

Characteristic of silicone rubber as radioprotection materials on radiodiagnostic using x-ray conventional

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Characteristic of silicone rubber as radioprotection materials on radiodiagnostic using x-ray conventional

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Abstract. The use of x-rays in diagnostic activities should consider the balance between the radiation dose and the image quality as one of the radiation protections to the patient. To provide radiation protection to the patient, a radiation shield from material with a high atomic number is required, and the alternative material is silicone rubber (SR) can be used. In this research, we have made radioprotection material in sheet form with SR material and catalyst. SR sheet was made using simple method casting with sample dimension of (17 x 17 x 1) cm³. Several test parameters including physical density, percentage of x-ray transmission, and image quality were characterized. The physical density value is 1067 kg/m³, percentage of x-ray transmission at minimum voltage and maximum voltage are 40.07% and 57.11%, respectively. The results of this study show that SR sheets does not significantly change image quality and SR material can be eligible to be used as radioprotection media in the radiodiagnostic field.

1. Introduction

Since x-ray was discovered by scientist Wilhelm Conrad Röntgen in 1895 has made a huge contribution in the world of modern medicine as one of the most powerful and irreplaceable diagnostic tools [1,2]. The use of x-rays in radiodiagnostic activities, one of which conventional x-rays should perform the optimization of the procedure with respect to the balance between the radiation dose and the image quality [3,4]. This is due to provide radiation protection in patients to prevent reactions with healthy tissue and to reduce the possibility of stochastic effects that can lead to cancer [5].

To provide radiation protection to the patient, a radiation shield is required which is made of a material that has a high atomic number (Z) such as copper (Cu), lead (Pb), tungsten (W), and bismuth (Bi) [4,6,7]. However, the use of such materials has a deficiency one of which has no flexibility so that it cannot cover the surface of the patient's body when it will be irradiated using x-rays. Alternatively, silicone rubber (SR) is used as a radioprotection device because it has a flexibility.

Silicone Rubber (SR) is a synthetic polymer derived from polydimethylsiloxane (PDMS) [8-9]. SR material has several properties such as high elasticity, high resistance with various types of irradiation, and low toxicity [10-12]. From its physical properties, SR becomes a widely used material in various fields of industry as outdoor polymer insulator and cell biocompatibility [13-15]. In the medical application, SR material has been used as a protection media on radiotherapy using electron radiation beams [16]. In another application of radiodiagnostic field, SR has not been done by other researchers.



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In this research, the synthesis of radioprotection material using SR and catalyst as hardener. Samples has been tested using conventional X-ray devices by varying the tube voltage. For the applications, SR material is applied to evaluate radiograph images.

2. Materials and Method

2.1. Sample synthesis

Sample was made using SR material from SR-RTV 52 and the catalyst derived from bluesil catalyst 60 R to create SR hardener. The material synthesis is simply made by cast method with dimension of sample size (length x width x thickness) equal to (17 x 17 x 1) cm³ to produce SR sheet form. For the volume of SR material and catalyst used is 278 ml and 11 ml, respectively. SR and catalyst were stirred using a mixer for six minutes, then the mixture was poured into a wooden mold. The next stage, the sample was waited until it really hardens for about one to two days. If it has hardened, the sample was removed from the wooden mold and the sample (SR sheet) can be tested as a material radioprotection.

2.2. Sample density measurement

Density measurement is required to determine the equivalence of tissue body. The density of SR sheet was calculated using the equation (1) [16]:

$$\rho = \frac{m}{V} \quad (1)$$

with ρ is sample density (kg m⁻³), m is mass sample (kg) and V is sample volume (m³).

2.3. Percentage of X-ray transmission

To investigate the percentage of X-ray transmission (PXT) was done by using mobile radiography systems (Polymobil Plus Siemens, Sweden) at Training Center Diponegoro University. Experimental set up of X-ray transmission can be seen at Figure 2. Sample was tested at tube voltage variations of 52; 63; 73; 85; 96 and 109 kV, respectively. The used tube current is 2 mA and distance between tubes and sample is set at 100 cm. PXT is determined by equation (2) [17]:

$$PXT = \frac{D_S}{D_{WS}} \times 100\% \quad (2)$$

with PXT is percentage of x-ray transmission, D_S is X-ray dose with SR material (mGy), and D_{WS} is X-ray dose without SR material (mGy).

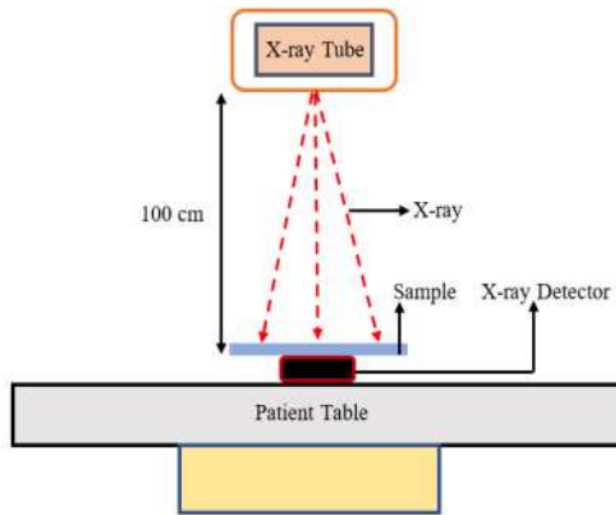


Figure 1. Experimental set up to measurement X-ray transmission

2.4. Image quality test

Image quality testing was performed at National Diponegoro Hospital (RSND) using digital radiography (DR) technology (Siemens, Sweden) with voltage and current tube are 52 kV and 2 mA, respectively. This is because the exposure factor used is in accordance with the standard inspection of adult human hand organs. The test was done using the right hand by exposing X-rays without and with SR sheet material. Image results are displayed in jpg files and comparing the image quality using a histogram graph.

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3. Results and Discussion

3.1. Sample synthesis result and density

SR sheet as synthesis result can be seen in Figure 3. SR sheet of 0.3085 kg is calculated using equation (1) and density value is 1067 kg/m^3 .



Figure 2. Silicone rubber (SR) sheet

3.2. Percentage of X-ray transmission

Percentage of X-ray transmission sample can be seen in Figure 3. Based on Figure 3, the percentage of X-ray transmission for minimum voltage (52 kV) is 40.07% and for maximum voltage (109 kV) is 57.11%. These results indicate that increasing tube voltage will increase percentage of X-ray transmissions and causes greater radiation penetration. SR sheet material has been able to protect X-

ray dose up to 42.89% at maximum voltage and 59.93% at minimum voltage, respectively. Based on the percentage value of the X-ray transmission, the linear attenuation coefficient value can be calculated using the equation (3) [7]:

$$\mu = -\frac{1}{x} \ln \left(\frac{D_s}{D_{WS}} \right) \quad (3)$$

with μ is the linear attenuation coefficient (cm^{-1}) and x is the thickness of SR sheet (cm). The linear attenuation coefficient can be seen in Figure 4. Based on Figure 4, the linear attenuation coefficient value for the minimum voltage (52 kV) is 0.91 cm^{-1} and for the maximum voltage (109 kV) is 0.56 cm^{-1} , respectively. Increasing tube voltage will decrease the coefficient of the linear attenuation. If compared with Azman et al using acrylic material composite Pb [18], the linear attenuation coefficient value in this research is greater. This shows that SR sheet has ability to absorb X-ray radiation dose better than acrylic material. This is because SR has polysiloxane (Si-O) bonds and methyl (CH₃) bonds [19], the presence of these two bonds makes SR able to reduce X-ray penetrating power. X-rays absorbed by the SR sheet are low-energy X-rays so that patients do not receive excessive radiation doses.

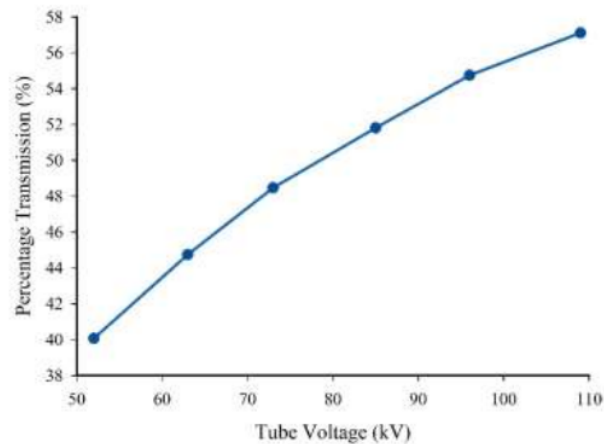


Figure 3. Percentage of X-ray transmission of SR sheet with tube voltage variation

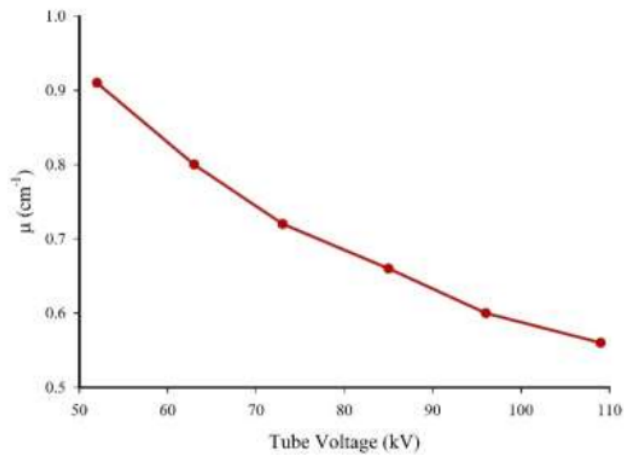


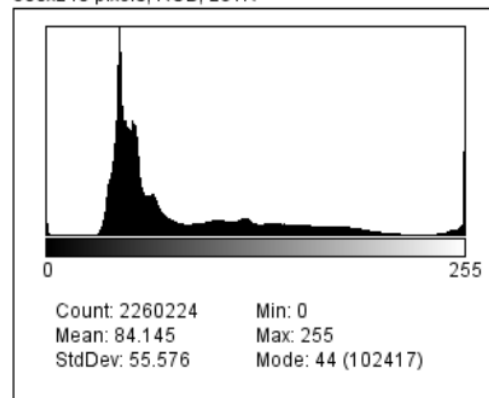
Figure 4. Linear attenuation of SR sheet with tube voltage variation

3.3. Image quality

DR image of sample can be seen in Figure 5. Based on the result, at a voltage of 52 kV it can provide absorption of x-ray radiation by almost 60% so only 40% of x-rays can penetrate the hand to produce a diagnostic image. However, in terms of image quality when viewed visually there appears to be no difference in the two images. When compared using a histogram graph, the two images have different histogram graph shapes. The histogram graph in Figure 5 (b) shows a graph with greater dark dominance than Figure 5 (a). The dark graph in Figure 5 (b) is caused by the use of SR sheets that cover the hand area. So the use of SR sheet as radiation protection device can be used as consideration for radiodiagnostic examination.



300x240 pixels; RGB; 281K



(a)

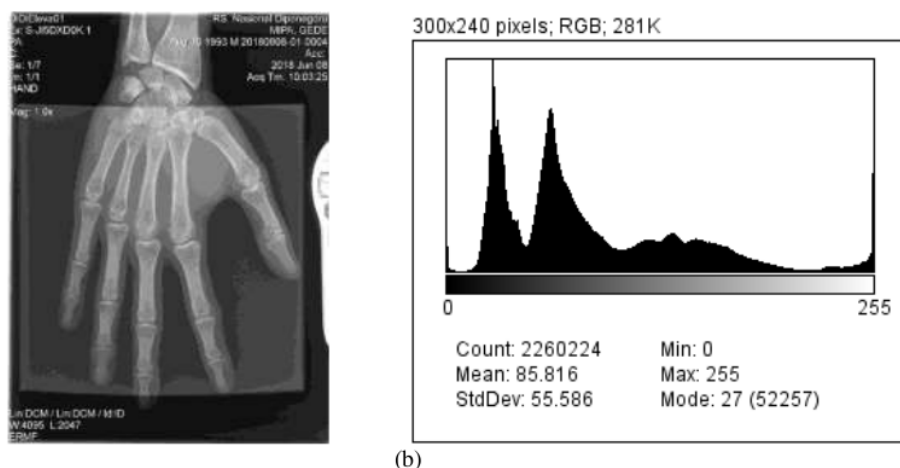


Figure 5. X-ray diagnostic image on right hand (a) without SR material and (b) with SR material

4. Conclusion

The density measurement of SR material is 1067 kg/m^3 corresponding to soft body tissue. The percentage of X-rays that can still penetrate the sample below 60% and the resulting image can still be viewed properly when using the sample although it has different histogram charts. So that, SR material has the potential to radioprotection material on X-rays conventional application.

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