AUTOMATED AND QUANTITATIVE METHOD FOR QUALITY ASSURANCE OF DIGITAL RADIOGRAPHY IMAGING SYSTEMS

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ABSTRACT

As the transition to digital imaging technologies continues to gain momentum in the NDT industry, users are concerned with monitoring the performance and stability of their imaging systems. Industry standards (ASTM, CEN) have defined test phantoms and methods, but many users are finding these cumbersome to use and/or too expensive. As a result, several military and government defense contractors have developed lower cost alternatives, but these still require tedious and sometimes subjective analyses. This paper will describe a unique phantom and an automated method for the quality assurance (QA) of digital imaging systems, providing a simple and quick way to quantitatively measure the key characteristics of storage phosphor-based computed radiography (CR) imaging systems and direct-digital, flat-panel, detector-based direct radiography (DR) imaging systems. The procedure to acquire images is quick and simple to conduct, which helps to reduce system downtime. The analysis is fully automated, providing precise and sensitive quantitative measures, eliminating all subjectivity and third-party measurement-device dependence. The interface provides a go/no-go status of key performance parameters such as spatial resolution, noise, detective efficiency, exposure response, dark image signal level, geometric accuracy, etc., enabling the inspector to have complete confidence in the imaging system.

Keywords: Radiographic Testing (RT), computed radiography, performance monitoring, digital radiography, test phantom

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INTRODUCTION

Since the adoption and acceptance of digital radiography in non-destructive testing, users have invested a great deal of time, money, and other resources to learn the technology and make it a success. Hence there is much interest in protecting these investments and ensuring these digital imaging systems are performing at an optimum level, and that they are delivering what their manufacturers claim. In many cases, such monitoring is required by prime contractors or spelled out in purchaser-supplier agreements.

DISCUSSION

Current Process Control Methods

There are a number of test targets, or “phantoms”, currently available for such performance monitoring. International standards now specify a comprehensive set of user tests, and phantoms have been designed and are now commercially available for long-term performance and system stability monitoring. These phantoms, while meeting the intent of the standards, are frustrating current and potential users in a number of ways. First, they can be somewhat time-consuming to analyze, taking time away from revenue-producing inspections. Further, the variety of targets often requires either subjective analyses or tedious manual methods. And finally, the cost of these phantoms can be overwhelming for many small-and medium-sized inspection organizations. As a result, resourceful users are developing alternatives that are simple to create and more cost effective. While these alternatives seem like logical solutions, they can further complicate the situation with more and confusing choices, and they still do not address the need for simplicity and reliability.

A New Approach

Now, there is indeed a better way. A patented method [1] provides for a simple phantom created by a combination of stamped and laser-cut apertures in a metal absorber (Figure 1). In addition to providing sharp edges, some of the apertures contain absorbers to provide various degrees of exposure attenuation. The digital image of this phantom is analyzed by a unique software application that precisely locates the apertures and edges, and performs a variety of calculations to characterize system performance. The following descriptions show how the system is used to monitor a CR system, although it can be used with either or both computed radiography and direct digital radiography imaging systems.
How does the system work? When a digital image of the phantom is produced at a given pixel pitch, the apertures are imaged at known and precise locations relative to each other. The software analyzes the resultant pixel data to locate the transitions in pixel values, and hence precisely locate each of the apertures (Figure 2). The aperture locations are then used to calculate a variety of parameters relating to geometric accuracy such as pixel size in both fast and slow scan directions, pixel aspect ratio, scan non-linearities, and pixel placement error.
For example, pixel size is determined by the distance between all of the reference markers in the direction of the fast and slow scans. Given that the location of the apertures and the scanning pixel pitch are known, the computation of actual pixel size and any associated error is a simple software task (Figure 3). Likewise, the pixel size can be determined all along the fast and slow scan axes, resulting in a measure of scan speed linearity. The pixel sizes in the fast scan and slow scan directions are also used to derive the pixel aspect ratio, and this can be calculated for the left, middle, and right sides of the image, as well as for calculating an average aspect ratio error.

![Image](image_url)

**Fig 3:** The precise locations of the reference markers (apertures) are used to compute a variety of geometric parameters; in this example, pixel aspect ratios.

Modulation Transfer Function (MTF), a measure of sharpness, is derived from the edges of the large aperture near the center of the phantom. The derivative of the edge produces a line spread function, and the Fourier Transform of the line spread function results in the MTF (Figure 4). MTF is a measure of image modulation as a function of spatial frequency; therefore, the software performs the calculation at all frequencies from zero to the Nyquist Frequency. For monitoring purposes, however, a single point at 50% of the Nyquist Frequency is chosen, although the entire MTF curve is available for display to those so inclined. While such calculations are not for the timid, the software can accomplish this with unparalleled speed and accuracy.

The large apertures near the center of the phantom are fitted with absorbers of known properties, producing varying pixel values. With a standardized X-ray exposure technique of 80 kV and 10 mR dose, and standardized scanner calibration, these absorber
properties produce "expected values" from which exposure latitude and linearity can be determined. The pixel values in a 2.0 × 2.0 cm (0.8 × 0.8 in) square are also analyzed for a calculation of image noise level.

A "Total Quality Tool"

In addition to the analyses described above, we can put the software to work on a standardized flat-field uniformity image to characterize a variety of critical uniformity parameters. The maximum variation in response to a uniform exposure is an overall measure of field uniformity. The difference in response between adjacent lines in the slow scan direction is a measure of transport "chatter." A line position noise function is derived from the position of the start of any of the fast scan lines. Similarly, periodic fluctuations in the slow scan direction indicate banding associated with the drive mechanism, and any other fluctuations between adjacent lines or rows of pixels are logged as general streaks.

What makes the Total Quality Tool unique among modern process monitoring tools is its automated nature. A user interface allows the operator to analyze an exposed imaging plate and get an immediate reading on the health of the system with status lights for each of the system tests. The calculations are compared against a table of expected results and tolerances and will present a green light if the system is "good to go," an amber light when results are approaching their limits, or a red light when service or recalibration is indicated (Figure 5).

There is no subjectivity on the operator's part, so there is no need to be concerned with numbers, tolerances, or decisions. User-friendly documentation guides the operator to an appropriate course of action in the case of an amber or red light, eliminating guesswork and minimizing downtime. The system logs the latest fifty test results, and the operator may review any of these test logs and/or individual test results.
Fig. 5: The user interface showing the phantom image test results in the form of status lights. Four of the tests passed (green); two failed (red).

It is important to note that this tool is not intended for digital imaging system qualification, per se. Nor is it intended to be used across different imaging platforms for comparison purposes, as it is designed to accommodate a particular system’s imaging and operating modes. The real performance capabilities of an imaging system, and its relative performance against competing systems, should be determined well ahead of its acquisition, through practical demonstrations with real imaging and inspection applications. It is after the acquisition, during routine use, handling, maintenance, and transportation over a period of months and years when the capability for long-term stability and performance monitoring becomes important.

SUMMARY

Today’s NDT professionals are fortunate to have a variety of tools and resources available to help them navigate through the maze of digital technology. On the other hand, the choice of tools can sometimes be overwhelming and frustrating, adding unnecessary stress to the task at hand. This automated, user-friendly Total Quality Tool for the monitoring of digital radiographic imaging systems simplifies CR and DR system monitoring. It makes the NDT inspector’s job easier and the operation more cost effective. By all measures, it inspires confidence in the inspector’s work, the system’s performance, and its results.

REFERENCES