TECHNICAL HIGHLIGHTS FOR NDT DIGITAL RADIOGRAPHY (X-RAY) INSPECTION

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Abstract
Digital Radiography (DR) is finally taking its rightful place in the arsenal of NDT technologies. With film X-ray dyeing out as film manufacturers stop film production, NDT technicians seek new solutions for X-ray NDT. DR is the leading, most innovative top technology for X-ray inspection available today. With its high quality imaging, NDT results and analysis quality is increased. Amorphous Silicon (a-Si) flat panels are up to 100 times more sensitive than film and allow for great images with reduced exposures or energies.
The high signal to noise ratio enables improved probability of detection (POD), and combined with fast and easy set up on site, the inspection time is shortened significantly, reducing costs and plant shut down. The software provided with DR enables image enhancement that makes even the tiniest detail visible to the human eye. In this article we will review the properties of hardware and software required to maximise the quality potential of results that can be achieved with this advanced technology.

1. Hardware

In laboratories there is almost no special hardware (except the detector itself) required to operate a DR system. The detector is connected to the computer directly with a short data cable and it receives its power from an AC power supply via a short power cable. With portable inspection systems (for field work such as is done in factories, refineries or shipyards on site) the detector cannot be connected directly to the computer like it is done in laboratories. For reasons of safety (radiation) and work efficiency the computer is located at a larger distance from the detector and X-ray source (the detector and X-ray source will be moved and carried to various inspection sites but the computer will be placed in one area). There is also generally no AC power supply available at every location (using the power supply from the detector manufacturer is usually not an option). Power to the detector must be provided with suitable and special hardware.

There are many types of digital detectors emerging in the market today which have great potential on paper. Whether CMOS, Amorphous Silicon flat panels or amorphous Selenium plates; the potential of these detecting technologies can only be maximised with suitable hardware. The hardware connected to the detector must not limit the amount of information that can be extracted from it. It is of no use that a detector can generate an image of 16 bit if the supporting hardware, such as power suppliers and cables, create a noise level that is equivalent to the least significant bit (LSB) of a 10 bit system. In such a case, most of the critical information from the detector will be lost in the noise. It is important that the noise created by external electronic components will not limit the detector real data. “You are only as strong as your weakest link”.

2. Software

Good software will be able to use the information extracted from the hardware of the detector in the most efficient way. An excellent detector supported by great hardware is not enough; the continuation of the system equation is for good software to be able to maximise and realise the true potential of the detector.

A user friendly interface will ensure higher quality of results and high POD. If the user finds it hard to understand the way to use the software tools as was intended by the software developer, or if the NDT operator finds it hard to repeat important inspection procedures (sequences of software actions) successfully, the user will compromise or even give up using some of the potential advantages of DR technology. This means the user does not take advantage of the true potential of the software and associated hardware. Software user interface must be created to satisfy the end users' needs and not the needs of the programmers who are developing it!

DR system software offer many enhancement tools; however only few operators can make good use of all these tools because their contribution to the analysis is not understood. With a good DR system software, the operator needs only a few tools to get great results. Automatic calibration, good zooming and high quality sharpness as well as automatic Window Levelling, allow the operator to make the most of the images and provide excellent analysis fast, with a short learning curve. These four tools will now be shortly reviewed.

2.1 Calibration

One of the software tools that most affects the ability to achieve high quality results from a digital detector, is calibration. Calibration is an algorithm that serves to calibrate the detector pixels by performing the following two actions:

a. Calibration insures that each pixel in the digital detector starts measuring X-ray from the same level – this is normally called "Offset" correction.
b. Calibration ensures that each pixel in the digital detector will respond similarly to X-ray, meaning that for a specific amount of X-ray (which penetrated the object and hit the detector), the reading from all the pixels will be the same – this is normally called "Gain" correction.

Calibration quality is determined by the number of points/ reference images taken in the process and their quality. The frequency of performing calibration depends on the following criteria:

a. The quality of image required: the higher the image quality needed, the higher the frequency and level of calibration performed.
b. Working conditions: changes in the type of X-ray source used, distance between the detector and the X-ray source, radiation energy level used etc. Frequent changes will necessitate frequent calibration.
c. The object being examined.
d. Extreme change in environment: this is especially relevant for portable systems. When working on site, as the environment conditions (like changes in temperature and even humidity) can play a part.

Calibration strongly contributes to the image quality and increases POD. Figure 1 shows a weld on a stainless steel pipe with total wall thickness of 6 mm examined with a DR system under

different calibration levels. The inspection was conducted in a laboratory and all other conditions (except the calibration) were the same. The X-ray on the left (a) was taken with a system with a bad calibration. The image in the middle (b) was taken with the same type of system which had gone through a short but quality automatic calibration process (less than 1 minute). The image on the right (c) was taken with a DR system (same type) that had gone though a high level quality calibration process with averaging of 100 reference images. With bad calibration only the two first wires are visible (a), with short automatic calibration, the third wire is visible (b) and with high level of calibration 4 wires are clearly visible (c).

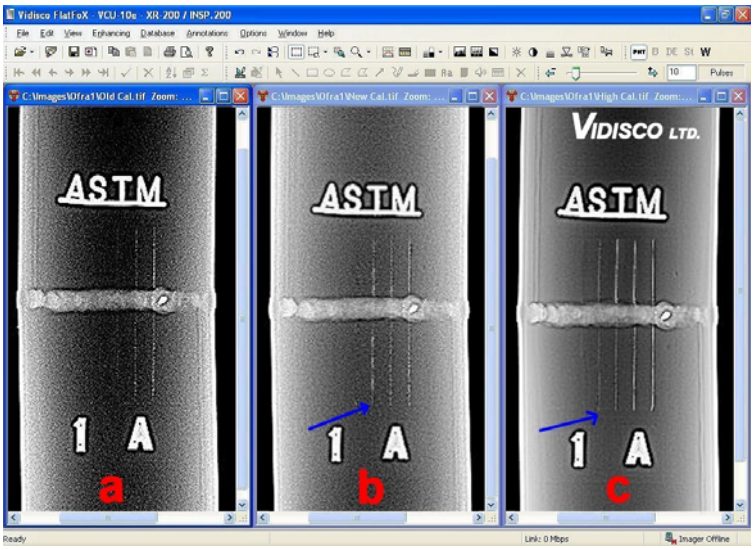

Figure 1: Calibration Quality Effects Image Quality

Again, calibration frequency and its level are determined by the image quality required - if you need to see only 2 wires, the calibration frequency is most likely to be very low. If you need to see 3 wires or more, automatic or high quality calibration, performed more often will get the job done.

Some DR software offer an automatic calibration procedure. This option enables any operator to increase the quality of images achieved by conducting a simple, fast and automated process. Advanced software offer the operator the option to set the amount of reference images to be averaged, and thus determine the level of the automatic calibration process according to the quality of the image required.
When working in and out of a laboratory, it is important to have the ability to save more than one calibration set for different inspection or environment conditions (e.g. one set for extreme cold and another set for very warm climate).

2.2 Zoom

In many NDT inspections the defects being sought are very small and sometimes not visible to the naked eye. When using film the use of a magnifying instrument is a normal part of analysis. When using a DR system, a good Zooming algorithm in necessary for high quality of analysis and detection.

An X-ray image of an lp/mm IQI was saved and viewed with the software of a leading DR system (Vidisco professional Flat*f*oX) and a commonly used open source free graphic viewer. First the image was viewed in its original size in both programmes, and then the zoom was increased gradually. When the image is viewed in its original size (fit to screen, 39%), it looks very similar (see Figure 2). When the zoom was increased the image started to pixelize already at 200% in the free viewer, whereas in the DR system software the zoom was still very smooth and detailed. Even at 800% (see Figure 3) the DR software exhibits a good image (b), and the highest resolution can be clearly seen. Although the freeware viewer enables a high zoom, at 800% the information is no longer usable (a).

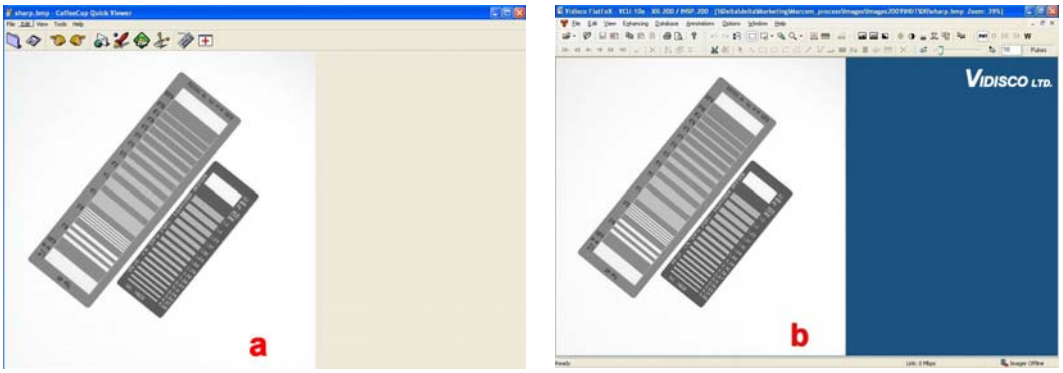

Figure 2: Zoom Comparison – Original Size

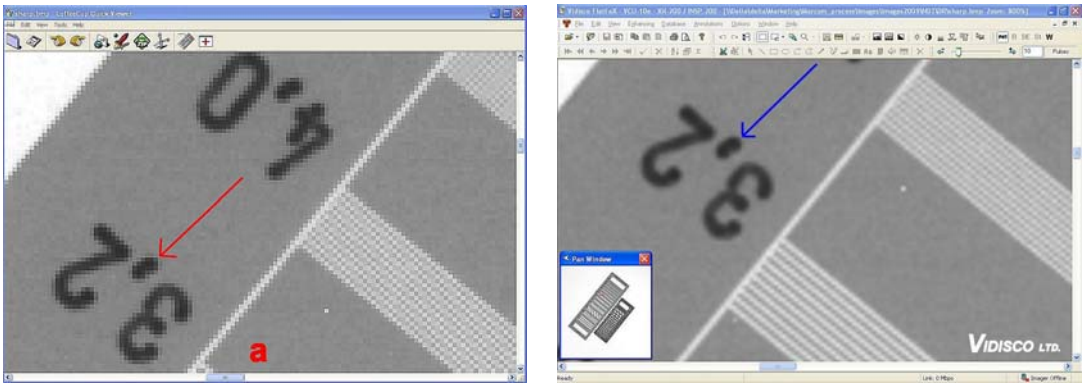

Figure 3: Zoom Comparison - 800% Zoom, no Digitization in DR System Software (right)

2.3 Window Leveling

The Window Levelling tool enables the operator to view the relevant spectrum of grey levels in an X-ray image and thus to maximise the ability to see defects in this relevant area. Even if a digital detector can produce a 14 bit image, a standard computer screen can only show 8 bit. With Window Leveling the operator can see the entire 14 bit information on an 8 bit screen, by looking at different parts of this information each time. The Window Leveling tool does not cause any changes in the raw data! It only helps enlighten the relevant area in which the required information is to be found.

In Figure 4 an X-ray image of an aircraft rib is viewed with various options of Window Leveling. The image on the left (a) has not gone through Window Leveling at all, so only 8 bit of

information is visible. The image on the right (b) is viewed with incorrect Window Leveling and the information is lost due to “burning” of the information, the image on the bottom (c) is viewed with correct Window Leveling (using an automatic algorithm), which enables the operator to see defects clearly.

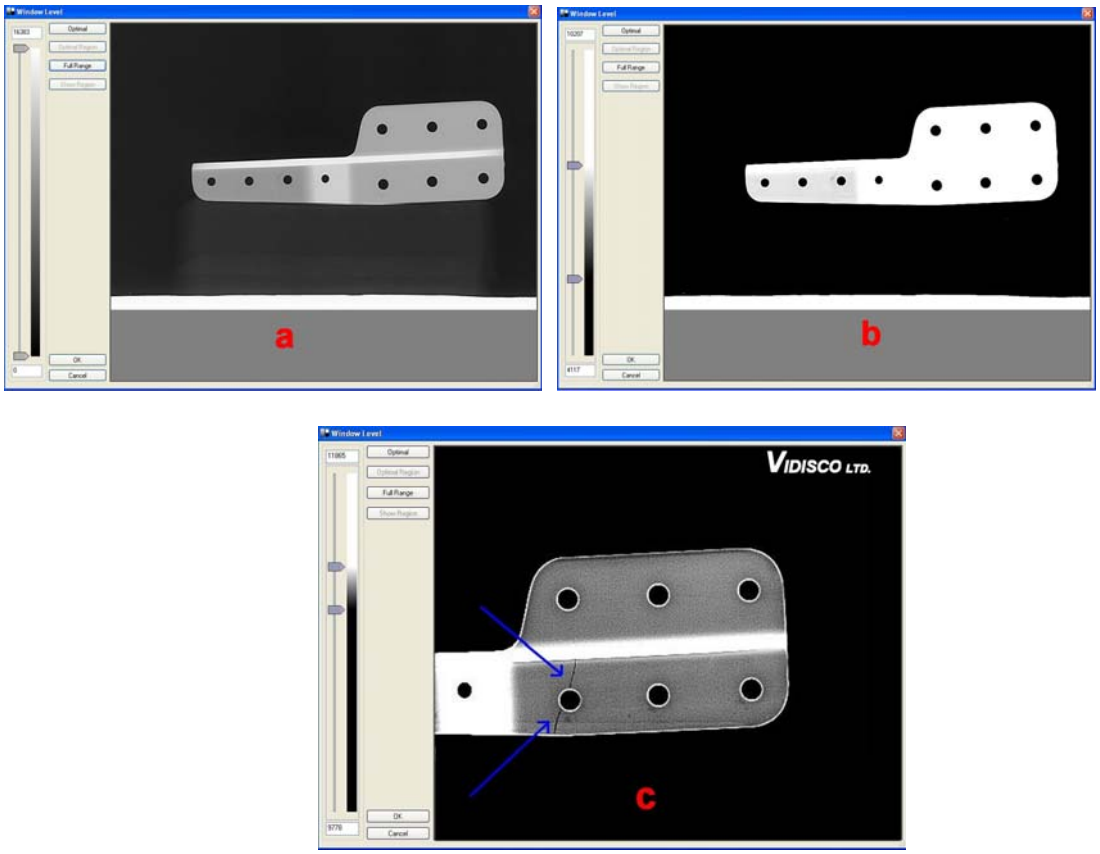

Figure 4: Window Leveling Usage

Advanced DR software offer an automatic Window Leveling option. This option is a simple way for most operators to extract the required information from an image. The automatic Window Leveling algorithm analyses all the grey levels in the raw image and highlights the layers in which the most information can be found. The operator can also to fine tune the automatic Window Leveling algorithm results by using the manual tool.

2.4 Sharpness

The Sharpness algorithm is sometimes called by different names. The result of this algorithm is that the image becomes sharper and defects are easier to see. A good sharpening algorithm does not cause a significant noise increase in the sharpened image, which can cause loss of detail (instead of enhancing detail), thus lowering the quality of analysis. A good sharp and clean image will enable the operator to make correct and detailed analysis.

In Figure 5 an X-ray image of a plate weld was saved and viewed with a commonly used viewing freeware on the left (a) and dedicated DR system software on the right (b). The image in

the DR system software is sharp and details are clear (even when zoomed in), with very little noise added in the background so that all the IQI wires are visible. The noise in the image viewed with the free viewer causes the thinnest wires not to be seen. The missing details could lead to false detection.

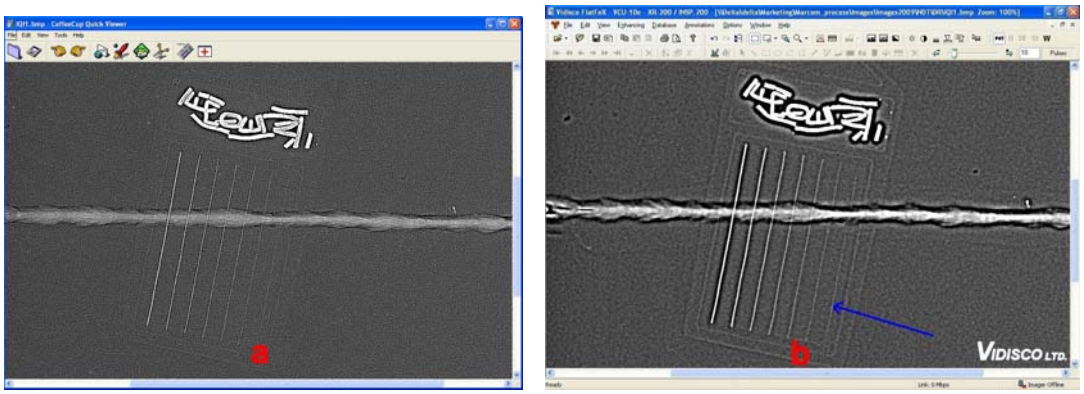

Figure 5: Sharpening Algorithm – Same File Viewed with Two Different Software

Summary

Digital radiography (DR) is a most advanced technology and it holds within it a great potential for high quality, fast and yet exact inspection. However, to make the most of this potential it is important to understand that digital detectors are not "Plug & Play" devices. The quality of the results does not only depend on the experience of the operator, but greatly depends on the experience and knowhow of the system producer. The combination of system hardware and software, which supports the digital detector, is essential to maximising the quality of results.

Purchasing a detector (even the most advanced one) with a basic software is not enough. For best results, one must purchase an entire DR system, with technology that supports the abilities of the detector.

When working in the field, out of the comfortable zone of a laboratory, all of the above mentioned parameters become even more important and extreme. In order to provide fast setup and high quality images immediately on site, a portable DR system needs to offer the best combined hardware and software specifically designed for the challenging, extreme conditions found in field inspection.

A higher level of analysis will become the required standard in years to come. Thus advanced NDT technology will play an ever increasing role in the market. For inspection systems to be able to provide high quality results that the market demands, they must be properly suited to the user and focused on the operator's needs. The difference between a good digital detector and an excellent DR system that is able to reliably serve a customer, is that a good system takes into account the operator's limitations, and must be designed specifically to make the operator's work easier, combining advanced technology and expertise into a user friendly, comprehensive solution. A successful DR system is only one that can quickly, easily and reliably find the defects (or prove there are none) for the NDT inspector under the demanding conditions in which he must work and inspect.