ACQUIRED IMAGE QUALITY IN DIGITAL INDUSTRIAL RADIOGRAPHIC EQUIPMENTS

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Abstract. The computerized radiographic application in the industrial area is a recent event. The imaging plate is the equipment used as imaging receiver during the exposition radiographic technique, which consists of a flexible photostimulable phosphor screen, capable of storing the photons energy of the incident X and γ rays and of a reading unit which uses a laser device to stimulate a visible light. As two types of phosphor screen are manufactured, one for general use (General Plate – GP) and another one for specific using (High Resolution – HR), one of the objectives of this study was to evaluate the spatial resolution capability in both plates using the Kodak equipment. Furthermore, equipments from different makers, Kodak and General Electric Company - GE, were compared. Two phosphor screen HR were used as the main objective of this study. Imaging Quality Indicators – IQI were used to evaluate the spatial resolution of the images in accordance with ASME and DIN standard. The results show that after evaluating the GP and HR Kodak plates, the HR plate was capable of showing a larger resolution of details. However, after evaluating the performance of the HR Kodak plate and GE plate, over the same acquisition condition and with the same size of the laser focal set of 87 μm, the results show a superiority in the GE equipment used for industrial radiographic, mainly for processed images in each specific ambient of digital processing and its performance in meeting satisfactorily the ASME code and the DIN standard.

1. Introduction

The computerized radiographic began in the early 1970s but just in the end of 1980 it was noticed an increase in the use of this technique in medicine. In the industrial area the application of the technique is recent as shown in some works presented on the 15th World Conference on Non-destructive Testing (WCNDT) [1-7], in Rome in 2002. And just the specific knowledge of the Imaging Plate, a digital image receptor, considered dated for the medicine, could be transferred to an industrial area due to its flexibility similar to the conventional film.

The Imaging Plate consists of a flexible photostimulable phosphor plate responsible for storing photons energy of the incident X and γ rays. This screen is submitted to a reader unit that utilizes a laser to stimulate the visible light. Once stimulated the visible light travels through fiberoptic up to a photomultiplier tube responsible for amplifying the electronic signal and then it is quantified by an analogical-digital converter (ADC) [8]. The signals are quantified on the position (x,y) correspondent to the photostimulable screen and stored on the computer memory for a future visualization and inspection by a specialist.

The acquired image system describes the process in which an image originated from an analogical detection system is converted in a digital image. This system is divided in two stages: the image formation and digitalization. The success of these stages depends on a radiographic technique for the exposition of the target study and of the image receptor system. It is important to emphasize that once the exposition technique had been defined for a such target study, the image receptor employed in this work, the imaging plate becomes the main responsible for the image quality. Therefore, two specific factors of the equipments are considered to have direct influence on the image, the size of the focal point of the laser, for image reading and digitalization, and the phosphor plate where the image is initially formed.

The focal point is fixed in each equipment and the manufacturers use standard sizes with 100 μm and 50 μm, whereas the phosphor plate has specific features according to its manufacturer. Two types of phosphor plates are manufactured on the Imaging Plates equipments, one for general use (General Plate – GP) and another one for specific use (High Resolution – HR). The HR plates are capable of producing images with superior quality to the GP ones. The main factors that contribute to this difference are the composition and the thickness of the phosphor plates. The GP plate has a phosphor layer with a thickness of 300 μm, whereas the HR plate has a layer with a thickness of 150 μm.

To verify and prove the radiographic sensibility of the films used in the industrial radiography, it is employed image quality indicators – IQI defined by DIN EM 462 [9] standard or on the American Society of Mechanical Engineers – ASME code [10], always in conformity with the thickness of the metal sample, showing a solder with or without reinforcement and in conformity with the localization of the IQI during the exposure radiographic technique.

The radiographic sensibility of a film is verified through the IQI image defined and inserted in the image of the metal sample. Moreover, it is established a wire essential which is in fact a wire whose diameter indicates that the image shows a limited minimum quality of spatial resolution and therefore it is ready to the visualization and assessment. The wire essential is established in function of the thickness of the examined wall, type of material and type of solder. It is admitted that the wire essential is considered well visible when 10 mm long is visualized in the interest area of the radiography that can be on the solder or joint.

2. *Materials and Methods*

Digital images were obtained using an X-ray equipment of the Laboratório de Instrumentação Nuclear – LIN/COPPE as a radiation source. Four (04) standard metal samples were used as target study and Imaging Plates equipments of the ACR-2000i Kodak Industrex [11] and GE [12], as images receptors.

It was selected the wire Image Quality Indicators – IQI more adequate to the metal samples and that are commonly used in the conventional industrial radiography to evaluate the image quality formed in the radiographic films. According to ASME the IQI selected is indicated to heavy materials of group 1, which are carbon steels and according to the thickness of the pieces the B series is more indicated that goes from wire 6 to 11, with diameter ranging from 0.25 mm to 0.81 mm, respectively. It was also selected an IQI according to DIN standard for iron content materials that is the case of steel with a series of wires that goes from no 10 to no16 with diameter ranging from 0.40 mm to 0.10 mm (Table 1).

Table 1. Range of IQI and Identification Number of Wires (Codes ASME and DIN).

Series B ASME		Series 10/16 DIN	
Diameter	Nº of Wire	Diameter	Nº of Wire
0,25	6	0,40	10
0,33	7	0,32	11
0,40	8	0,25	12
0,51	9	0,20	13
0,64	10	0,16	14
0,81	11	0,12	15
		0,10	16

The first acquisition stage was performed using the exposure radiographic techniques. The images were obtained with the wire IQI (ASME and DIN) selected and always positioned over the solders, in the centre of the screens, as it is recommended to the films. It was also used the double wires IQI, that range from 0.5 pl/mm to 20 pl/mm. The radiographic exposure technique was optimized for each metal sample and performed with the low resolution phosphor plate (GP) and with high resolution (HR) of the Kodak Imaging Plate.

The objective of this stage is to verify if variation between low resolution and high resolution phosphor plate are noticed in the formation of the digital images and if some plate is capable of offering a higher resolution of details for industrial radiography.

The obtained images were analysed using a Kodak Industrex Lite 1.5 program in its original state and automatically processed by software. The images in its original state use all scale of gray color given by the computer. Whereas the processed images present histograms that privilege objects with intensity within a tonal range of the grey scale possibly performed through a mapping function.

The second stage of the acquisition was performed using just the HR plate of the Imaging Plate from another manufacturer – GE – and it was kept under the same conditions of the exposure radiographic techniques.

The aim of the second stage is to verify if the variations are notable between the phosphor plates of high resolution from the two manufactures of the Imaging Plate – Kodak and GE – on the formation of the digital images and which manufacturer is capable of offering a higher resolution of details for the industrial radiography.

The images were analysed and the results were compared with the two manufacturers in function of the sensibility indicated by the IQI on the original and processed images on its specific environment of processing. The laser focal point in both equipments is of 87 μm.

The ASME code has established that a digitalization system of radiographic films has to be capable of solving a standard of 7 pl/mm for digitalized systems with a focal point with a size of 70 μm, or at least 5 pl/mm for focal points greater than 70 μm [10]. However the Imaging Plate equipments employed present a laser focal point of 87 μm and in this work it will be establish a standard of 7 pl/mm.

The results must be analysed to verify the images acceptability to visualize the imaging report, in function of the sensibility found on the images through each IQI used, and indicate if the proposed method to evaluate the spatial resolution of the digital images is also useful for monitor evaluation used in industrial radiography.

3. Results and Discussion

Variations were noticed on the digital image formation between phosphor plate of low and high resolution – GP and HR - Kodak, respectively. This deference of behaviour is attributed to the composition and thickness of the phosphor plates. The thinner phosphor layer with 150 μm of thickness (HR) decreases the probability of scattering of red light of the laser taking around 60 seconds to be read on the reader unit, despite the HR plate needs a double exposure time required by GP plate for the image formation. On GP plate with a thickness of 300 μm, offers a higher probability of scattering of red light of the laser for when it strikes on the phosphor layer, part of the light can to suffer scattering inside the layer for being thicker and needing a bigger interval of time to be read, taking around 80 seconds. When the laser light to suffer scattering the electrons trapped on the plate and the ones that load the useless information are not stimulated anymore and the information is not duly quantified.

Another factor is the size of the phosphor particles that are smaller on the HR plate – ranging from 4 μm to 5 μm , and on the GP plates they are almost the double – ranging from 8 μm to 10 μm. The smaller particles form smaller grains on the HR plate, creating lowest levels of bright and contrast on the obtained image. While the greater particles form greater grains on the GP plates, creating highest levels of bright and contrast on the obtained image.

Comparing the performance of GP and HR plates to give a greater resolution of details for the industrial radiography, the results show that the HR plate is superior to the GP plate, mainly processed images. So, the second stage was performed using just the HR plate of the GE equipment.

The results on the second stage shown in Table 2 show that the processed images presented again a greater sensibility for all samples. The distinguished wires are emphasized on the table. It is possible to notice that the HR plate – GE – was capable of offering a higher resolution of details for the industrial radiography than the HR plate – Kodak – mainly in function of IQI from ASME and DIN. However, it was not found results significantly different for double wire IQI.

Table 2. Metal samples digital images obtained with HP plate from GE.

Sample	Phosphor Plate	Image	ASTM 1B		DIN FE 10		Double Wire	
			Wire Found	Wire Essential	Wire Found	Wire Essential	Wire Found	Wire Essential
RING	HR	Original	-	6	-	12	5	7
		Processed	6*	6	12*	12	8*	7
	HR	Original	-	6	-	12	7*	7
		Processed	7	6	12*	12	8*	7
PIPE	HR	Original		5	-	13	8*	7
		Processed		5	13*	13	9*	7
	HR	Original		5	-	13	8*	7
		Processed		5	13*	13	8*	7
THIN PLATE	HR	Original	7	6	11	12	9*	7
		Processed	6*	6	14*	12	8*	7
THICK PLATE	HR	Original	11	9	-	9	7*	7
		Processed	7*	9	12*	9	7*	7
Where:	■ – indicates the IQI doesn't be used;							
	* – indicates the better results, when the found wire is equal or better the essential wire.							

On the RING images, obtained with GE equipment, it was found the essential wires, number 6 (ASTM) and number 12 (DIN), that correspond to details of 25 μm. While it was found details of 40 μm and 33 μm, on the obtained images using the Kodak equipment.

On the PIPE images it was found a similar result, with GE equipment, it was found details of 20 μm. While it was found details of 20 μm and 25 μm, on the obtained images using the Kodak equipment.

On the THIN PLATE images it was found a similar result, with GE equipment, it was found details of 25 μm and 16 μm. While it was found details of 20 μm and 25 μm, on the obtained images using the Kodak equipment.

On the THICK PLATE images it was found a similar result, with GE equipment, it was found details of 33 μm and 25 μm. While it was found details of 40 μm, on the obtained images using the Kodak equipment.

As the model of spatial resolution test given by Society of Motion and Picture Television - SMPTE standard image is considered inadequate, as shown in recent researches (13 and 14), and the metal samples images obtained in this work present a greater number of (visible wires) referring to each IQI, and mainly a greater quantity of pl/mm on the double wire IQI in relation to what is given on the test with the SMPTE standard image, thus these images can be used as standards to evaluate too the spatial resolution of the monitors assigned to industrial radiography and it can be used as a test on the monitors quality control.

4. Conclusions

More and more the workstation has been modernized using new technologies that are proposed, mainly when arise new opportunities to store important information in digital format without the necessity of controlling physical and biological agents as humidity, fungus and moth that decay and lead to the loss of these information as time goes by. That is why the industrial radiographic area has been investing in a gradual way in a environment digital for visualization. However, the efficiency of the visualization depends greatly on the stage of the image acquisition and the quality of the monitors, in which the images are visualized and problems with images acquisition could compromise the interpretation of these images due to the low spatial resolution.

To assure the capacity of offering a greater resolution of details for the industrial radiography, it was compared two Imaging Plates equipments from different manufacturers – Kodak and GE – where the images were produced with photostimulable phosphor plates of high (HR) and low (GP) resolution and then they were evaluated in function of the image quality indicators – IQI, according to ASME code and DIN standard, commonly used in the conventional industrial radiography.

The images produced by the plate with high resolution (HR) – Kodak – were capable of showing higher resolution of details in relation to the plate of general use (GP) from the same manufacturer. Although the HR plate – GE – showed results superior to the one that was reached with the HR plate – Kodak – under the same condition of acquisition and with the same size of the laser focal point that was of 87 μm. The results show the superiority of the GE equipment in relation to the Kodak one used for industrial radiography, mainly for the processed images in each specific environment of the digital processing and its performance in meeting satisfactorily the ASME and DIN codes, for the images spatial resolution for all of samples have shown equal or superior to the one which is established by ASME or DIN codes, conferring the images acceptability to visualization to be performed by the inspector. The same was not possible with the Kodak equipment for it responded to the ASME code just in relation to the double wire IQI.

To supply a deficiency of the SMPTE standard image the test to measure the spatial resolution proposed in this work with a greater number of *pl/mm* can be used to evaluate the spatial resolution and the monitor contrast, as a test applied on the procedure of quality control of the monitor used in the industrial radiography, considering that all line pairs per *mm* (*pl/mm*) are not discernible in all obtained images and that the (wire IQI) can be used for a estimative more refined of the spatial resolution.

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