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RESIN BASED STEPWEDGE AS A SUBSTITUTE FOR SOFT TISSUE ON DIGITAL RADIOGRAPHYC SYSTEMS

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ABSTRACT

It has been fabricated step wedge-based resin as a substitute for soft tissue on digital radiographic systems. It is need to be varied in expose factor and focus to film distance (FFD) to produce a good image contrast in digital radiography systems. Radiograph image of step wedge which photographed in soft file form was analyzed by Matlab-based software programmed. To know the good contrastive image by qualitative (eyesight) and quantitative (transmission energy of object and optic density) analyses were conducted. The result showed the relationship between object thicknesses to value of ln 〖〖GL〗_x/〖GL〗_0 〗 that's inversely proportional and form a pattern of linear line, so value of ln 〖〖GL〗_x/〖GL〗_0 〗 shows transmission energy of X-ray passing through the object. Optic density (OD) analysis in expose factor and FFD variation have form a pattern of exponential between thickness and value of 〖log〗 〖〖GL〗_o/〖GL〗_x 〗. The value of log 〖〖GL〗_o/〖GL〗_x 〗 shows high contrast radiograph image. It was also obtained the optimal expose factor to get good image quality is at current 32 mA and time exposure of 0.1 seconds at a voltage of 45 kV also FFD optimal on expose factor is 100 cm.

Key Word: step wedge, resin, digital radiography.

INTRODUCTION

X-ray is able to distinguish the density of various tissues in the human body in its path, so in the medical field x-ray used to the diagnoses some diseases. The soft tissues of the body which consists of muscles, nerves, fascia and tendons have low density and atomic number. Whitley (2005: 494) argues that the technique of soft tissue radiography is a common technique used for radiography of muscle, skin, and glandular tissue without the use of contrast media. Soft tissues radiographic techniques typically are used in breast screening (mammography) breast which generally consists only of lipids and mammary gland tissue (fibro glandular). It was also radiographic examination of the neck bone tissue of larynx and paring or in Struma patients who also called goiter is swelling on the neck due to enlargement of the thyroid gland.

X-ray radiation is very dangerous for the body because the X-ray has the great energy of ionization and penetration. Therefore it is very important to use phantom for investigating the expose using X-ray cannot be directly used for experiment with humans. While the cost to make the phantom in the medical field is expensive, so use of resin based phantom is one of the solutions due to its easy to get in the market. Further, a step wedge shaped phantom can determine the effect of the thickness of each step. Exposure of X-ray was imposed on the step wedge to produce radiographs that can describe the intensity of the pixels of each thickness (Hayat et al, 2013). Meanwhile, digital radiography results also presents a two-dimensional image of the anatomical structure in the form of files. The image is presented in the numerical results of the intensity of the transmitted X-rays passing through the patient. In addition, the image is composed of pixels, while the matrix of pixels is image element (Bontranger, 2010: 47).

METHODS

Materials and equipment

Step wedge made of unsaturated polyester resin was manufactured by Eternal Synthetic Resins (Changsu) Co., Ltd. According to Fink (2005; 1) the unsaturated polyester resin is a polyester formed from the condensation polymerization mixed of vinyl monomers (styrene) 60%. Curing process Eternal 2441PI resin with a radical initiator and promoter. Promoter (Cobalt N24 / 21) helps initiator decomposition since providing free radical. Mepoxe is an initiator that containing a few percent methyl ethyl ketone peroxide for polymerization of unsaturated polyester resin. Catalyst function on the resin to make the harden resin is faster. Furthermore, the resin is cut using the turret milling tool in order to form step wedge. The following specifications, the width is 1.5 cm, the length is 5.2 cm, the high max is 7.5 cm, the number of steps are 5, the difference in thickness / step are 1.5 cm, and the difference in length / step: 1.5 cm (Figure 1).

Figure 1. Resin based step wedge

Experimental

This work was done by using a format of mobile digital radiography technology to expose resin based step wedge. The digital radiography (DR) is developed using the existing components in the domestic or regional markets. Schematically as Figure 2, 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 (Susilo et al, 2014).

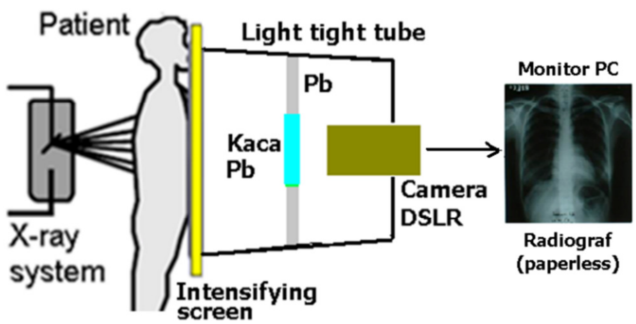


Figure 2 Digital radiography systems
(Reprinted from Susilo et al, 2014)

Furthermore resin based step wedge was exposed using a digital radiography system with variations in the value of the voltage (kV) and the focus to film distance (FFD). Based on the theory Whitley (2005: 494), it was selected expose factor having low kVp category with a variation of parameters voltage of 45 until 50 kV and variations expose distance (FFD) from a distance of 80 up to 100 cm. in this work, we used voltage (kV) variation for FFD, current, and time of 80 cm, 32 mA, and 0.1 s respectively and for FFD variation the optimal factors expose was used.

Quantitative analysis

Radiograph image digital radiography were analyzed using Matlab-based software programmed. Radiograph image type * .JPG was observed, then taken a certain part (crop) of background and all steps ROI's (region of interest). The selected ROI results qualitatively are indistinguishable from the dark to the light and quantitatively, indicated by the value of gray level (gray level) of 0-255 (Susilo et al, 2009). According Priyawati (2011), filter image can be done to increase the brightness of the image. Mathematical operations performed by adding pixels to a certain value. The common radiography bright of a sample represents its optical density (DO), i.e the logarithm of the ratio of the incoming light intensity on the film to the light intensity transmitted through the film, that is mathematically expressed as:

$$\mathrm{OD} = \log(\frac{I_0}{I_x}) \text{ ……….. (1)}$$

With I_0 is the intensity of incoming light on the film and I_x is transmitted light intensity. In the same way. Equation (1) can be written in the term of gray level (GL) as:

$$\mathrm{OD} = \log\frac{GL_0}{GL_x} \text{……………… (2)}$$

With GL_0 as the value of GL on the background image of the radiograph and GL_x is the value of GL on the object (Susilo et al, 2013).

The image resulted by radiography system is a mapping of X-ray beam that transmitted (I_x), the first beam (I_0), object thickness (x), and linier absorption coefficient (μ). Therefore, the photon energy loss due to layer thickness, then beam intensity reduce. I_0 and I_x relationship is as follows (Rowlands, 2002):

$$I_x = I_0 e^{-\mu x} \text{ …….. (3)}$$

Using Matlab, equation (3) can be also written as:

$$GL_x = GL_0 e^{-\mu x} \text{ ……… (4)}$$

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 3).

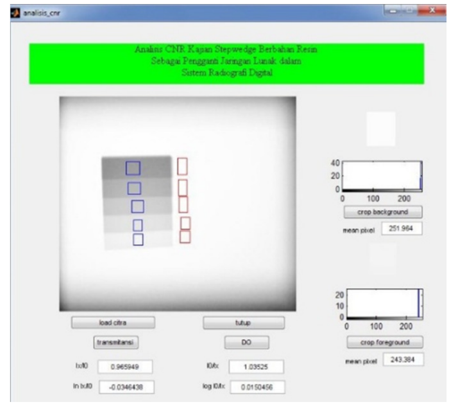
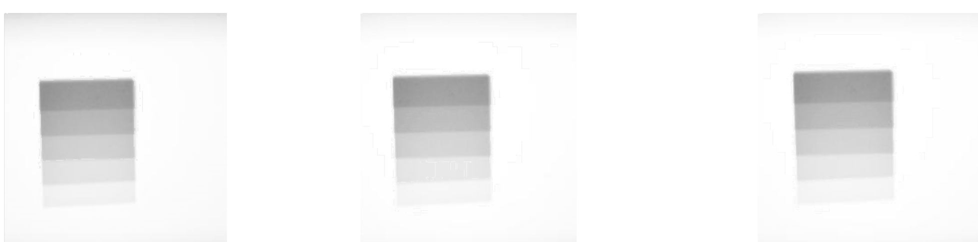


Figure 3. Display Matlab GUI analysis

RESULTS AND DISCUSSIONS

Interaction of X-ray and the material was influenced by the production of X-ray and atomic material number. According to Fink (2005). Polyester are a resin having the ester functional group in their main chain and it's according to Camber (2009) appropriate the body tissues whose Carbon reaches up to 75.39 %. The soft tissues of the body have an effective atomic number between 6 and 7.5. Therefore, the resin is used as a substitute for soft tissues for expose to X-ray in this work. This work is to determine the optimal factors expose of soft tissues to obtain a radiograph image with good quality, 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 average number of GL (gray 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.



(a) (b) (c)

Figure 4. Radiograph image on the voltage (kV) variation value (a) 45 kV (b) 47.5 kV (c) 50 kV

In the voltage (kV) variation, the radiograph image can be observed in Figure 4. Visually, it can be seen that image radiograph quality is almost same in the voltage (kV) variation. The object is thicker, contrast between the object and the background is higher, and vice versa. Using the same device, the mapping of X-ray passing through the object can determined. Value $\ln\frac{GL_x}{GL_0}$ is the natural logarithm of the ratio value of gray levels (GL) object to the GL background. Figure 6 shows relationship between the thicknesses object and value of $\ln\frac{GL_x}{GL_0}$ are inversely proportional. The object is thicker, the value of $\ln\frac{GL_x}{GL_0}$ is smaller and then X-ray intensity ratio transmitted to intensity X-ray is greater. Since the larger ratio, contrast of the radiograph image is higher. Therefore, the value of $\ln\frac{GL_x}{GL_0}$ indicate the transmission energy of X-rays passing through the object.

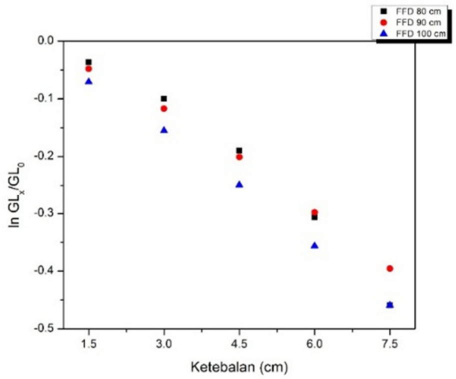
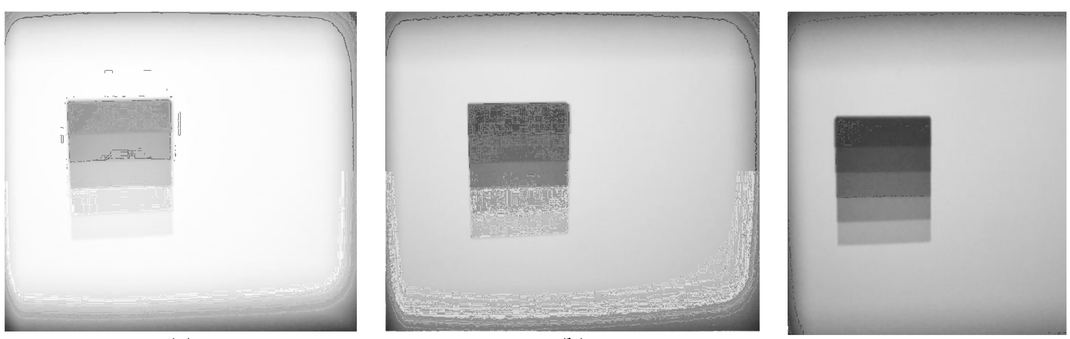


Figure 5 The relationship between thicknesses and value of $\mathbf{ln\frac{GL_x}{GL_0}}$ on the voltage (kV) variation

In quantitative analysis, the graph on Figure 5 shows value of voltage 45 kV, where every thickness has a smaller value of $\ln\frac{GL_x}{GL_0}$ smaller than that of other. While the voltage (kV) variation, the value of 45 kV is optimal voltage for presenting the image of a radiograph with good quality. The value of $\ln\frac{GL_x}{GL_0}$ form a pattern of linear line generally, but the line does not have linearity with a thickness of 4.5 to 7.5 cm due to the effect of Heel, which allows the thickness of 1.5 and 3 cm percentage of X-rays does not reach to 100%.

In the voltage (kV) variation, 45 kV is optimal voltage, so the FFD variation (cm), used a value of 45 kV voltage, current of 32 mA and exposure time of 0.1 seconds. Qualitative analysis can be seen on Figure 6, whose the radiographs image is increasingly contrast when FFD increases.



(a) (b) (c)

Figure 6 Radiograph image with FFD variation (a) 80 cm (b) 90 cm (c) 100 cm

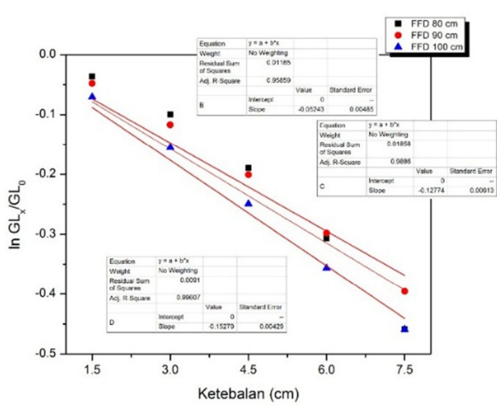


Figure 7 Relationship between thicknesses (cm) and value of $\mathbf{ln\frac{GL_x}{GL_0}}$ on FFD variation (cm)

Quantitative analysis, Figure 7 shows the relationship between thicknesses object (cm) and value of $\ln\frac{GL_x}{GL_0}$ that is inversely proportional. The FFD is greater, the relationship between thickness (cm) and value of $\ln\frac{GL_x}{GL_0}$ tends to be linier. Using simple linear line analysis, it was obtained gradient value. According to the equation (4), the gradient value indicate the linier absorption coefficient value. The gradient value is negative, so the linier absorption coefficient value is positive. The further distance, the linier absorption coefficient value is greater, and vice versa. The average squares regression (R^2) is 0.981, so it can be concluded that there is a positive and significant correlation between thickness (cm) and value of $\ln\frac{GL_x}{GL_0}$. Since this is influenced by the Heel effect, according to Carroll (2001) the further FFD, the region having a percentage of the intensity of X-rays 100% is greater. On the charts, FFD 100 cm forms a linear pattern than the other. Since the object receives the same percentage of the x-ray intensity in every object thickness, the FFD 100 cm is optimal.

The OD measurement used gray level (GL), the voltage (kV) and FFD (cm) variation have exponential pattern. In Figure 9 and 10, the cathode-anode voltage value increases then $\log\frac{GL_0}{GL_x}$ value is smaller generally and vice versa. According to Bushong (2001) as optical density as greater than the contrast radiographs image is higher, and vice versa. Therefore the value of $\log\frac{GL_0}{GL_x}$ is greater which indicates the higher radiographs image contrast. The result obtained by Susilo (2013) dan Fahmi (2008).

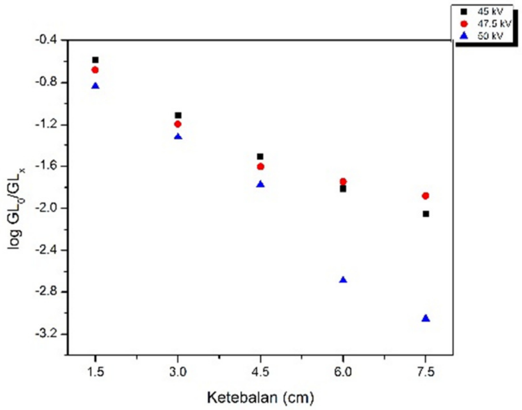


Figure 9 Relationship between thicknesses (cm) and $\log\frac{GL_0}{GL_x}$ on voltage (kV) variation

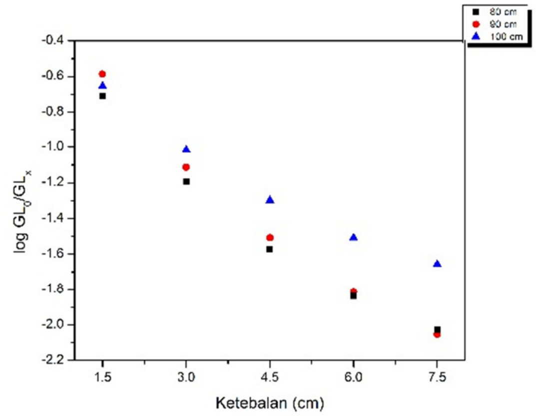


Figure 10 Relationship between thicknesses (cm) and $\log\frac{GL_0}{GL_x}$ on FFD variation (cm)

CONCLUSION

Polyester Resins can be used a material to compete soft tissue in X-ray exposing. To get a good image of the radiograph, it can be done by image contrast which is influenced by expose and geometry factors, so in this work it was conducted variation of voltage (kV) and FFD (cm). This work also obtained optimal expose voltage at currents of 32 mA and exposure time of 0.1 seconds at 45 kV and FFD of 100 cm. The result showed the relationship between thicknesses object to the value of ln 〖〖GL〗_x/〖GL〗_0〗, so the ratio of the x-ray intensity transmitted to the X-rays is greater. The larger ratio, contrast of radiograph image is higher. Therefore, the value of ln 〖〖GL〗_x/〖GL〗_0〗 indicates the transmission energy of X-rays passing through the object. Optical density (OD) measurement in the variation of the voltage (kV) and FFD (cm) showed exponential pattern between thicknesses (cm) and value of log 〖〖GL〗_0/〖GL〗_x〗, so the value of log 〖〖GL〗_0/〖GL〗_x〗 indicates the radiograph image contrast.

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