ENHANCEMENT OF IMAGE QUALITY IN DEFECT DETECTION FROM CONVENTIONAL RADIOGRAPHY IN DIGITAL RADIOGRAPHY

POBOLJŠANJE KVALITETE SLIKE U OTKRIVANJU NEDOSTATAKA – PRIJELAZ S KONVENCIONALNE NA DIGITALNU RENDGENSKU SNIMKU

SOTJA, Enkelejda; NARDONI, Giuseppe & NARDONI, Pietro

Abstract. *This paper explains the difference between images in conventional X-ray film and plate scan images in digital radiography CR. For that we have built the exposure charts and characteristic curves for material steel, (1) film D7, density 2, ffd= 70cm, screens= 0.10 mm, automatic processing and (2) IPS plate CR 50P, resolution 100µm, speed 6,67mm/sec. Experimentally we have proved that conventional radiography method offer a very good film viewing, with high sensitivity, contrast, borders definitions. CR image resolution is less than can be achieved with finest grain film, but have a big range performance on screen to elaborate the image*

Key words. *contrast, sharpness, digital radiography, conventional radiography*

Sažetak: *Ovaj rad objašnjava razliku između konvencionalnih i digitalnih rendgenskih slika. Eksperimentalno smo dokazali da konvencionalna rendgenska metoda daje dobar prikaz,ima visoku osjetljivost i dobar kontrast. Digitalna rendgenska snimka je nešto lošija,ali ima širok spektar mogućnosti korištenja.*

Ključne riječi: *kontrast, oštrina, digitalna rendgenska snimka, konvencionalna rendgenska snimka*

Authors´ data: Enkelejda **Sotja,** Lecturer, Polytechnic University of Tirana, Albania, esotja@yahoo.com; Nardoni **Giuseppe**, General Director I&T Nardoni Institute S.R.L, Brescia, Italy, nardoni@numerica.it; Nardoni **Pietro**, I&T Nardoni Institute S.R.L, Brescia, Italy, nardoni@numerica.it.

1. Introduction

The industrial radiography is a non-destructive method that uses the penetrating and ionizing (X-ray or gamma-ray) radiation, that pas through the object, and the detector of the radiation. This method of ndt is very important to detect defects (internal and surface, likes porosity, cracks, lack of fusion, lack of penetration, foreign inclusions), differences in thickness, changes in structure, assembly details etc. in quality assurance of the piece, or structure conform standards, specifications or technical requirements. X-rays were discovered in 1895 by W.C.Rontgen, and gamma rays in 1896 by A.H.Becquerel. They are the same phenomenon, with the difference, X-rays have origin in a vacuum tube excited by impressed voltage, gamma-rays is spontaneous production during decay of a radioactive substance [1].
The detector can be 1.photografic film, held in a light-tight cassette that allows the rays to pass through the piece. To develop the image on film are needed chemicals. This process is knower like conventional radiography. 2. Radiation –sensitive detectors that not requiring the use of chemical to produce the image. This process is knower like digital or computer aided radiography (CR) or direct digital radiography (DR)[1].

1.1 Conventional radiography

To create conventional radiographic image attenuated rays are passed through on object of study onto a film emulsion of silver halide where they react with a chemical processing agent
This film is in plastic or paper cassette that is usually placed close behind the specimen and the rays are switched on for an appropriate time, that is important to have good contrast or sufficient density.
The film is taken away and processed photographically , developed, fixed, washed and dried, a process that is expensive, both in terms of materials and equipment, is time consuming, and environmentally unfriendly.
Advances in technology have significantly improved x-ray equipment, however because the degree of detail on film images depends upon crystal size and the emulsion, the quality of radiographic image depends on silver halide and other molecules in the film.

1.2 Digital radiography

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. The types are:
Film Digitization- process whereby a radiograph is produced in conventional manner on a normal sheet of industrial x-ray film, the film is than 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 [1].

Direct Radiography (DR)- the image is captured directly on 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. [2][3].
Computed Radiography (CR)- uses an imaging plate, that's contains photo sensitive storage phosphors which retain the latent image. When the imaging plate is scanned with 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 valuable point 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 [2][3].

2. Radiographic image quality

The reliable detection of defect is the most important task of ndt. The human factor in conventional radiography is very decisive, the analyses of the film is done exclusively by the expert radiograph which has duty to control each film in order to detect the presence of defect to identify e measure them. This is a difficult job because of a low dimension of defects, bad contrast and a noised nature of the radiographic film.
In the digital radiography is important the processing of image to improve the image quality, making the analysis process easier, more reliable, no so depended from human factor o other parameters. Digital image processing covers the set of the processes of improvement e extraction of qualitative information in digital images.
The main topics when we discus image quality are the resolution (spatial resolution) and contrast. Resolution is expressed as line pairs per millimeter, and is one of the factors that can be measured and compared in order to rate image quality. The resolution of conventional radiographic images is limited to the inherent resolution of the film itself (20 line pairs per mm). The resolution of digital imaging systems is determined by the charge-coupled device detector and resolution of the monitor used to see images. Their spatial resolution is generally inferior to film-based systems (7 to 10 pairs per mm^2; or in50% drop in spatial resolution) [3].
Contrast is very important in film radiography images; contrast between dark and light parts reveals relative differences in density. The contrast of a film is product of lot components; each of them has his influence in a film image or in less ideal contrast. Digital radiography does not require film processing, so this avoids the influence of mistakes or not correct developing process. Digital contrast resolution is expressed as the number of grey levels. Film provides 16 to 24 levels of grey. In current digital we start with 10-bit or 12-bit, or 1024 and 4096 values of grey. These grey are reduced in 8-bit, resulting in a typical image with 256 levels of grey. So with digital radiography is possible to exceed film imaging in context of gray levels more than 10 times, and that is very important to increase the diagnostic value of it [4].

3. System parameters

3.1 Exposure charts

For image quality are very important parameters such as kV, mA and exposure time. An exposure chart give us the relation 1) material thickness, 2) kilovoltage kV; 3) time of exposure and intensity, mAmin [4][5]. A simple method for preparing an exposure surface is to make a series of radiographs of a stepped wedge sample consisting in a number of steps.

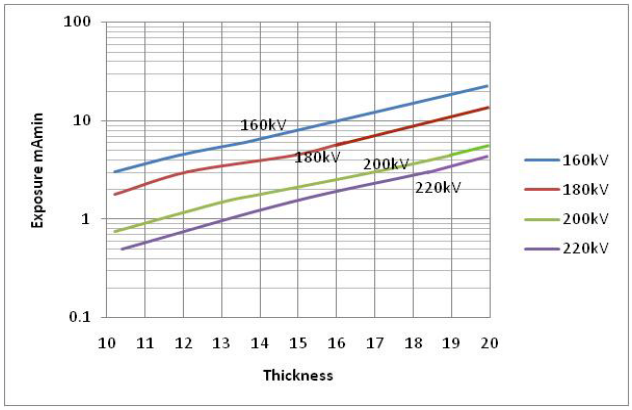

Figure1. Exposure chart based on experimental results, scanner CR50P (Pegasus), plate IPS, source-detector distance 700mm, digital value 20000counts.

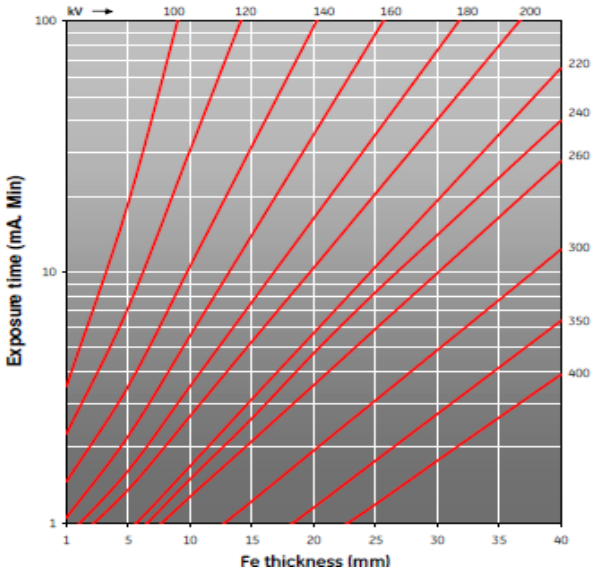

Figure2. Exposure chart based on Ge Inspection Technologies, scanner CR50P, (Pegasus), plate IPS.

We used stepped wedge from 1mm to 15mm placed over a steel plate with 5mm thickness, first two millimeters are with steps 0.2mm differences between each-other, radiographed at several different exposures at each number of kV. In figure 1 the relation between thickness-grey value and exposure (mAmin) is obtained from our

experimental data where a desirable grey level is selected as the basis for the preparation of chart and figure 2 from Ge Inspection technologies to be compared [1].

3.2 Energy

Charts below express the relation between thickness, and density (fig 3) or grey level (fig 4) in different level of energy. It's built based on our experimental results, for five level of energy at the same exposure. From these results we can tell that in conventional radiography the increase of energy have the same impact on density. But in digital radiography for the same increase of energy, in our experiment is 20kV starting from 140kV the increase of grey level is not with equal values. Differences are bigger in exposure at high energy.

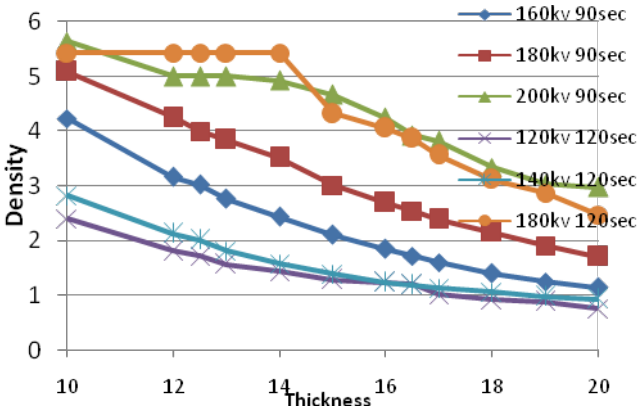

Figure 3. Preliminary chart, conventional radiography

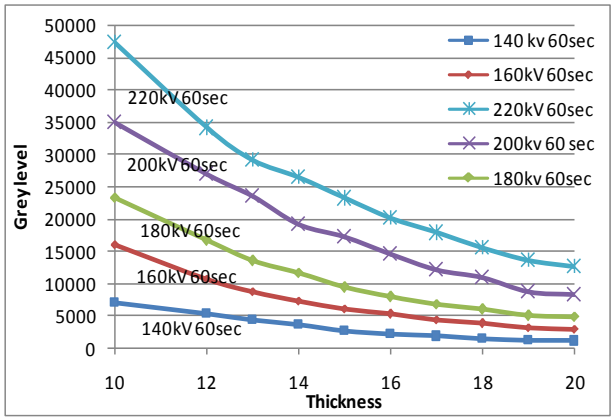

Figure 4. Preliminary chart, digital radiography CR

3.3 Characteristic curve

The characteristic of film has taken from Agfa data (fig 5). The characteristic curve for IPS plate scanned with CR50P 7, (fig 6) is built based on our experimental data, to express the relation between exposure and grey level. It is used the same stepped wedge exposed under different exposure time without change of energy.

We can say that the part of diagram with desirable grey level is from 25000 to 45000, over which level start the saturation of plate. It's clear that, with increasing the time the grey level increase, increasing quickly the contrast (figure 5). For shorter exposure the contrast is very lower, so for good contrast we have to use radiography with as longer as possible exposure.
Small thicknesses are penalized related to big thickness.

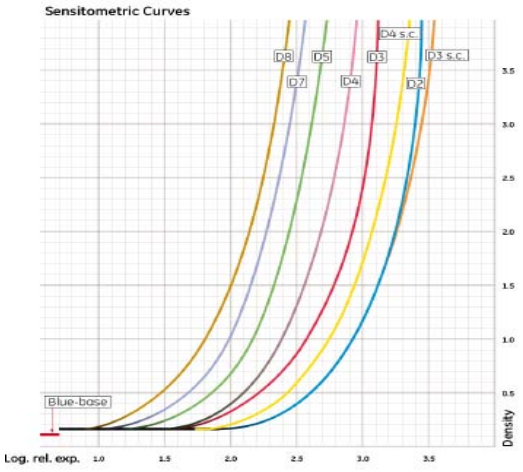

Figure 5. Characteristic curves from Agfa's film, conventional radiography

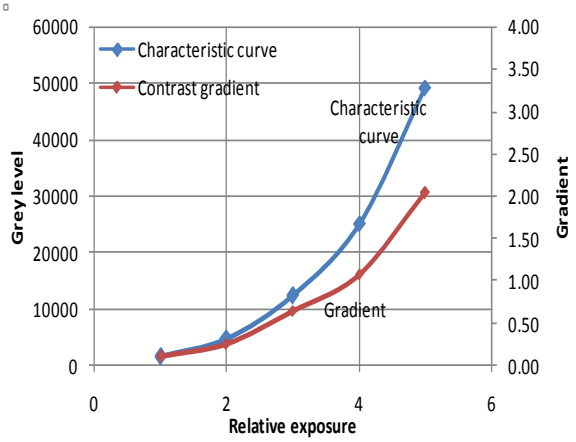

Figure 6. Characteristic curves from our experimental results, digital radiography

So the contrast obtained using higher kV is better than the contrast obtained using lower kV. The range of grey level to obtained higher contrast is from 25000 to max 45000 to, taking present that interval of time in which, from the max point, the plate can go on saturation, is very shorter.
Higher contrast means higher sensitivity to detect defects, so to obtained good contrast we need to exposure with as higher as possible energy, higher the energy better the sensitivity.

3.4 Sensitivity

System performed parameters must be determined initially and monitoring regularly to ensure the results. According to EN 462 [1], [3] the best measure system is using the Duplex Wire figure 9. According to UNI EN 1478-1 the resolution criterion for the evaluation of duplex wire consists: two wires of a pair wire are resolved if the dip between the line max is greater than 20% of the max intensity.

For the plate 10mm we can see the element 7D (figure 7), diameter 0.20mm. We can guarantee the 2% sensitivity for class A. If is needed the class B the difference is only 0.04mm (diameter 0.16mm) and the digital radiography is not accepted.

The results express that conventional film has high sensitivity, higher resolution and good borders definition compared with CR system where the size of pixel is around 30 - 200μm compared with 5μm for the conventional film.

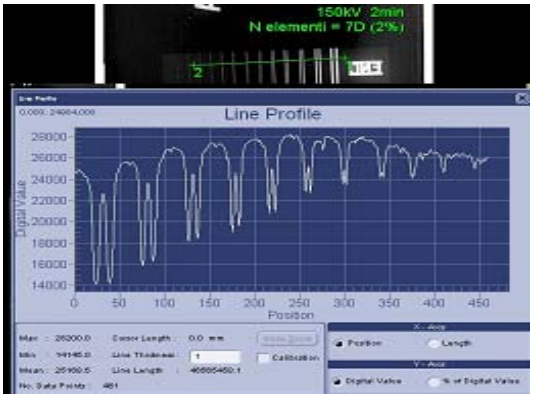

Figure 7. Image of Duplex Wire expressed in grey level by Line Profile

4. Experimental Tests

Inside are three different kinds of parts under exposure.

First; a welded plate with a lot of porosity, lack of inclusion (figure 8).

Second; welded tube with diameter 296 mm (figure 9).

Third; corroded tube under coating material, diameter 48mm, tube from heating general system of the city (figure 10).

From images is proved that with post-processing is possible 2% sensitivity, and is possible to measure all defects inside.

Figure 11 shows radiographic image of heat systems tubes, with diameter 48mm and thickness 4mm. This has been done under exposure in two directions, without remove coating. The program itself allows measuring the thickness of tube.

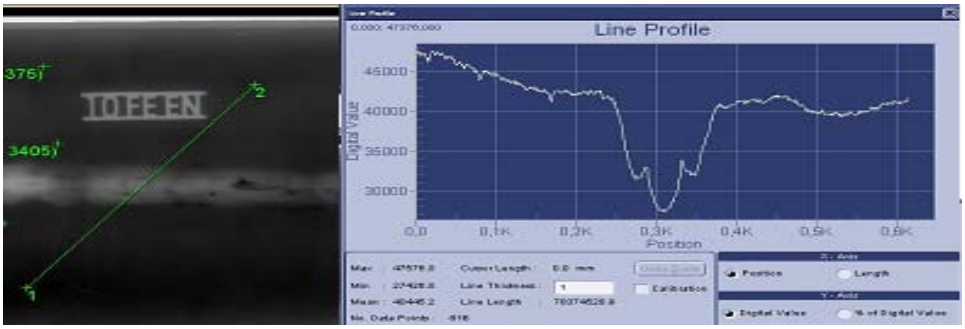

Figure 8. Digital radiography of welded plate with line profile that gives grey counts for part of welding

Figure 9. Welded tube Al with diameter 296mm

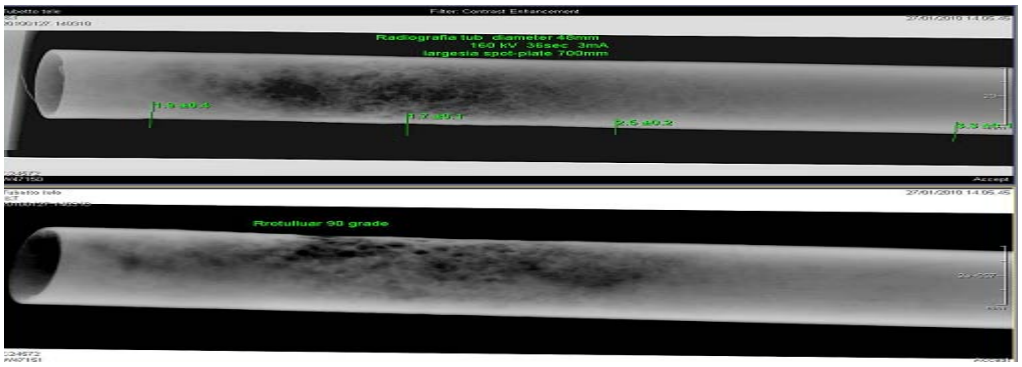

Figure 10. Corroded tube with diameter 48mm

5. Conclusions

Digital radiography has significant advantages like exposure time reduction, no need for chemical development process what bring it to friendly to environment, easily post-processing, accurate corrosion measurement, no material limitations, no temperature limitations and no need for preparation work or remove coatings or insulation. By the light of the obtained results we can recommend in digital radiography CR a level of grey up 25000 to 45000, because in this interval contrast is higher.

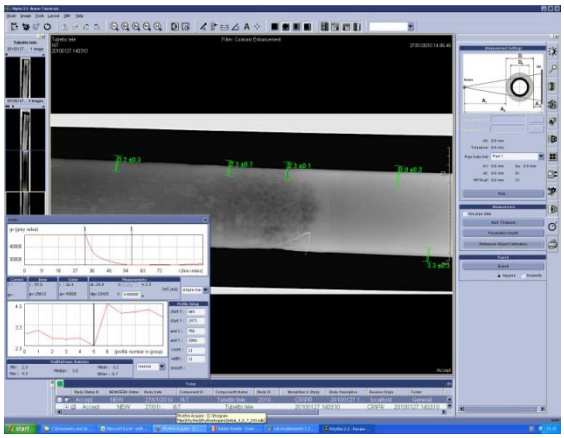

Figure 11. Corrosion dimensioning

Another important consideration has been raised during the test; few cents of millimeters in wire diameter can cause a level of sensitivity more than 2% and consequently not accepted by the code.
This change in our opinion has not effective impacts on the POD of type of defects like, lack of penetration, porosity, cracks, and slag inclusion.

6. References

[1] *GE Inspection Technologies*. Industrial Radiography- Image forming technique, *Available from:* www.geinspectiontechnologies.com. *Accessed:* 11-05-2010
[2] *Non-Destructive Testing Handbook;* (2002). Vol 4, Radiographic Testing *American Society for Non-destructive Testing*, USA.
[3] Ramesh, J.(2005). Digital Applications of Radiography, 3rd MENDT - Middle East Nondestructive Testing Conference & Exhibition - 27-30 Nov 2005 Bahrain, Manama.
[4] Weimin, B.; Bueno, C,; Wong, B.S.& Wang, X. (2009). Generation of radiographic techniques for digital radiography applications, *Insight* Vol 51 No6.
[5] Uwe, E.; Uwe, Z.& Bavendiek, K. (2005). ANNUAL Conference of German 6 Society of NDT, Rostock, May 2nd- 4th, cd of *Proceedings*, 10 pages.
[6] Mario, B.(2008). *Introduzione della radiografia digitale*, Bytest Srl, Volpiano [TO], Italia.
[7] Bianchi, M.; Rivara, F.& Rusca, S. (2010). Caratterizzazione della radiografia computerizzata (CD/DR) con schermi al fosforo e confront con la radiografia convenzionale a film, Instituto Italiano della Saldatura- *Giornale AIPnD*- Settembre 2009, 9 pages.
International Standards:
1. EN 462
2. UNI EN 1478-1: 2005 Non-destructive testing - Industrial computed radiography with storage phosphor imaging plates - Part 1 and Part 2

Photo 177. Jankovac / Jankovac