Digitized Radiograph Processing for Better Vision and Evaluation

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Abstract: - In this investigation, the thickness loss and defects size were evaluated by gamma radiography technique. Defects which were studied were flat bottom holes. For this purpose, Foma R7 radiographs were digitized after processing in a Laser scanner. Some digital image processing filters also were applied for noise smoothing. The information of images was saved in the matrix form of gray levels. Gray levels were changed to optical densities by assessment the reference radiograph. The density of each point of radiograph was compared with a reference point and by considering the effective linear atomic absorption coefficient thickness loss in any point of samples was quantified in Matlab environment. Results indicated that this method can be used successfully for providing the thickness profile of pipe and plates.

KEY-WORDS: - Radiograph Digitizing; Thickness Profile; Optical Density; Gray Level

1 Introduction

Direct radiography is the most advantage of Real Time Radiography (RTR) which is a non-destructive testing (NDT) method, whereby an image is produced electronically rather than on film so that very little time occurs between the item being exposed to radiation and the resulting image. Though advances have been made in digital radiography, most of radiographies are still performed with conventional films in industrial applications, especially due to limitations in the spatial resolution of the digital radiographic systems. Digital imaging provides the ability to store the detailed analog information of radiograph in digital form and it makes possible the application of image processing. Two techniques of digital image production is available, film less by means of using imaging plates where image is directly converted to digital signal and digitized radiography films.

In film digitization, optical densities of conventional radiograph are converted into gray levels by measuring the light transmitted through the film. A charge coupled device or a laser device can be used for scanning system. Density range, pixel size and scanning system affect the quality of digitized film. General requirements of digitizing can be seen in refs. [1-4]. Converting measured optical densities into exposure values will lead to extract important details of object. In medical application the digital radiography is more developed than that in industrial applications. Exposure response of film is a function of geometrical arrangement of radiography, photon beam energy and film processing condition. Defect orientation, size and depth can be estimated by exposure measurements. Radiation application in medicine researchers have shown that film response increases with depth and defect size, also specimen height and size affect the film response [5-7]. It has been claimed that film sensitivity strongly depend on depth but weakly dependent on field size [5]. Sykes [6] found little change in sensitivity with depth (5-15 cm) for field sizes less than 10×10 cm2 and Danciu [7] was found response of films was virtually independent on film orientation.

Optical density of radiograph has a relation with exposure as well as beam path thickness. So, if a numerical approach can be found for these relations, defects and corrosion size and depth can be quantified. Corrosion detection has been studied so far by digitized radiographs [9-14]. Scattering effect also has been used for calculating the thickness of pipes with an error less than ±0.5 mm [15-16]. Digital tangential radiography also has been used for corrosion detection in pipes [9,11,17].

The method which has been used by several authors calculates the thickness loss of pipe or plates as compared with a reference point [8,12,13,18]. The basis of this method is related to this fact which optical density has a linear relation with radiation intensity and relating to a thickness by linear atomic absorption coefficient. Effective atomic absorption coefficient is strongly different than its theoretical values and shall be measured by using the calibration blocks [18], due to

radiation scattering. In the first part of the present investigation which this method was investigated, effective linear atomic absorption coefficient was calculated by assessment the calibration blocks. Then in the second part of the study, a numerical method was suggested for thickness calculation by assessment the characteristic curve of radiograph.

2 Experimental Procedures

An inside-machined cylindrical step block with outside diameter of 165 mm (8 step with thicknesses of 4.2, 5.6, 7.1, 8.6, 10.1, 11.5, 12.8 and 14.7 mm) as well as a step plate block with 100 mm width (5 step with thicknesses of 5, 10, 15, 20 and 25 mm), as shown in Fig. 1, were provided for studies. A flat bottom hole in each step of pipe block was machined which its diameter was equal to step thickness and its depth was equal to 50% of step wall thickness. Material of blocks was St-37. A gamma projector with Ir-192 source was used for exposures. Foma R7/pb was used as radiography film. Radiography arrangement was double wall single image, as shown in Fig. 2.

Processed Radiographs were digitized by a Microtek 8700 scanner. According to EN 14096 and ASTM E1937, the sensitivity and calibration of scanner were tested by assessment the maintained methods and standard EPRI film [3,4,19]. In each scanning process, a density step calibration tablet was scanned with radiograph to control the relation between the optical density of radiographs and gray level. Scanned radiographs are shown in Fig. 3.

Matlab V.6.5.1 environment was used for image processing. Each radiograph was converted to a matrix form of gray levels. Images were filtered initially for noise removing. Some information for image processing can be found in refs. [20-23]. By using these filters inherent unsharpness of conventional film should be removed, completely. The relation between the gray levels and optical densities was calculated by assessment the reference density radiograph. Gray level matrix was changed to optical density matrix. A point with the minimum density was selected as reference point. Then the difference of thickness in any point of radiograph as compared with reference point was calculated by comparing the optical densities.

In the second part of the study, characteristic curve of R7 radiographs firstly was drawn. Then a numerical model was obtained and density matrix was changed to thickness matrix by feeding radiographic data into the program in Matlab V.6.5.1 environment.
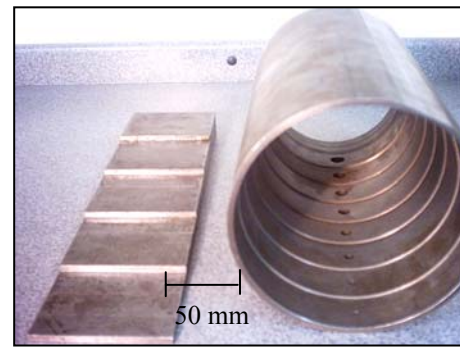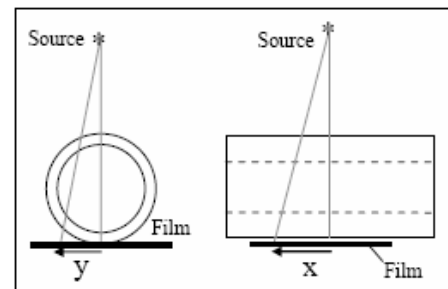

Fig. 1- Step pipe and plate

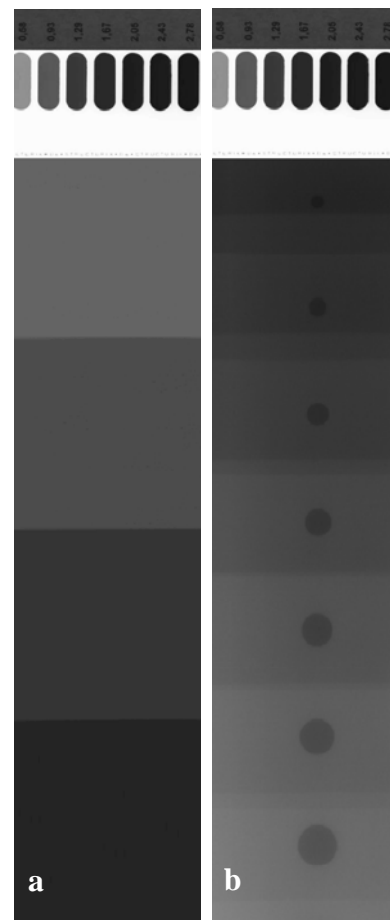Fig. 2- Radiography arrangement and introducing parameters

Fig. 3- Scanned radiographs: a) step plate and b) step pipe

3 Results and Discussion

The radiation intensity (I) for a radioactive source which passes through a material, having th thickness, is given by:

$$I = I_0 .ti. \exp(-\mu_{eff} .th) \tag{1}$$

where I is exposure in Roentgen, ti exposure time, I_0 initial intensity, th thickness of material and μ_{eff} is effective linear atomic absorption coefficient. I_0 can be given by:

$$I_0 = RHM .A.SFD^{-2} \tag{2}$$

RHM is the radiation exposure at one meter distance to source in Roentgen per hour, A is activity of source and SFD is source to film distance. It can be seen that the increased optical density of radiographs (optical density minus fog density) usually has a linear relation with radiation intensity, as is followed:

$$D - D_{fog} = k.I \tag{3}$$

where D is optical density, D_{fog} is inherent density of radiograph ($D_{fog} \sim 0.29$), k is film gradient coefficient depend on the film and radiation source type. The change of optical density as a function of exposure in Roentgen is shown in Fig. 4 for an Ir-192 source and Foma R7 and R4 film. The variation of optical density as a function of exposure is called as characteristics curve.
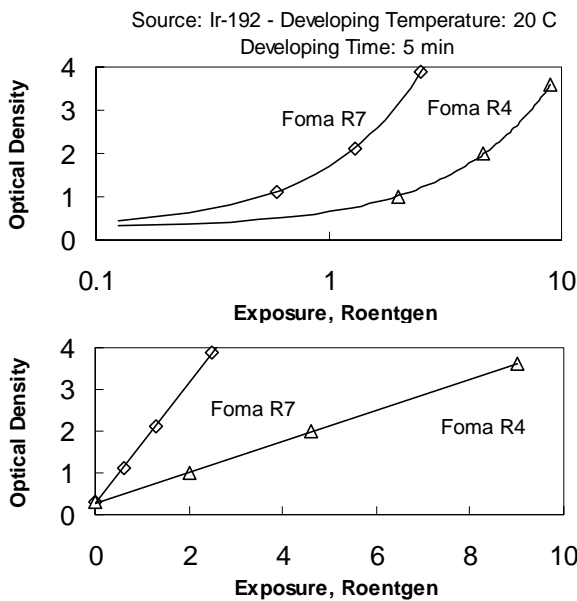

Fig. 4- The relation between the optical density and exposure for Foma R4 and R7 radiographs and Ir-192 gamma source

According to Equations (1) and (3), the relation between the thickness and optical density can be given by:

$$th - th_R = \frac{1}{\mu_{eff}} \ln(\frac{I}{I_R}) \tag{4}$$

$$h = \frac{1}{\mu_{eff}} \ln(\frac{D - D_{fog}}{D_R - D_{fog}}) \tag{5}$$

t and t_R are the thickness of interested point and references point, respectively, I and I_R are the exposure in Roentgen in interested and references point, D and D_R are the optical density in interested and references point and h is thickness differences between the interested and references point. The method for calculation of μ_{eff} is using calibration blocks. Obtained results for μ_{eff} is 0.041mm^{-1} for St-37 with Ir-192 source.

When source to film distance is large enough, Equation (5) can be used successfully for drawing the thickness profile of pipe or plates. When source to film distance is small, then, according to author's observations, D and D_R should be replaced by following values, respectively:

$$D \div \cos^n(\alpha) \rightarrow D \tag{6}$$

$$D_R \div \cos^n(\alpha) \rightarrow D_R \tag{7}$$

α is the degree between the radiation vector and the normal vector of the surface. Power of n is a constant in the range of 4-8 depending on the source to film distance and length of area of interest. Our experiments showed that n=5 was acceptable for many samples.

In digitized radiographs, gray levels at the first should be changed to optical densities by assessment the reference density radiograph, then in a suitable software, thickness loss as well as thickness can be monitored by using the mentioned equations. The results showed that a logarithmic relation between the gray level and optical density can be found in the density range of 0.5 to 3. The relation between the optical density and gray levels for radiographs of this study can be seen in Fig. 5. It should be noticed that this relation is different in each radiograph scanning system [1]. So, using the reference radiograph in each scanning procedure, as used in Fig. 3, would be necessary.
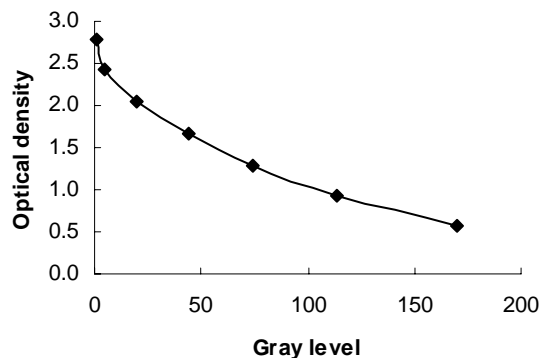

Fig. 5- The relation between the optical densities and gray levels for a 8-bit image
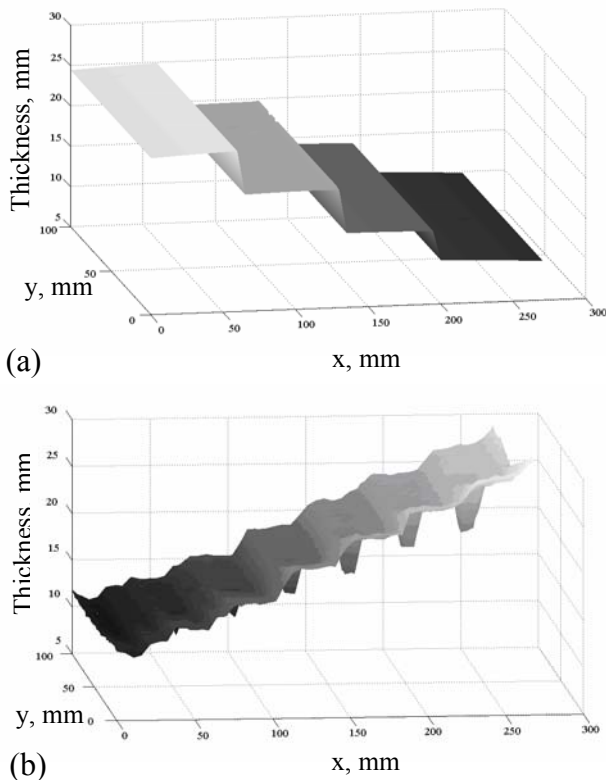
(a)

(b)

Fig. 6- The variation of thickness along the X and Y axis, calculated by Equation (5) for: a) plate and b) pipe

The variation of thickness profile which obtained by Equation (5) can be seen in Figs. 6a and 6b for the plate and the pipe, respectively.

It is important that by digitizing the radiograph a three dimensional image of specimen can be produced. The method which was used in this work is adoptable with the previous studies [24-27]. Defect size and thickness loss are visible in this method. Any density higher than the fog density is acceptable in this method for inspecting. Some defects, which can not be seen visually, may be interpreted in this method by image processing. It should be considered that orientation of defect and edge effects are highly affecting the precision of this method. This method is suitable when it is necessary to monitor large defects such as pitting, erosion and corrosion defects. The accuracy of this method can be increased by increasing the number of exposures for a specimen. One of the most important advantages of this method is that the insulation of pipe or plate will not affect the result of this technique as compared to ultrasonic scanning system.

4 Conclusions

The thickness profiles of the pipes and plates were quantified by assessment the radiograph digitizing and image processing in a program developed in Matlab environment. Images were saved in the gray level and optical density matrixes, respectively. Optical density was changed to thickness loss and thickness in three dimensional co-ordinates. This method is sensitive to density variation as well as thickness variations and can be used successfully for thickness monitoring and large defects.

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