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RADIOSCOPY-BASED DIGITAL RADIOGRAPHY SYSTEM FOR INDUSTRY

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ABSTRACT

A hand-made radioscopy-based digital radiography system has been made for earthenware and ceramic quality inspection at the Kasongan Handycraft Centre of Bantul, Special Region of Yogyakarta, Indonesia. It consists of an x-ray generator of 75 kV, 20 mA that can be operated using 220 VAC, a digital image converter of x-ray radioscopy, an object conveyer for sample loading and unloading, a digital image capture apparatus, and a computer system along with some software developed in our research group. The first software is software for digital image capturing and controlling conveyer. The second software is for image manipulation, processing and analysis. Some object has been tested to explore its capabilities. This paper reports the performance of the system based on some IQI standards and real object.

Keywords: *Digital radiography, earthenware, non-destructive inspection, radioscopy*

INTRODUCTION

X-ray radioscopy system (Boerner and Strecker, 1988; Wang et al., 2008) is one of old fashion system for real time analog inspection process. It consists of an x-ray generator and a radioscopy unit based on fluorescence screen (Ercoli and della Rocca, 2000; Nakajima et al., 1992; Pesce et al., 1995). The fluorescence material may be found on a conventional film cassette. The x-ray is exposed to the object with continuous x-ray burst (van Landeghem and Suys, 1980). This process is called fluoroscopy mode, which is in contrast with radiography mode that used impulsive x-ray burst. The fluoroscopy mode is usually used for real time online inspection, while the radiography mode is commonly used in conjunction with film radiography (Nikl, 2006). Therefore, a radioscopy system is mostly used for quick and direct inspection without a need for image documentation. Once an image document is necessary, film radiography is applied, and so a radiography mode is applied (Suparta et al., 2005).

An industrial radioscopy system (Ghose and Kankane, 2008; Peng, 2008) uses lower anode-cathode voltage (HV voltage in kV), low filament current (in mA), but longer exposure time in comparison to the radiography system that using film radiography. For online inspection, it may take 3-15 seconds exposure depend on the purpose. Exposure time may increase depend on operator experience. On the other hand, a radiography system is normally taken in less than 1 sec, but it needs higher HV voltage and higher filament current to ensure a good quality of x-ray shadow to the radiography film is achieved (Suparta et al., 2005).

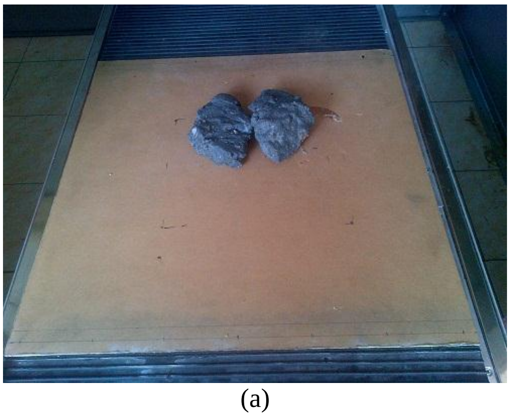
Since digital radiography becomes a technology trend (Harara, 2008; MacMahon, 2002; Patel, 2005), any analog system may be converted to be digital system or replaced by a new system with supposed to provide equivalent quality. A computed radiography (CR) system has been introduced, but it is too expensive and it is still indirect process. No significant benefits are gained when it used for industrial inspection since it fails to perform online direct inspection. On the other hand, a direct digital radiography (DDR) system is introduced. Although this system can perform direct process to obtain digital images, it is certainly unable to be used for online direct inspection (Lestari and Suparta, 2010; Suparta et al., 2009; Suparta et al., 2010). The electronic sensor devices on the system are considered very fragile for long time exposure or intensive x-ray burst. However, for those two systems, all needs digitization process, which is technically very fast.

A radioscopy system is essentially a visual presentation. Thus, a radioscopy image can be converted into digital image directly based on video or photograph digitization (Suparta et al., 2005). The quality of digital image is increased when the digitization process is performed in total dark environment. The digital image resulted can be transferred online to a digital display, e.g. computer monitor display.

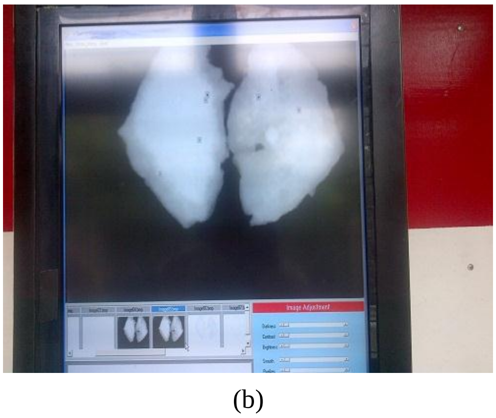
Once a digital radioscopy system can be developed (Suparta et al., 2005), an online digital inspection can be performed. However, such online digital radioscopy system is still hazardous since it takes long exposure, more than 3 seconds. Therefore, an attempt to reduce radiation exposure has to be explored. This paper reports an attempt on developing a digital radioscopy system. The system is specifically used for industrial inspection, especially for quality inspection of earthenware or ceramic products.

MATERIALS AND METHODS

A digital radioscopy system has been developed at the Department of Physics, Gadjah Mada University Yogyakarta Indonesia (Nakajima et al., 1992). It has been installed at the Kasongan Handycraft Centre of Bantul, Special Region of Yogyakarta, Indonesia for earthenware and ceramic quality inspection. It consisted of an x-ray unit that is powered by a 220 VAC. It provides HV voltage up to 75 kV and filament current up to 25 mA. Exposure time for radioscopy mode can last for 3 minutes, while exposure time for radiography mode may start from 0.1 sec. The system was look like an x-ray baggage scanner, normally found at an airport as is shown in Figure 1.



(a)



(b)

Figure 1: A radioscopy-based digital radioscopy system at the Gadjah Mada University. (a) Object on conveyer, (b) Display monitor and control panel

A target object was put on the object plate which was become unity with the conveyer belt. Then, when an inspection was carried out, the object plate was moved by operating the rotating motor so that the conveyer moved. Once the object plate reached a right position below the x-ray unit, a sensing unit triggered an automatic x-ray exposure. Therefore exposure time could be set at a radiography mode for very short expose, e.g. 0.25 – 0.50 seconds. The extra benefit obtained since the x-ray power can be set at radioscopy mode for 75 kV and 25 mA. Thus, the system has used the best combination of x-ray power and time exposure. High power was used to ensure a good penetration to the object was obtained, while a low radiation dose was achieved due to short exposure.

A digitization process was performed using a conversion of dynamic visual shadow in the dark box, called converter unit. Using a CCD camera, the visual shadow was converted into video signal. Then, the video signal was converted into digital image. The system was set to convert a time lapsed video capturing to yield 20 digital images per second. However, since the exposure time was set for 0.25 sec the number of good images obtained was about 3-5 images per exposure. All images could be displayed directly on the monitor display as digital images. Thus, the system definitely could be used for online direct real time inspection.

In order to obtain better quality image, all good images were processed to yield single good image. Firstly, a normalization using background images was carried out. After that, an image summation followed by images averaging process for all good images was performed. This was expected to reduce quantum noise. A further noise reduction was performed to remove high or low frequency signal to provide a good visual and acceptable image.

Objects being scanned are shown in Figure 2. A standard ASTM wire tester (Figure 2 (a)) was used to examine the system performance. An earthenware product e.g. ash tray (Figure 2 (b)) and a flower vast (Figure 2 (c)) as an example of ceramic product were examined.

(a) (b) (c)

Figure 2: Real objects to test radioscopy-based digital radiography system. (a) wire test, (b) ash tray, and (c) vast

RESULTS AND DISCUSSION

Performance testing to the system has been carried out using a set of wire tester. The original radiography image resulted is shown in Figure 3(a). Then, after a summation process for all obtained good images, a less noisy image was obtained as shown in Figure 3(b). The image quality was still unsatisfying although its grey-level histogram was look well distributed. Therefore, a further window leveling was carried out so that a better contrast and brightness was achieved as shown in Figure 3(c). It was more natural since a radiograph of wire test should have no degradation grey level. A further noise removal was carried out so that the image looks have good contrast and good brightness, while its grey-level histogram has good shape in Figure 3(d). The thinnest wire can be identified well.

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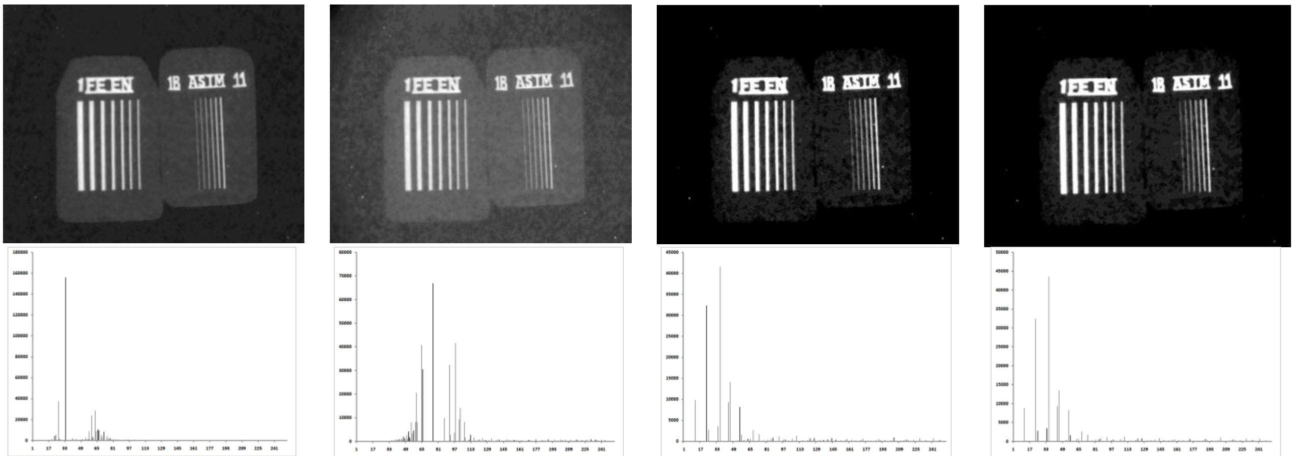
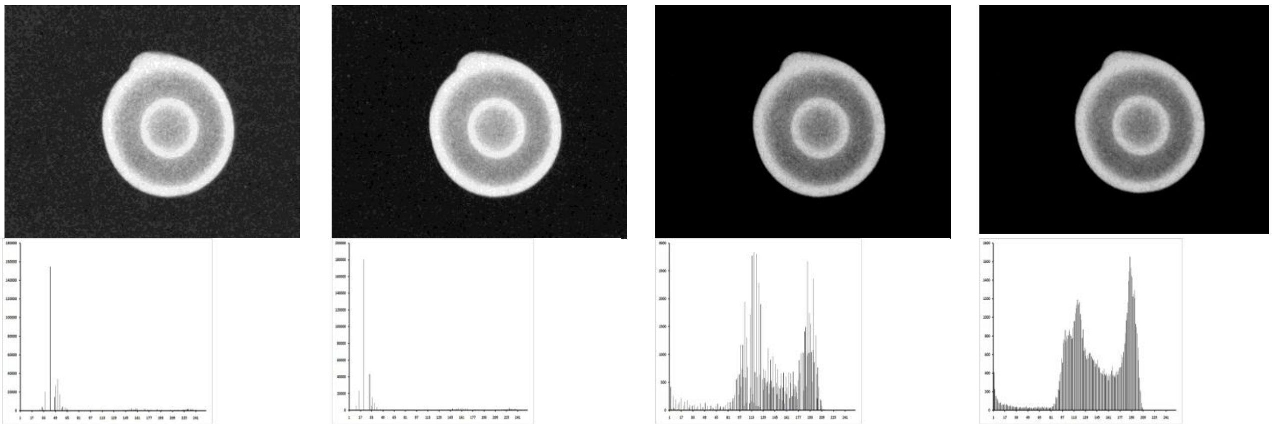
Further testing has been carried out using a real earthenware object, a small ash tray. The original radiography image resulted is shown in Figure 4(a) and in Figure 4(b) a less noisy image yielded from a summation process for all obtained good images is shown. The image quality was unsatisfying since its grey-level histogram tends to dark. Therefore, a further window leveling was carried out to obtain better contrast and brightness, as shown in Figure 4(c). It was more acceptable since the radiograph of ash tray should have degradation grey level. To ensure good contrast and good brightness image was obtained, a further noise removal was carried out. As a result, its grey-level histogram has good shape as shown in Figure 4(d). The defect was indicated well by non-uniformity in the centre of image.



(a) (b) (c) (d)

Figure 3: Radiographs of wire test along with their consecutive histogram

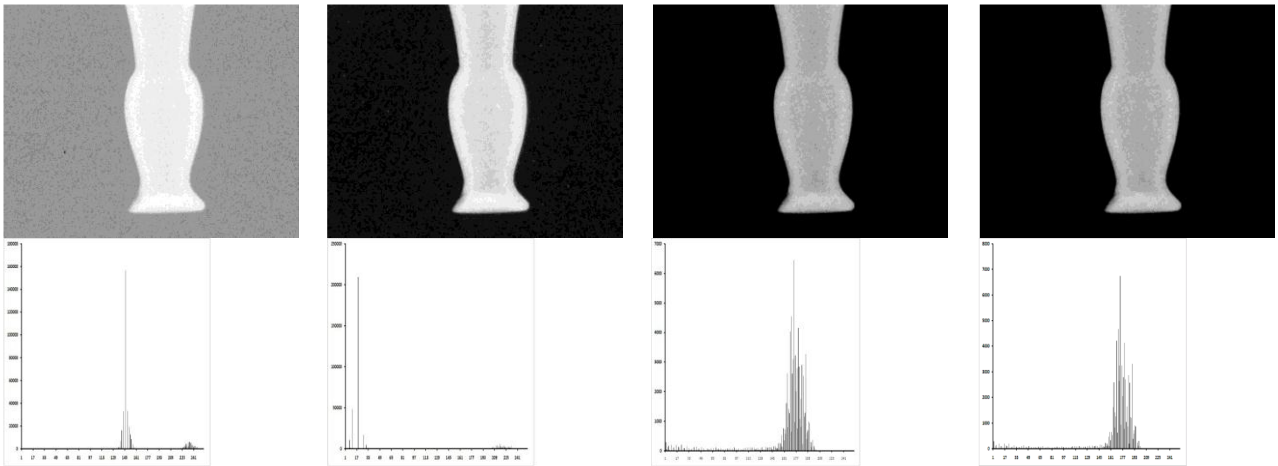


(a) (b) (c) (d)

Figure 4: Radiographs of ash tray, as an example of earthenware along with their consecutive histogram

Another testing has also been carried out using a real ceramic object, a typical flower vas. The original radiography image resulted is shown in Figure 5(a). The image was less satisfying as it was indicated by its histogram. A less noisy image yielded from a summation process for all obtained good images is shown in Figure 5(b). The image quality was more natural since the material classification was clearly indicated. Ceramics has more fine material compared to earthenware. Therefore, the grey-level histogram tends to be well grouped. Therefore, when a further window leveling was carried out, a better contrast and brightness was obtained, as shown in Figure 5(c). To ensure good contrast and good brightness image was obtained, a further noise removal was carried out to yield image as shown in Figure 5(d). A defect on the bottom was indicated well.

From these results, good and quick digital images from radioscopy can be obtained using small x-ray power but were taken in radiography mode instead of fluoroscopy or radioscopy mode. A simple summation process to remove noise and further noise compensation may be applied. As a result, the good quality image in term of contrast and brightness can be displayed directly on the monitor display. Some internal defects can be examined using bare eyes. Thus, a quick inspection can be performed without much treatment in image processing.



(a) (b) (c) (d)

Figure 5: Radiographs of flower vas, made from ceramics along with their consecutive histogram

CONCLUSIONS

From this project we learned the way to develop an experimental unit for earthenware or ceramics product inspection system based on x-ray digital radiography system based on radioscopy. The system has worked for medium size of product such as vas or ash tray. It was able to distinguish internal crack and material redundant within product. The system can determine any crack in a size of 1 mm. A further test on materials characterization may be performed since the materials of earthenware or ceramics may comprise various materials.

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