5 Conclusion

Film radiography is still in use in many industries due to their high spatial resolution needed to detect very small defects. However, new generation of digital detectors become more and more competitive to film radiography, they give similar film performance and defect sensitivity for many application.

Transition from film radiography to digital radiography is not for every NDT organization which doesn't have sufficient justification to make the initial expense. But when there are justifications, the benefits of the transition are many and, after all, this transition is an inevitable evolution of NDT industry.

References

[1] Introduction to digital radiography, http://www.kodak.com/go/health.

[2] J. M. Wells, On the future of 3-D visualization in non-medical industrial X-ray computed tomography, 16WCNDT, September 2004 Montreal, Canada. .

[3] P. F. Lister, Applications of X-ray computed tomography in the wood products in industry, 16WCNDT, September 2004 Montreal, Canada.

[4] J-M Casagrande and al, comparison between a flat panel detector and multi-linear detector for x-ray NDT, ASNT conference, July 2003, Totowa, USA,.

[5] R. Hanke and al, Automated high speed volume computed tomography for inline quality control, 16WCNDT, September 2004 Montreal, Canada.

[6] U. Ewert, U. Zscherpel, and K. Bavendiek, Film replacement by digital x-ray detectors – the correct procedure and equipment, 16WCNDT, September 2004 Montreal, Canada.

[7] U. Zscherpel and al, Comparative analysis of radiological detector systems, 8th ECNDT, Barcelona 2002.

[8] Martin Simon, and al, Development of multi sensor and multi source computed tomography systems, International Symposium on Digital industrial Radiography and Computed Tomography, Jun 2007, Lyon, France.

[9] Lars Hammar, Hakan Wirdelius, Radiography sensitivity improved by optimized high resolution x-ray detector design, International Symposium on Digital industrial Radiography and Computed Tomography, Jun 2007, Lyon, France.