Digital Applications of Radiography

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ABSTRACT

Conventional radiography with film is superior to other NDT methods in many different applications as a picture tells a thousand words. In radiography the film method is usually the reference model that various other methods are compared with. Recent technological advances make it possible to meet a wide range of NDT applications with digital solutions. Digital Radiography can be used for many extended investigations in the traditional areas of radiography as well as for completely new applications. Digital radiography has significant advantages compared to conventional film radiography for certain applications in terms of image quality, exposure times and possibility of detection. This paper gives an overview of digital radiography, method, applications and major benefits.

INTRODUCTION

The options for radiography include not only film, but with recent technological advances, it is now possible to meet a wide range of NDT inspection applications with **digital solutions** that are reliable and cost effective.

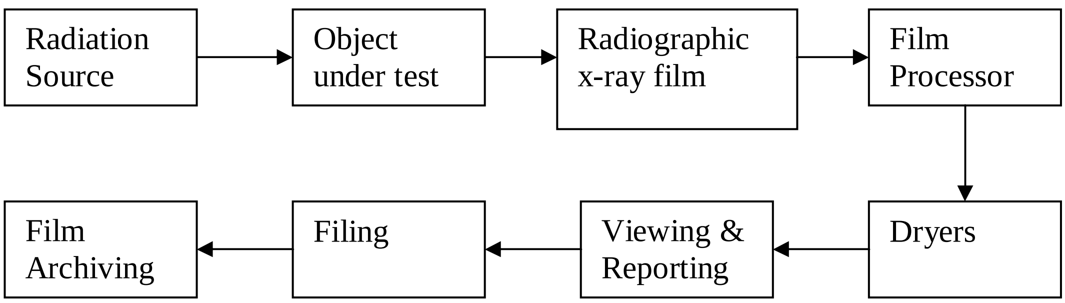
Digital radiography or computed radiography by use of reusable storage phosphor screens, offers a convenient and reliable way to replace film. In addition to the reduced cost on consumables, the return on investment of computed radiography systems is strongly determined by savings in exposure time, processing times and archival times. Furthermore, intangible costs like plant shutdown, environment safety and longer usability of isotopes are increasingly important when considering replacing film by storage phosphor systems. More and more applications can be covered by improving the image quality of digital radiography systems. Digital images offer a lot of advantages in terms of image manipulation and workflow.

Film scanning, Computed Radiography and Direct Radiography by using different kind of flat panel detectors all have their specific application fields.

For the purpose of this presentation, the digital applications examined are primarily computed radiography and to a lesser extent direct digital radiography using flat panels.

The choice to go digital depends on cost, quality requirement, workflow and throughput.

BASIC CONVENTIONAL FILM RADIOGRAPHY



Factors such as costs, radiographic response time, environmental green policies, processing time and radiation safety measures have made the customers to look at other methods of inspection.

Hence introduction of digital imaging is a very good alternative to the conventional film. **In digital radiography,** a radiograph is created, not on conventional silver halide film, but with the use of another device that allows the radiograph to be represented as an array of discrete **digital** intensity values, or pixels.

DIGITAL RADIOGRAPHY – WHY?

1. Financial – Improved productivity due to significantly reduces exposure times
2. Safety – Lower exposure levels; focused beam operator hazards eliminated
3. Environmental – Chemical processes; disposable handling, consumption reduced
4. Time – Immediate feedback; data confidence
5. Process Improvement – Data archive; storage, transmittal, labor savings

TYPES OF DIGITAL RADIOGRAPHY

Film Digitization

Process whereby a radiograph is produced in the conventional manner on a normal sheet of industrial x-ray film, the film is then placed in a reader, the image is read and digitized for viewing and archiving on software.

Film digitization helps extract greater information from film, assists in long term archiving and allows remote analysis by networking.

Disadvantages

- Uses hazardous chemicals and recurring film purchasing costs
- Have the film processing time

Direct Radiography (DR)

Utilizing this process, the image is captured directly on the flat plate and the image is transmitted directly to the computer. No intermediate steps or additional processes are required to capture the image. Process provides a direct feed from panel to imaging workstation. Direct Digital Capture is suitable for applications where medium and finer grain film is employed.

Types

- Amorphous – Silicon digital x-ray detector systems
  - Capable of high resolution real time radiography
- Amorphous Selenium detector systems
  - High resolution, but no real time
- CMOS Technology
  - High resolution, but limited real time capability

Disadvantages

- Detector cannot be cut or bent to confirm to components

Computed Radiography (CR)

Rather than utilizing conventional x-ray film to capture an image, computed radiography uses an imaging plate. This plate contains photo sensitive storage phosphors which retain the latent image. When the imaging plate is scanned with a laser beam in the digitizer, the latent image information is released as visible light. This light is captured and converted into a digital stream to compute the digital image.

A key consideration in the use of flexible storage phosphor plates and CR systems is that any exposure source that can be used with conventional X-ray films can also be used with this filmless technology. More importantly, the flexible storage phosphor imaging plates can be directly substituted for film. They can be used in the same film holders and cassettes as those used for film and can be used in applications requiring a flexible medium, such as bending them around a circumferential specimen. This compatibility with existing sources and cassettes makes a transition from traditional film radiography to CR a fairly uncomplicated and inexpensive proposition. Computed radiography suitable for applications where coarse grain film is employed.

The Equipment

- A computer
- A mega pixel, high resolution monitor
- Flexible, phosphor screens (instead of film): The imaging plate is a flexible image sensor in which bunches of very small crystals(grain size: about 5 µm to 25 microns) of photo- stimulable phosphor
- A laser scanner for the screens
- A radiation source

Process

First, phosphor screen is exposed to record an image. At this stage the image recorded by the screen is an invisible latent image. The next step is to process phosphor screen through the reader and processing unit. In this unit the screen is scanned by a very small laser beam. When the laser beam strikes a screen it causes light to be produced(stimulation process). The light that is produced is proportional to the x-ray exposure. The result is that an image in the form of light is produced on the surface of the phosphor screen. The light detector measures the light and sends the data on to produce digitized image. As the surface of the phosphor screen is scanned by the laser beam, the analog data representing the brightness of the light is converted in to digital values for each pixel and stored in the computer memory as a digital image.

DIGITAL APPLICATIONS OF RADIOGRAPHY

There are many applications of digital radiography in industries like oil/gas processing plants, petrochemical plants, pipeline, nuclear power stations, aircraft industry, automotive industry, compressor stations, rail track, and shipbuilding.

1. Computed Radiography has wide applications in corrosion detection and measurement. It is used under any thickness or type of insulation and coating material, through any internal product, on large and small diameter pipes, on thick and thin wall pipes. It is sensitive to general wall loss and pitting type defects. Also corrosion hidden by pipe support, remaining thickness measured through external scale scabs and flange wall thickness loss are the applications of computed radiography (Figure 1 to 10).
2. Wall Thickness Measurement: Computed Radiography allows accurate wall thickness measurements from radiographs acquired through insulation while the component is on-line – at significantly reduced exposures as compared to conventional film. Identifying erosion/corrosion in this manner represents a significant cost savings compared to ultrasonic methods because it eliminates the cost of outside labor to strip insulation, prepare the surface and acquire data.
   - Wall thickness determination from film density variations.
   - Wall thickness determination by projection measurement.
3. Valve Inspection: Inspection of critical valves can be done more efficiently and cost effectively with computed radiography. Images can be acquired at significantly less exposure times compared to conventional film radiography, while eliminating film, development chemicals and costly disposal fees. Example - to check seat retention bolts for 14” to 36” valves (Figure 11).
4. To see detail inside the vessel. Example - condition of demister in vessel (Figure 12).
5. Weld defects(Figure 13).
6. As one of the non intrusive inspection technique. Example –vessel nozzles inspection.
7. Turbine blade inspection.
8. Castings Operations
9. Aerospace: Airframe, rotor blades, tubing, engine components
10. Security
11. Reinforced concrete
12. Composites

Advantages over Conventional Radiography

Digital radiography has significant advantages compared to conventional film radiography for certain applications in terms of image quality, exposure times and possibility of detection.

- Radiographic film has somewhat limited dynamic range (Figure 14 film latitude or working range of exposures) while digital radiographic phosphor screen have a wide dynamic range. Exposure latitude over 1000 times more than film. In digital radiography, good image contrast can be formed over a wide range of exposures. Better than film for assessing corrosion.
- The storage phosphors on the Digital Imaging Plate have an extremely wide dynamic range. This gives a high tolerance for varying exposure conditions and a greater freedom in the selection of the exposure dose. As a consequence, the need for retakes is drastically reduced.
- Digital radiographic image: - Ability to copy and duplicate without loss of image quality, E-mail image which can be read on any PC, Software image enhancement and analysis tools, Ability to zoom, compare multiple images and perform a variety of analytical functions while viewing the images, No image degradation over time, Rapid storage and retrieval
- No requirement for darkroom or chemical processing; environmentally friendly
- Exposure time reduction from 5 to 20 times less than film
- Safe operation with minimum Small Controlled Area
- Up to 10,000 times re-usable phosphor flexible plates
- Less physical storage space required
- The wide dynamic range makes it possible to investigate and evaluate more complex shaped parts with a wider thickness range than possible with film in only one exposure i.e. Reduces numbers of exposures for multi-thickness sections
- Digital radiography with high energy X-ray like the betatron or gamma radiation like Co60 is an excellent NDT method for condition monitoring of valves, fitting etc.

Other Advantages of Computed Radiography

- Easily interpretable image
- Easy and accurate corrosion measurement
- Sensitive to pitting and general corrosion
- No parent material limitations
- No internal product limitations
- No temperature limitations
- No pipe preparation required
- No need to remove coatings or insulation

Benefits

1. Increased production rates
    - Equipment setup time – less than 20 minutes
    - Exposure times
        - Less than film at same energy level
        - Same as film at reduced energy level
    - Image development time savings with CR

2. Increased personnel and environmental safety
    - Reduction in radiation exposure
    - Elimination of hazardous

3. Portability of equipment
    - More portable than conventional x-ray film systems

4. Film replacement
    - IP effectively substitutes for film using same basic set-up, settings and using existing film holders

5. Image quality
   - CR compares favourably to film for most applications
   - Benefits of electronic processing – Archival, storage, communication, etc.

6. Cost saving over film with re-usable digital imaging plates

7. Communicating images electronically
   - No handling of physical film
   - Reduced costs for transporting films fro site to site
   - No degradation of images
   - Electronic back-ups of images
   - Considerable savings on image archiving, retrieval and storage

8. Elimination of dark room facilities and chemical development processes
   - More effective use of laboratory space
   - No chemical costs
   - No hazardous chemical disposable and associated costs

9. Reduction in radiographic intensities
   - Lower radiation dosages
   - Improved health and safety for personnel
   - Less disruption to manufacture and repair

Disadvantages with digital radiography

1. Cost– Initial cost of equipment is high as compare to conventional radiography.
2. Digital radiography spatial resolution (size of the smallest detail) is considerably lower than provided by film radiography and therefore it is still not widely accepted by QA/QC. With the introduction of latest radiographic digitization systems (for example with scan resolution of up to 50 microns or 20 pixels/mm), weld inspection will also be possible by digital in near future.

How to validate digital applications?

There are several factors affecting the quality of a computed radiography image including geometric unsharpness, signal/noise ratio, scatter and contrast sensitivity. There are several additional factors (e.g. scanning parameters), which affect the accurate reading of images on exposed imaging plates using scanner.

1. Compare a hard copy film radiograph created by conventional film radiography against the soft copy image on computer against a hard copy print generated from digital image. Matching results provides the acceptability of the digital applications.
2. Digital images to comply with international standards.

International Standards:

1. ASME V Article II on digital image
2. EN 14784-1 & 2: 2005 Non-destructive testing - Industrial computed radiography with storage phosphor imaging plates - Part 1 and Part 2

CONCLUSION

There are specific features of the digital radiography process that affect the characteristics and quality of the images. This must be considered and adjusted to obtain optimum image quality. Advances have been made in digital radiography methods and various validations have confirmed.

Decision to transit from film to digital radiography to be taken based on cost saving and improved productivity in long term. Small organization may lack sufficient justification to make the initial expense but for big organization where it does make sense, the benefits are many. The right solution and choice will completely depend on the requirement of the user. Throughput, environment, infrastructure and workflow are the key factors. Digital applications of radiography will replace film in the future.

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