Susilo

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Study of Lead as a Source X-ray Radiation Protection with an Analysis Grey Level Image

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Abstract. X-ray utilization in the medical field still has a potential danger for human. This occurs when exposure to x-ray radiation received exceeds the dose limit value. It requaires a radiation shielding to prevent the hazard, and lead is one of metals usually used as x-ray radiation shield. This work aims to determine the metallic lead properties to find out of the stepwedge lead radiograph image. The instruments used are the plane x-ray, digital radiography system and personal computer installed by MATLAB, while the material is stepwedge lead. The image of radiograph was analyzed using GUI applications on MATLAB software to determine the values of grey level from the image and the optical density of the radiograph image. The results showed the greater optical density the higher the image contrast, and the value of optical density in the image is inversely proportional to the voltage x-ray since the value of grey level at high voltage is smaller than that of at low voltage.

1. Introduction

X-ray is one of the radiation source used in medical field for diagnose the presence of a disease in the form of anatomy portrait featured in the film of radiography. For using x-ray one should pay some attention to work safe from its radiation, since x-ray still has a potential danger for humans. This happens if the x-ray radiation exposure received by humans exceeds the dose limit value, so that an attempt for x-ray radiation protection is required. The government has issued government regulation No. 33 of 2007 about safety radiation and security of sources radioactive. Determination of the limiting dose is exercised by Nuclear Energy Regulatory Agency of Indonesia (BAPETEN). Determination of the dose limit value based on ICRP (International Commission on Radiation Protection) at 2008 that the dose of radiation exposure must be below 20 mSv in one year [1].

Shield of radiation mandatory has two specific characters as the core of characteristics, i.e. it can absorb x-ray radiation, and it must not too thick since it is worn by workers working in the field radiation [2]. Thick retaining walls the primary radiation is a brick wall with thick 25 cm or concrete (ρ = 2.2 g/cm^3) with thick 15 cm equal to lead having thickness of 2 mm. Lead equivalent of concrete at each of these voltages as a function of the barrier thickness [3]. This shows that lead is very potential for shielding radiation. Lead is a stable nuclear in the last product of the radioactive series uranium, actinium, and thorium where if it interacts with α, β, γ or x – ray, it cannot decay into other elements, but the energy of the radiation will be absorbed since it has a high mass numbers and density. Lead has a mass density of 11,34 g/cm^3 so with the thickness of 2 mm lead can absorb the entire x-ray energy of 100 keV [4].

These days metallic lead has many benefits in life. One of its benefits is as the cover of electricity installation on the rooftop. Along with the development of technology, electricity installation on the housetop is no longer using lead as the cover. Therefore, the trace lead plate which is no longer used

will be waste and contaminate the environment. Lead is one metal that endure corrosion. The other benefit of lead is as shielding material of x-ray radiation. The x-ray's room uses lead plate as a radiation protection material. Thus it is needed a test toward trace lead plate as the material of x-ray radiation protection, so that the waste of trace lead plate can be decreased. The used method to find out absorption of a material was by measuring radiation intensity before and after passing through the material [5]. One of researches about metallic lead as the material of x-ray radiation protection was measuring dose rate of x-ray radiation, by measuring radiation dose rate it was known spare power of that material. This work did a test on radiograph image of stepwedge lead, so that it can be known that trace lead can be used as the material of x-ray radiation protection.

2. Methods

The instruments are plane x-ray mobile Mednif SF-100BY, digital radiogaphy, and PC using matlab, while the material is a plate of lead with the size of 11 cm x 12cm. This work used six lead plates tested with different thickness. After that the sample was photographed using a system of digital radiography. The digital radiography system using X-ray gives exposure to the object, then the unit light-tight tube based of intensifying screen. Intensifying screen is sensitive to X-ray function that is convert X-ray into visible light, next image is formed on the object can be captured by DSLR camera [6]. In the present work, we used exposure factor current 16 mA and exposure time of 0.10 s. while the x-ray tube voltage varied at 50 kV, 60 kV, 70 kV and 80 kV to determine the comparative value of grey level. Testing was done by arranging reciprocal resembles the stepwedge, exposure using digital radiography system and the results were analyzed using software GUI Matlab 2013. For make radiograph image analysis easier, it was GUI Matlab developed by entering some source codes so that the user only use it without knowing how the command work (Figure 1).

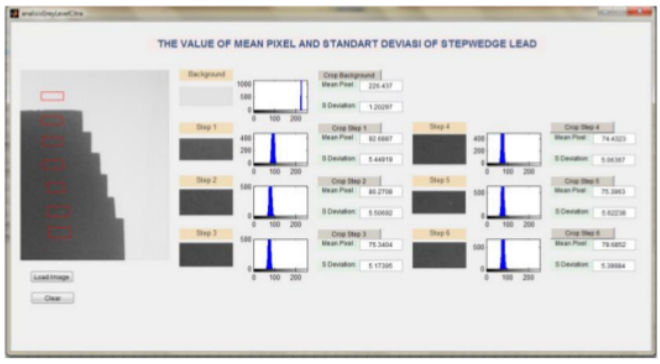

Figure 1. Display GUI Matlab Analysis

3. Result and Discussion

The factor affecting radiograph quality is exposure factor which consists of tube voltage (kV), tube current (mA) and exposure time (s). The right arrangement of exposure factor can produce optimum radiograph contrast which can show the grey level between objects having different density. The result of stepwedge lead radiograph image of the different voltages can be seen on Figure 2.

Figure 2 shows that the amount of x-ray voltage influences the result of radiograph image. On the voltage of 50 kV, image tends to be dark compare to that in the voltage of 60 kV. Image on the voltage of 60 kV tends to be dark compare to the image on the voltage of 70 kV and 80 kV. There is no significant difference from the stepwedge lead image. It needs an analysis using software MATLAB to find out the grey level from radiograph image. After doing analysis using software MATLAB, we can see the difference of grey level of stepwedge.

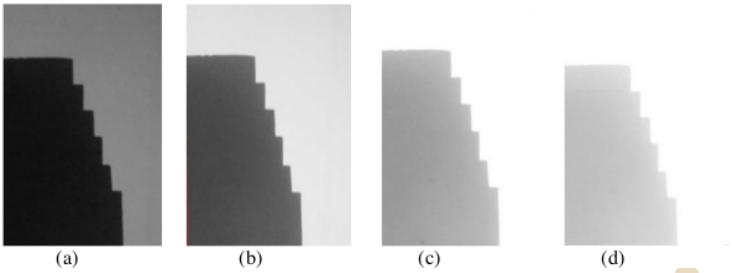

Figure 2. Radiograph image of stepwedge lead on voltage (kV) variation value : (b) 50 kV,(c) 60 kV, (d) 70 kV, and (e) 80 kV

According to [7], grey level image is comparable to the intensity of the x-ray beam, so the grey level value 0-255 can be used to determine the x-ray intensity I_o and I_x. Measurement of Optical Density (OD) value uses Grey Level (GL) can be done as in the determination of optical density with x-ray intensities Io and Ix, so the DO value using grey level can be written as [8]:

$$OD = \log(\frac{I_o}{I_x}) \quad (1)$$

$$OD = \log(\frac{GL_o}{GL_x}) \quad (2)$$

Digital Radiography (DR) system used in the work, the background part was brighter than the object, whereas in conventional radiography and computed radiography (CR) background is darker than that of the object. Graph of the relationship between the thickness of lead towards optical density of radiograph image with the variety of the x-ray voltage is shown in Figure 3.

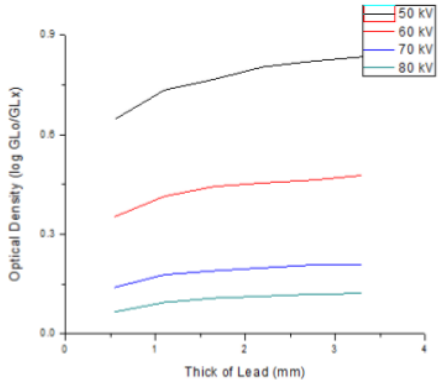

Figure 3. Graphic of relations the thickness lead against optical density radiograph image.

The magnitude of the x-ray tube voltage affects the amount of x-ray energy. The higher the voltage used, the greater the produced x-ray energy. X-ray tube voltage can also affect the produced penetrating power of x-ray and therefore it affects to the produced image quality of radiographs (contrast). Rated voltage will affect the quality and quantity of x-ray because the change affects the produced wavelength. X-ray wavelength is inversely proportional to the x-ray tube voltage. The higher the tube voltage value the lower the wavelengths.

$$c = \lambda f \quad (3)$$

$$E_k = hf - Q = h\frac{c}{\lambda} - Q \quad (4)$$

The kinetic of energy (E_k) equal to electron production (e) and voltage (V), so equation be (Meredith, 1997)

$$E_k = eV \quad (5)$$

$$eV = hf - Q = h\frac{c}{\lambda} - Q \quad (6)$$

$$\lambda = \frac{hc}{eV+Q} \quad (7)$$

According to [9] the greater the optical density, the higher the contrast of the image. Therefore, it can be concluded high grey level image sample has a high optical density. The graph shows optical density is higher towards accretion step. The greater the x-ray voltage, the smaller the optical density values. Because the value of grey level on a high voltage is smaller than the value grey level at low voltage. This happens because the voltage of 50 kV and 60 kV has a higher contrast image than the image at a voltage of 70 kV and 80 kV.

Interaction of x-ray and the material was influenced by the production of X-ray and atomic material number [10]. This work is to determine the intensity of radiation by radiograph image, using GUI Matlab on a radiograph image analysis. As visually, qualitative analysis is indistinguishable from the dark to the light. Using Matlab, radiograph image analysis by take some (crop). Background and all steps ROI's (Region of Interest). Results of ROI's crop were indicated by the mean pixel of grey level. ROI cropping process all steps were performed on the middle object. Since the central of ROI object is perpendicular to the x-ray tube, the x-ray percentage to the object is 100%. Then, the background ROI was cropped parallel to the step.

The results shows that a reduction in the intensity of x-ray radiation significantly as increase of the lead absorbent material thickness. The photons interact with material, some of the photon energy is taken by electron as kinetic energy, and some are used to fight the atom binding energy or change into a new photon. Primary photons do not interact by crossing the material and out of the material [11]. Radiation absorption of a material is the ability of a material to absorb and hold the radiation to pass through the material. However, the absorption ability of the material depends also on the type of radiation that the absorber material [12]. The number of primary photons that escaped from the material decreases exponentially defined in Equation 8.

$$I = I_0 e^{-\mu x} \quad (8)$$

In accordance with the ALARA (As Low As Reasonably Achievable) principle which states that the exposure dose of radiation received by humans should be as low as possible [13]. In the field of radiology, the used radiation protection materials are lead. Lead is a metal that has high linear absorption coefficient of 0.506 m-1 [14]. So that the lead can absorb x-ray radiation energy. As a result of x-ray radiation intensity is significantly reduced in lead thickness 0.55 mm and on the thickness of 1.1 mm and so the radiation intensity is reduced slightly which will form an exponential equation according to Equation 8. The results showed grey level image analysis can replace the method of radiation dose rate analysis that is commonly used as a method of testing the radiation absorbent material. Radiation intensity is proportional to the grey level image, so by looking at the grey level of the image of the radiograph, it can determine the intensity of the radiation from the image. This study used the trace lead with the mass density of 10.53 g / cm3. With a high mass density, trace lead can absorb the energy of the x-ray radiation. Compared to other radiation protection material such as barium which has mass density smaller than lead so that the energy absorption potential is also lower [15].

4. Conclusion

Grey level analysis proportional to the intensity of radiation can be used to find out the contrast of the image, and may know the linear coefficient absorbency of the material. Optical Density inversely proportional to the voltage of the x-ray. Because the value of grey level on high voltage smaller than the value of grey level at lower voltages.

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