17th World Conference on Nondestructive Testing, 25-28 Oct 2008, Shanghai, China

Quality Evaluation for the Digital Radiography Inspection Based on Imaging Parameters

Fanqin KONG [1]
[1] GE Inspection Technology
5F, Hongcao Building, 421 Hongcao Road, Shanghai 200233, China
Phone:+86-21-34144620 ext.6027 Fax:+86-21-64857191
E-mail:fanqin.kong@ge.com Web: www.GeinspectionTechnologies.com

Abstract

The systme properties and qualities should be measured periodically to ensure the good condition of the digital radiography imaging system. The parameters of unsharpness, contrast and signal to noise ratio were defined and measured in this paper. Based on these parameters, an evaluationg for the system could be achieved for the digital radiography inspectiong. By means of measuring the unsharpness using modulation transformation function(MTF) method and duplex method, the basic spatial resolution could be determined. Contrast properties were described by the contrast sensitivity and the wall thickness range. The signal to noise ratio was characterized by the measurement of mean and standard deviation value on different regions of interesting. The Image Quality Indicator(IQI) was used to control the imaging qualities. Under its incorporating with three imaging parameters, the inspection system could be check for its reliability and stable performance. Also it could provide a guidance to check and accept a new system.

Key Words: Digital Radiography, Unsharpness, Contrast, SNR

1.Introduction

With the development of X-Ray digital technologies, many kinds of digital conversion devices are being developed, for example the digital flat panel detectors, computer radiography scanners and image intensifiers. The inspection results could be shown as the digital images on the screen. There are also some other functions that can not be achieved on the film inspection, such as the defects analysis, defects size measurement, database building, data sharing with remote terminal computers.

The digital radiography technologies, whatever the hardware or software were used, made the X-Ray inspection more efficiency and less-dependent on operators. Nowadays they are more and more used in many kinds of industry fields, such as oil&gas welding inspection, aeronautic engine parts casting inspection and so on. For it is different with the traditional film technologies, the traditional means of evaluating the systems or measuring the image quality used in film inspection can not be used in digital radiography systems. There are also some parameters related to the hardware like long term stability and linearity need to be measured to ensure the good operational condition of the equipments[1][2][3].

Usually, measuring the contrast and unsharpness, signal to noise ratio (SNR) and so on is looked as the main means to evaluate the properties and qualities[4][5].

2. Unsharpness measurement

Unsharpness U is also called as the basic spatial resolution, it includes two parts, one is the inherent unsharpness U_i, it describes the transmission limit for small object details, and usually it is directly decided by the system hardware and independent of the exposure conditions. The other part is the geometric unsharpness U_g. The geometric unsharpness is related to the focal spot size. For every X-Ray focal spot having a certain size, when the object was penetrated by such kind of X-Ray , there will be a half-shadow area on the image according to the geometrical theory. The half-shadow is called as geometric unsharpness U_g and could be measured by the formula (1).

$$U_g = f\frac{l_2}{l_1} \tag{1}$$

f is the X-Ray focal spot size, l_1 is the distance between the focal spot and the object, the distance from the object to the x-Ray conversion device is l_2 .

Unsharpness limites the distinguishing ability for the object details. Measuring the unsharpness and optimizing the geometry setting and hardware performance to get better sharpness is necessary for the user and manufacture. MTF (Modulation Transfer Function) method and Duplex wire method are used to measure the unsharpness.

MTF describes the contrast transmission as a function of the object size. It also characterizes the unsharpness of the digital radiography system in dependence of the conversion device used in the inpection system. It is the normalized magnitude of the Fourier-transform(FT) of the differentiated edge spread(ESF) of the linearized output intensity, measured perpendicular to a sharp edge. Usually the MFT could be calculated according to the formula(2).

$$MTF(fx) = \frac{1}{\int_{=\infty}^{+\infty} LSF(x)\,dx} \left| \int_{-\infty}^{+\infty} LSF(x) \times e^{-2\pi j(xfx)}\,dx \right| \tag{2}$$

$$LSF(x) = \frac{dESF(x)}{dx}$$ LSF is the line spread function

For measuring the unsharpness and calculation of MTF, a digital image will be made of an object of high density with a sharp edge and a constant thickness. The image is calibrated so that the signal intensity(grey value of the image) is linear in relation to the radiation dose. A profile is extracted from the linearised image of the sharp edge, perpendicular to the edge. Averaging several profiles to enhance the SNR(signal to noise ratio) is necessary. The MTF is calculated from the first derivative of the profile by calculating the Fourier magnitude spectrum and nomalising to 1 at frequency zero. The unsharpness is determined from the MTF value at 20%. The corresponding resolution value SR is calculated by formula(3). This value is defined as the unsharpness U .

$$U = SR = \frac{1}{2 \times MTF_{20}} \tag{3}$$

For measuring the unsharpness using the duplex wire method, the duplex wire IQI can be applied. About the positioning of the duplex wire IQI directly on the X-Ray conversion device(like flat panel detector, image intensifier, IP plate), different devices have different ways. Such as the computer radiography inspection technology with image plate, the measurement will be performed perpendicular and parallel to the scanning direction of the laser beam. The duplex wire IQI is used in angle of about 5^0 to the scanning direction of the laser beam and 5^0 to the perpendicular direction. Usually the first unresolved wire pair is taken for determination of the unsharpness value. This is the first wire pair which is projected with a dip between the wires of less than 20%.

This method has less accuracy than the MTF method. If there are differences exit between the read-out value of the MTF-method and the duplex wire method, the duplex wire method value is taken[6].

2 . Signal to Noise Ratio (SNR) measurement

Noise is a main factor to decrease the image quality. Its influences on the images could confuse the operators and make it more difficult to distinguish the defects. Noise is usually from X-Ray photon fluctuation and A/D conversion, also from the digital hardware characteristic like reading out noise and so on. Noise level is measured by the SNR. SNR is the quotient of mean value I_{means} of the linearised signal intensity and standard deviation σ of the noise at this signal intensity. It could be calculated by the formula(4).

$$SNR = \frac{I_{mean}}{\sigma} \qquad (4)$$

The value SNR depends on the radiation dose and the imaging system properties.

The signal intensity I_{means} and standard deviation σ shall be computed from a region without shading or artifacts. Sample SNR value will be taken in different regions of the image area under test to ensure that SNR value's stable and believable. The size of ROI(Region Of Interesting) used to measure the mean intensity and the noise shall be at least 20 by 55 pixels and it belongs to an area ROI. A kind of data processing technique for assuring reliable signal to noise measurements could be used as below. This can be achieved using a commonly available image processing tool. That means the signal and noise could be calculated from a data set of 1100 values or more per exposed area. The data set is subdivided into 55 groups or more with 20 values per group. For each group with index i, the value I_{means_i} is calculated as mean of the unfiltered group values and the value σ is calculated from the same group values. An increased number of groups yields a better uncertainty of the result. The final value I_{means} is obtained by the median of all I_{means_i} values. The final σ value is obtained by the median of all values.

3.Contrast properties measurement

Contrast properties include the contrast sensitivity and wall thickness range.

Contrast sensitivity shows the transmission limit for wallthickness changes as a function of wall thickness, and it is the ratio of minimal transmitted wall thickness change $\Delta w_{\min}$ to wall thickness w with $SNR(\Delta w_{\min}) \geq 2$. The contrast sensivity value could be calculated by the formual(5).

$$C_s = \frac{\Delta w_{\min}}{w} \times 100\% \quad (5)$$
$$\text{with} \quad SNR(\Delta w_{\min}) \geq 2$$

For measuring the contrast sensitivity, a steel plate of thickness d in combination with a step wedge(steel) on the source side of the plate will be positioned in front of the input screen. The step wedge is positioned in the direction of the read out line of the detector and in the centre of the input screen. In the output signal, the signal to noise ratio SNR of each step wedge could be measured. The minimal thickness step with a $SNR \geq 2$ is regarded as the minimal detectable wall thickness change $\Delta w_{\min}$. In order to reduce the influence of quantum noise, the feature of signal averaging may be used.

Wall thickness range is the difference of wall thickness which gives a useful digital signal. It showes the maximum wall thickness range which can be viewed within one range. At the beginning of the measurement, radiation parameters like energy and tube current shall be defined and fixed. Usually only a small part about 10% of the front screen shall be irradiated in order to reduce scattering effects. The other 90% area will be shielded by the Pb material. In front of the input screen a step-like test indicator with a step height about 1mm is placed. The thinnest step $\Delta w_{\min}$ which gives the maxium amplitude $S_{\max}$ of the output signal is the starting point of the measurement. The test indicator will be shifted step by step in the direction of the thicker part. For each step the corresponding signal amplitude is measured until the SNR is less than 2. In order to reduce the influence of quantum noise the signal averaging may be used. The difference of wall thickness between thinnest $w_{\min}$ and thickest wall thickness $w_{\max}$ is the wall thickness range Δw_0.

$$\Delta w_0 = w_{\max} - w_{\min}$$

4. Result

The three typical parameters were often used to check the quality of image and system properties. The measuring means and method need to be adjusted with different digital inspection system. And the minimum requirement is also different.

Reference

[1] U.Zscherpel, U.Ewert, K.Bavendiek, Possibilities and Limits of Digital Industrial Radiology, Int. Symp. on Digital Industrial Radiology and CT, Lyon, June 2007.

[2] U.Ewert, U.Zscherpel, K.Bavendiek, U.Heike, W.Meade, New Digital Radiography Procedure Exceeds Film Sensitivity Considerably in Aerospace Applications, Proc. 9th ECNDT, Berlin, September 2006.

[3] Veronique Rebuffel1, Jean-Marc Dinten, Digital Radiology: an Opportunity for Quantitative Measurement, DIR 2007-International Symposium on Digital industrial Radiology and Computed Tomography, June 25-27, 2007, Lyon, France.

[4] U. Zscherpel, Internet page: Standardization offundamental parameters of radiography digitizers at http://trappist.kb.bam.de/CENNFD/ cenahg3.html.

[5] M.Purschke, Radioscopy – New Perspectives Gained through European Standardization, 7th ECNDT, Copenhagen, 26-29 May 1998.

[6] EN14784-1:2005, Non-destructive tesing- Industry computed radiography with storage phosphor imaging plates- part 1:Classification of system, 13-15.March, 2005.