Development of X-ray Imaging System for Facility Diagnosis in a Narrow Space Crowded with Many Pipes

Background

Inspection of stress corrosion cracking *1 and thinning of pipe walls in power plants and other facilities is a key issue to keep facility soundness. Since most plant facilities are complicatedly crowded with many pipes, development of x-ray imaging techniques applicable to narrow spaces (-10cm) is desired. In addition, an online system without post-processing such as development of an x-ray film is very useful in case of retry at the same point, especially in narrow spaces to which accessing is not easy.

Objectives

The purpose of this study is to develop an online x-ray imaging system applicable to narrow spaces in plant facilities which are crowded with many pipes.

Principal Results

1. Construction of an x-ray imaging system

A small x-ray image sensor using CCD *2 was selected as a detector for online measurement in narrow spaces. Furthermore, by attachment of this small sensor to an x-y stage for sensor scanning, wide regional diagnosis was possible (Fig. 1).

2. Reduction in recording time of radiography

Since the number of scanning points should be large for wide regional diagnosis, it is strongly desired that the recording time of each point should be short enough for efficient work. Here, in order to increase the sensitivity for high-energy x-rays, the CsI scintillator of the sensor was customized by thickening (Fig. 2). As a result, the recording time of each point was reduced to approximately 1 minute *3 for a pipe with elbow (the outer diameter is 60.5 mm with 8.7 mm thickness) which is used in power plant facilities. As for image quality, the minimum perceptible wire diameters of pentameters measured by the sensor are equivalent to those of x-ray film standards.

3. Image processing for obtaining a smooth x-ray image

Using the developed x-ray imaging system, scanned x-ray images of a pipe with a mock thinning were obtained. In order to reduce discontinuities at connection boundaries, software of rotation compensation and linear image synthesis was developed. Furthermore, we clarified that an image-processing filter *4 based on a human vision model is useful to increase the visibility of the connected image (Fig. 3).

Future Developments

We will estimate the validity of the developed imaging system on site and try for practical use.

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Reference

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Y. Oishi, et al., 2008, “Development of an X-ray Imaging System for Facility Diagnosis in Narrow Spaces”, CRIEPI Report H07006 (in Japanese)

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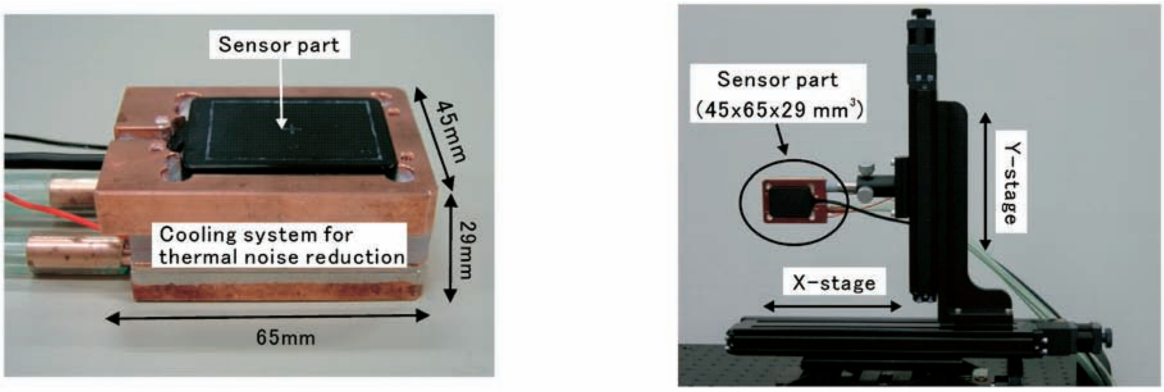
*1 : A phenomena in which a cracking arises at some parts, especially a pipe welding part, without striking force under an environment where metals are apt to corrode.

*2 : Abbreviation of Charge Coupled Device. CCDs are widely used in video cameras.

*3 : The recording time of each scanning point under the following condtions: ^{192}Ir radioactive isotope (8.2Ci ≒ 3.0×10^{11} Bq) irradiation, 30cm distance from the x-ray source to the sensor , and 24mm × 34mm size.

*4 : Here, a retinex filter was applied to the connected image. This filter makes the applied region noticeable from other regions and increases the visibility of the image.



(a) Magnification of the sensor part (b) Appearance of the system

Fig.1 X-ray imaging system for facility diagnosis in a narrow space

An online x-ray imaging system appicalbe to a narrow space (-10cm) was developed.

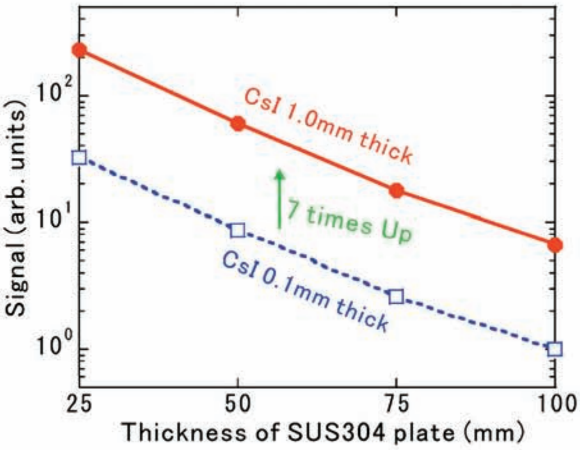


Fig.2 Comparison of sensor sensitivity

By thickening of the sensor scintillator, sensitivity increased approximately 7 times.

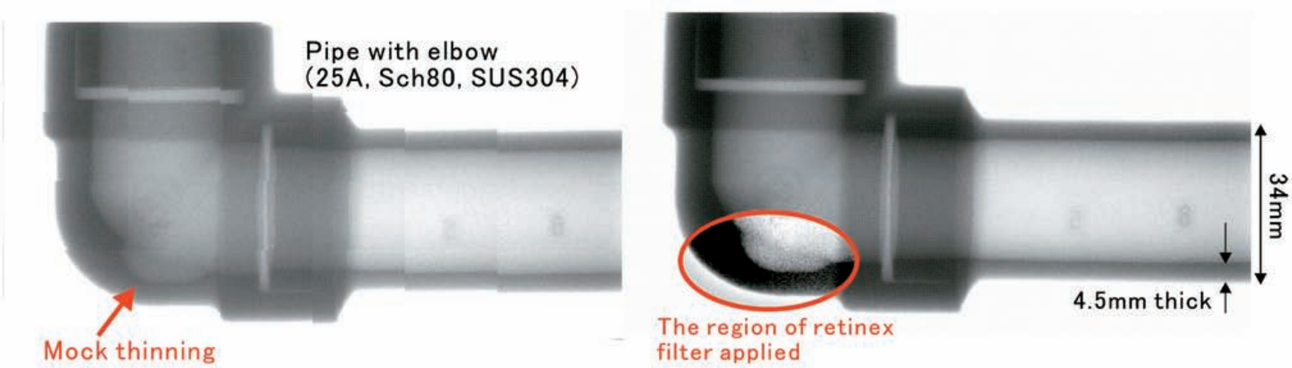
Table 1 The minimum perceptible wire diameter※a

SUS304 Thickness (mm)	X-ray imaging sytem CsI 1.0mm thick	X-ray imaging sytem CsI 0.1mm thick	X-ray film (standard values) ※b
50	0.63	0.63	0.8
75	1.0	1.25※c	1.0
100	1.25	>3.2※c	1.25

(mm)

※a 16S and 32S determined by JIS Z 2306 were used.
※b JIS Z 3106 A Class
※c Estimation by 900sec irradiation

The minimum perceptible wire diameters measured by 1 mm thick CsI are equivalent to those of x-ray film standards.



(a) X-ray image connection consisting of 6×4 images (b) After image processing of rotation compensation and linear image synthesis

X-ray source: ^{192}Ir(7Ci), 90sec irradiaton per image, Sensor: 0.1mm thick CsI

Fig.3 Image processing for obtaining a smooth x-ray image

Image processing of rotation compensation and linear image synthesis reduced discontinuities at connection boundaries. And the visibility of the mock thinning part increased by retinex filter.