

Evaluation of an Automatic Thickness Measurement System for Digitized Radiographs

Mehran TAHERI, A. MOVAFEGHI, N. MOHAMMADZADEH,
B. ROKROK, K. EDALATI, N. RASTKHAH,

Department of NDT, Radiation Protection Technological Center, INRA, Tehran, Iran

Abstract. Digital radiography is considered in this research. It can be done with different methods. In this research, film digitization is carried out directly by the CCD based scanner. Then, a semi-automatic digitization and image processing system is developed. The system uses a CCD-based scanner which can scan optical densities up to 4.2. The proposed system was used to apply various image processing and computer vision algorithms to improve the quality of digitized radiographic films and to calculate necessary information such as minimum, maximum and mean Optical Density (OD) of Region Of Interest (ROI). Also this software has been designed for analysing of digitized radiographs via measurement of optical densities and determination of line and surface OD profiles of ROI. These outputs can help us to make a construction of 3D mapping of corroded pipeline areas. This software has been written in MATLAB environment.

1. Introduction

Radiographic inspection is the most appreciated technique among the other non-destructive testing methods due to producing unique finger print record as the film. Digital radiography is performed in two ways [1]: directly by using digital radiography detectors (e.g. flat panel detectors and/or phosphor imaging plates); sometimes referred as film-less radiography; and indirectly by digitization of the high resolution films. The first method contrary to the second one is not able to create the appropriate resolution to identify gentle defects. Two types of scanners are available for digitization: CCD based and Laser based. A CCD based scanner is cheaper but produces lower quality images in comparison with the first one. In this research, a semi-automatic digitization and image processing system is developed. The system uses a CCD-based scanner which can scan optical densities up to 4.2. The proposed system was used to apply various image processing and computer vision algorithms to improve the quality of digitized radiographic films and to calculate necessary information such as minimum, maximum and mean Optical Density (OD) of Region Of Interest (ROI). Also this software has been designed for analysis of digitized radiographs via measurement of optical densities and determination of line and surface OD profiles of ROI. These outputs can help us to make a construction of 3D mapping of corroded pipeline areas. This software has been written in MATLAB environment.

2. Methods

2.1 Image digitizing and processing

The digital image converter used is Microtek ScanMaker i900 professional scanner which provides Dual-Media scanning and delivers productivity features with its 6400 x 3200 dpi optical resolution, 48-bit colour depth and optical densities up to 4.2 (max). The radiographic films are digitized by the scanner with a 16 bit image depth (gray levels) and a resolution of 600 dpi. Fig. 1 illustrates this scanner and a calibration film.



Fig. 1 The film scanner with a calibration film

The Microtek scanner ICC profiler (MSP) is a scanner calibration and profiling utility program exclusively designed for Microtek scanners. Used together with the colour calibration target (industry-standard Kodak® colour transparent film: Q-60), the ICC profiler determines the colour attributes of the scanner accurately. In addition to ICC profiler, a calibration film is used for correct automatic conversion of gray-level values to optical density values. This film is shown at Fig. 2 and used in every scanning.

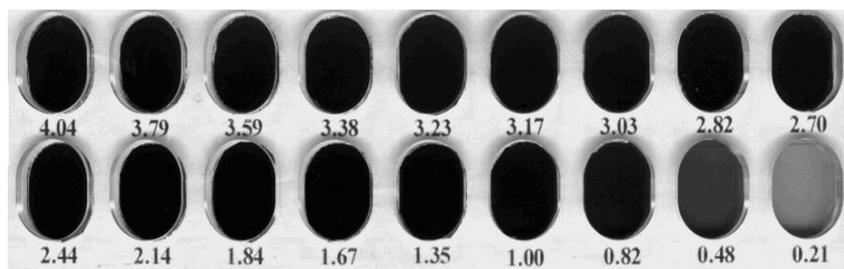


Fig. 2 The calibration film

2.2 Image Enhancement

The radiographic image processing is especially used to improve the image quality and making analysis process easier. The proposed algorithms have been developed and applied in MATLAB environment in order to enhance recognition of flaws. The technique, which was introduced in this paper, eliminates the noises by means of digital filters and improvement the contrast.

Median filtering is a nonlinear operation often used for reducing the noise and preserving edge simultaneously [2]. The image is viewed as a surface, with mountain (high intensity) and valleys (low intensity). It is desirable to maximize the contrast of objects of interest for minimizing the number of valleys. The contrast enhancement technique is the combined use of the top-hat and bottom-hat transforms. The top-hat image contains the "peaks" of objects that fit the structuring element. So that the residual between original image and opening image can be defined as Top-Hat transform. In contrast, the bottom-hat image shows the gaps between the objects of interest. In fact, the residual between closing image and original image is denoted Bottom-Hat transform [3]. To maximize the contrast between the objects and the gaps that separate them from each other, the "bottom-hat" image is subtracted from the "original + top-hat" image.

$$T-H(f, k) = f - (f \circ k) \quad (1)$$

$$B-H(f, k) = (f \bullet k) - f \quad (2)$$

and

$$Opt-cont = (T-H(f, k) + f) - B-H(f, k) \quad (3)$$

where "f" and "k" are the gray-scale image and the gray-scale structuring element, respectively.

2.2 Three Dimensional Profile Images Reconstruction

In this section, we used a predefined thickness measurement method for steel pipes [4]. Thicknesses values are evaluated using this relation for Ir-192 and Kodak AA-400 radiography film:

$$D = 900 \cdot \left(\cos\left(\frac{r}{OD}\right) \right)^{0.6692} \cdot E^{0.6692} \cdot SFD^{-1.3384} \cdot e^{-0.0320 \cdot t} \quad (4)$$

where t is thickness, E is exposure in Ci.min, D is optical density, OD is outer diameter of pipe and SFD is source to film distance. Then in MATLAB, the thickness values are mapped in a 3-dimensional profile images. The specimen is shown in Fig. 3. The specimen material is St-37 steel. So far, the accuracy of this model is shown [4].

Fig. 3 A 10 inch reference pipe block with internal flat bottom holes (as pitting), depth of pitting is 50% of through step wall thickness



Results and Discussion

Fig. 4 shows a test specimen (a girth welded pipe) and its images. Original digitized radiograph is shown in Fig 4 b. An unsupervised wavelet transform is applied on 4b and result is shown on Fig. 4c. Processed image with equation (3) is illustrated on Fig. 4d. It is clearly seen that Fig. 4d can provide better contrast for radiographic interpretation.

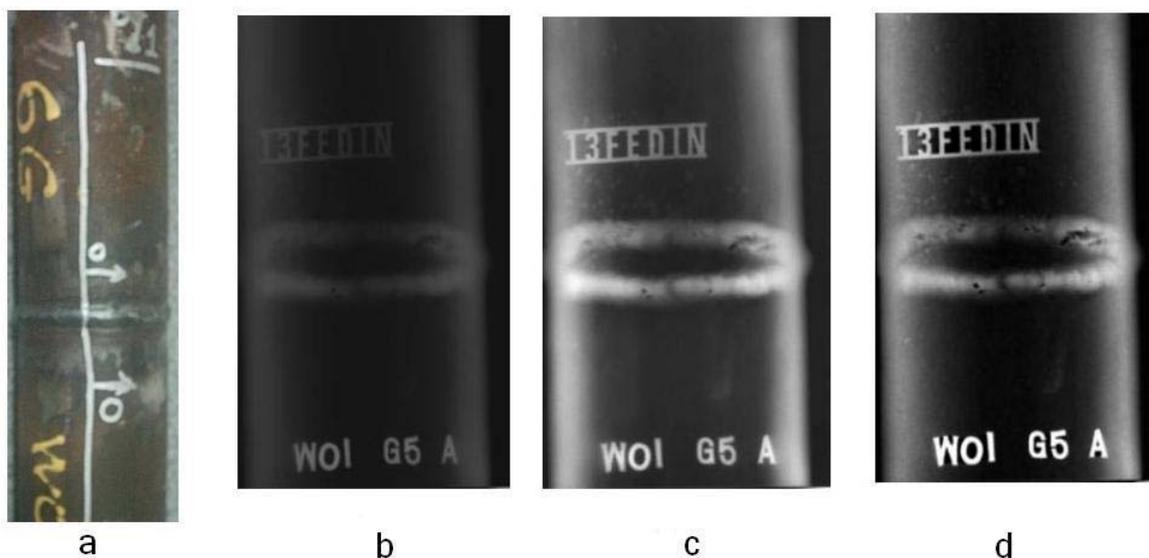
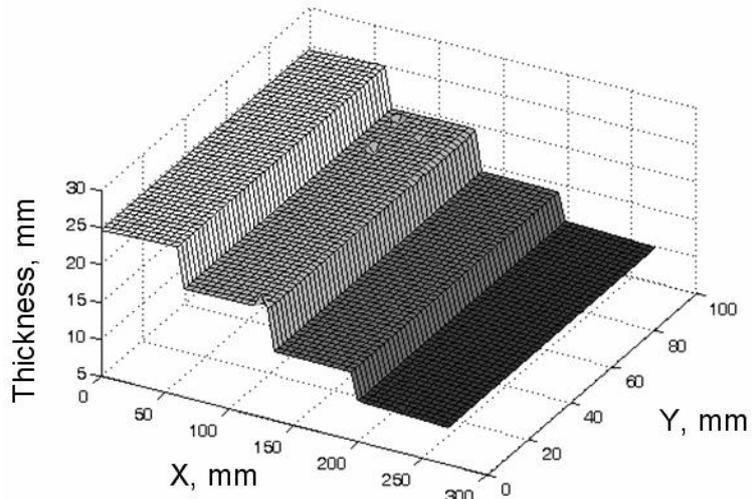


Fig. 4: a) Specimen: a girth welded pipe b) original digitized radiograph
c) Processed image using wavelet transform d) processed image with proposed method

Fig. 5 shows the calculated thickness profile of a step plate, with thicknesses of 10, 15, 20 and 25 mm. For thickness calculation equation 4 is used. Then, it is converted to a 3-D mapped image which can provide a spatial imagination of the results. This is very useful for detecting of some unknown defects which may exist in the test specimen.

Fig. 5 The calculated thickness profile of a step plate, with thicknesses of 10, 15, 20 and 25 mm



Conclusions

A numerical method is used for calculating the remained thickness and corroded depth. Also the constructed digitized radiograph of pipe and plates was converted to thickness profile by using obtained equation. Results were shown an acceptable accuracy of thickness measurement. It was also observed that some details which could not be inspected visually were detected by this technique.

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