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Composite of Hemp Fiber and Lead Acetate Epoxy Resin as an Alternative X-Ray Radiation Shielding Material

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Abstract

Research on hemp fiber composites with epoxy resin matrix and lead acetate as an alternative material for X-ray radiation shielding has been conducted to determine the optimal composition of radiation shielding samples made from hemp fiber, epoxy resin, and lead acetate. The method used to make composite samples with six different designs, namely using a ratio of 4 gams, eight gams, and 12 gams of hemp fiber to 80 gams and 160 gams of resin. The lead acetate used in each composition is 2.5 gams. In this study, three measurement processes were carried out: density, attenuation, and absorption. Density measurements were carried out by measuring the volume and mass of the sample, while attenuation and absorption measurements were carried out using a mobile X-ray aircraft with a Piranha multi-X-ray meter detector. In the three measures, the highest value was obtained in composition VI, namely with 12 gams of hemp fiber, 160 gams of epoxy resin, 80 gams of catalyst, and 2.5 gams of lead astate. The density value obtained was 1.120 g/cm^3. The sample with this composition can absorb 71.22% (1.24580 cm^{-1}) of radiation at 40 kV, absorb 66.91% (1.10621 cm^{-1}) at 60 kV and 60.22% (0.92191 cm^{-1}) of radiation absorbed at 81 kV voltage. Therefore, it can be concluded that the higher resin and hemp used, the more excellent density value obtained—the geater density of the sample, the geater value of attenuation and absorption.

INTRODUCTION

Nowadays, the development of technology is increasingly inevitable. Along with its growth, technology has expanded in various fields of life, including the health sector. Different technologies have been created to facilitate health examination and patient healing [1]. One example of technological advances we most often encounter is the use of radiation in diagnostics and therapy [2]. Radiation is used in several medical devices, such as Mobile X-Ray and CT (Computed Tomography) Scans, which are used for monitoring and diagnosing various health conditions [3], as well as LINAC (Linear Accelerator) and Cobalt 60, which are used for patient therapy [4]. However, it cannot be denied that the use of radiation can also pose a considerable danger, especially for radiation workers. Every day they have to work side by side with tools that expose radiation [5].

Radiation exposure cannot be avoided because the eye cannot see radiation and cannot be felt when it touches the skin [6]. When a person is exposed to radiation, the cells in his body will interact with the radiation and cause chemical changes in the molecules in his body [5]. If the radiation exposure hits the body is still low, the exposed cells can recover. But if the dose of radiation exposure that hits the body is quite large, it will cause damage to body cells [7]. People exposed to high doses of radiation are usually at risk of developing dangerous diseases such as blood cancer, skin cancer, lung cancer, and others (Mauliku & Ramadani, 2019). The body's damaged cells will multiply until they become cancer cells. Therefore, a protector is needed to reduce radiation exposure, which we usually call radiation shielding [8]. One of the radiation-protecting innovations studied is from composite materials [9].

Composites are a combination of two or more different types of materials, forming a new material with diverse or heterogeneous properties and characteristics from the characteristics of the original material [10]. The development of composite materials is increasingly Composites are widely used in human life, such as in the fields of transportation, architecture, property, and also in the health sector. Composites are often used because they have many advantages, such as relatively lower prices, higher strength, corrosion resistance, and lightweight [11]. Composite-forming materials significantly affect the characteristics of the composite that will be produced. Composites must be composed of two materials that have properties as reinforcement, and the other is a binder (matrix) [12]. The amount must be rigid and robust such as glass fiber, carbon fiber, ceramic and natural fiber. But over time, using natural fibers as composite materials has become more of an option [13]. In addition to the relatively lower price, using natural fibers is more environmentally friendly than other fibers. Natural fibers are also believed to have good mechanical properties for use as composite materials (Asroni & Nurkholis, 2016). Plants that can be used as composite fibers are plants that contain a lot of cellulose, for example, hemp plants [14].

Hemp plants grow fertile and are easy to cultivate in Indonesia [15]. This plant can grow in various land conditions, adapt to its environment, and resist pests [16]. Hemp fiber has more excellent water absorption and tensile strength than other fibers. Its heat, bacteria, and moisture resistance is also higher than others [17]. Hemp fiber makes reinforcement in composite materials a very appropriate choice [18]. Apart from support, the manufacture of Composites also requires a binder (resin) [19]. Resins have different grades and characteristics. Polyester resin, vinyl ester, and epoxy are the three most commonly used resin types. Epoxy resin has good toughness and strength and is hard, brittle, and resistant to heat and chemicals [20]. Also, epoxy resin does not have a pungent odor like other resins [16]. So this epoxy resin is very suitable for use as an adhesive in composites [20].

Combining hemp fiber with epoxy resin as a composite material is an excellent combination for radiation shielding. Previous research has been conducted on using hemp fiber composites and epoxy resins as radiation-shielding materials. One of them is research conducted by Nur Arviyanto in 2020 on a composite of hemp fiber and epoxy resin as an alternative to X-ray anti-radiation shielding material; where from the study, it is known that the most optimal composition to withstand X-ray radiation is with hemp as much as 12 g [9]. Apart from composites, research on radiation shielding using lead acetate has also been conducted. Lead is a type of heavy metal with a high density and atomic number so that it can weaken and even stop radiation. One of the studies conducted was by Fitler in 2018 on polyester lead acetate-based X-ray radiation shielding as an alternative to lead glass. The study showed that samples with a thickness of 1.5 cm could absorb radiation up to 99% at a voltage of 50 kV [8].

Based on this background, research was conducted to create an alternative X-ray radiation shield based on hemp fiber matrix epoxy resin and lead acetate. Combining the three materials is expected to be the latest innovation to obtain a good X-ray radiation shield composition at an affordable price and environmentally friendly.

RESEARCH METHODS

The tools used in this research are an X-ray plane, radiation detector (Piranha multi X-ray meter and tablet), X-ray shield, fume hood, analytical balance, sample mold, plastic cup, stirring spoon, tweezers, screw micrometer, scissors, label paper. The materials used were hemp fiber, epoxy resin(grade A), lead acetate ($Pb(C_2H_3O_2)_2$), catalyst (Cypos IL169), and aluminum foil.

This research was conducted using the mixing method, namely by mixing the material into a sample mold that has been weighed according to the composition in Table 1. After the sample hardens, the density is measured using Equation 1. And it tests the radiation intensity with an X-ray plane. After knowing the radiation intensity of the selection, the radiation absorption coefficient was measured using equation (2) and radiation absorption measurement using equation (3).

Table 1. Composition of thick sample variation and composition variation of composite with lead

Composition	Epoxy Resin (g)	Catalyst (g)	Hemp (g)	Lead Acetate (g)
I			4	
II	80	40	8	
III			12	
IV			4	2.5
V	160	80	8	
VI			12	

According to (Fitler, 2018), there are three stages of measurement in this research, namely density measurement (ρ) (gr/cm^3), attenuation coefficient measurement (μ) (cm^{-1}), and absorption measurement (%)DS). Calculate the density of a radiation shielding sample, equation (1) is used as follows:

$$\rho = \frac{m}{v} \tag{1}$$

According to (Gumilar et al., 2016), to find out the attenuation coefficient (absorption) of an object, the following equation is used:

$$\mu x = \ln \frac{I_0}{I} \tag{2}$$

According to (Abidin, 2015), to calculate the absorbency of the sample using equation (3).

$$DS = (1 - e^{-\mu x}) \times 100\% \tag{3}$$

RESULT AND DISCUSSION

Density measurements are taken to determine the density of each sample made. The model's thickness is needed to determine its effect on the radiation absorption coefficient of the piece. This research was conducted by giving several different composition variations to each sample. In addition, the selections were made using four materials with different densities. Hemp fiber has a 1.5 g/cm3 density, while lead acetate has a 3.25 g/cm3 density. Variations in the composition and thickness of these materials cause differences in density in each sample. The resin used is epoxy resin with a density value of 1.17 g/cm^3.

The density value obtained in composition I, II, III, IV, V, and VI are 1.101 g/cm^3; 1.109 g/cm^3; 1.116 g/cm^3; 1.106 g/cm^3; 1.115 g/cm^3, and 1.120 g/cm^3 respectively. The hemp fiber used in compositions I and IV is the same: four gams. Designs II and V also use the same mass of hemp fiber, namely eight gams; likewise, compositions III and VI use the same group of hemp fiber, namely 12 gams. The lead acetate used for each sample is the same at 2.5 gams. Figure 1 above shows that the greater the hemp fiber used, the greater the sample density.

A previous study was conducted by Olanda and Mahyudin in 2013 on the mechanical and physical properties of a composite material made of gypsum cement with the addition of betel nut (Areca Catechu L.) fibers. The study utilized betel nut fibers as reinforcement in the composite. The research obtained the lowest density value of 0.931 g/cm^3 when using 0% fiber percentage and the highest density value of 1.139 g/cm^3 when using 0.8% fiber. The graphical analysis results of the study showed that the addition of betel nut fibers influenced the density of the samples. The more fibers used, the greater the mass density, or it can be said that the addition of fibers is directly proportional to the sample density [21].

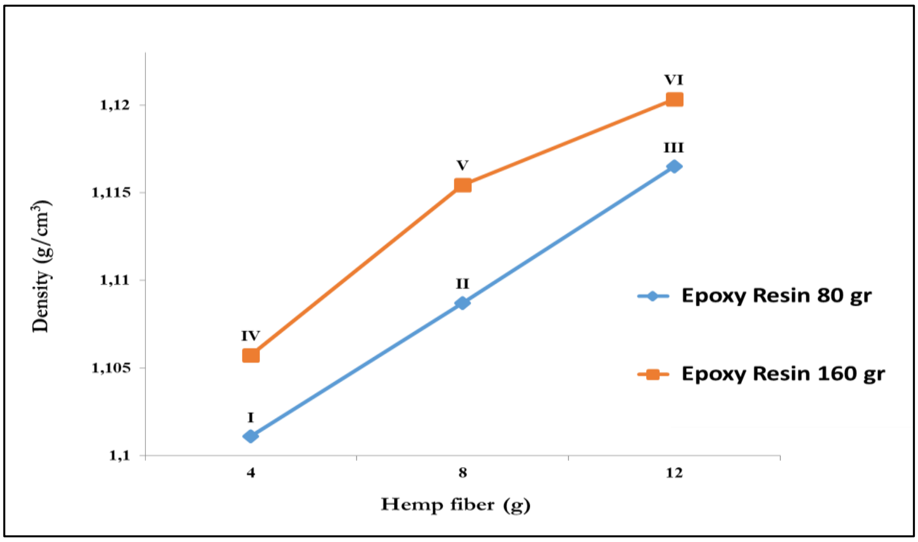

Figure 1. Density Values

The value of a sample's radiation absorption coefficient (attenuation) depends on the energy and type of electromagnetic radiation material absorbed by the model. The higher the atomic number of the material used to make the sample, the higher the value of the radiation absorption coefficient, so the better it is used as a radiation shield. Measurement of the attenuation coefficient and absorbance of the sample was carried out to determine how much X-ray radiation could be absorbed by the model. Different densities and thicknesses are obtained from the six variations of sample composition, which certainly affect the ability of radiation absorption. Figure (2) and Figure (3) show the measurement results of the attenuation coefficient and absorption.

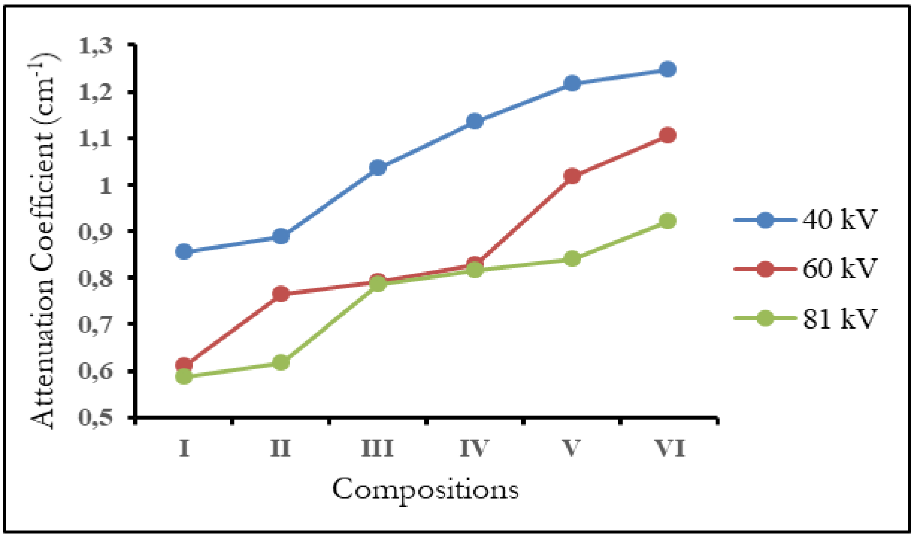

Figure 2. Attenuation Coefficient Values

In 2016, a study was conducted by Faid on composite sheets reinforced with 60 mesh coir powder using a natural rubber matrix with variations in the coir powder composition with gamma-ray radiation. The study utilized 60 mesh coir powder as the reinforcement in the composite. Three variations of coir powder were used in the research, namely 0 phr, 10 phr, and 20 phr. In the sample composition without coir powder, it absorbed radiation by 26.58%, while the sample composition with a 10 phr weight fraction of coir powder exhibited an absorption power of 31.44%, and the sample composition with 20 phr of coir powder absorbed radiation by 32.46%. The study's results indicated that the addition of the reinforcement (coir powder) could affect the samples' attenuation coefficient and absorption power. The attenuation coefficient and absorption power, at 0.0996451 radiation, were directly proportional to the amount of reinforcement composition (coir powder). The larger the piece of coir powder used in the sample, the greater the coefficient and absorption power of the piece.

Conversely, the smaller the coir powder composition used, the lower the attenuation coefficient and absorption power [22]. This finding aligns with the results of this study, which demonstrate that adding hemp fibers also correlates with the attenuation coefficient and absorption power obtained.

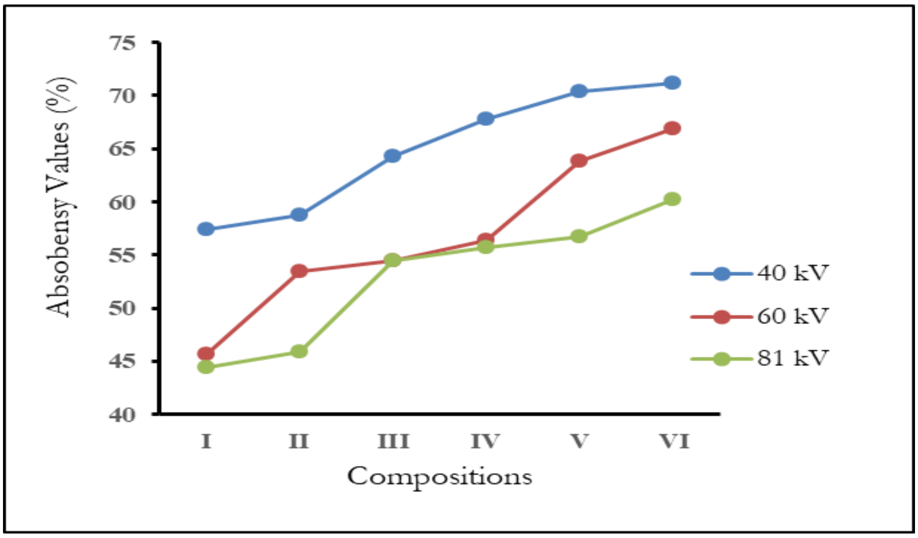

Figure 3. Absorbance Values

The overall measurement data of the attenuation coefficient and absorbency of the sample shows that adding hemp fiber will increase the absorption coefficient and absorbency of the piece. Likewise, with the addition of resin, the geater the resin used, the geater the absorption coefficient and absorbency. Hemp fiber and epoxy resin are directly proportional to the absorption coefficient and absorbency. In composition VI, the highest absorption coefficient and absorption power were obtained, namely 1.24580 cm^{-1} attenuation and 71.22% absorption power at 40 kV voltage; 1.10621 cm^{-1} attenuation and 66.91% absorption power at 60 kV voltage and 0.92191 cm^{-1} attenuation and 60.22% absorption power at 81 kV voltage. So it can be seen that of the six compositions used, the most optimal composition used as a radiation shield is composition VI, which operates 12 gams of hemp fiber, 160 gams of epoxy resin, 80 gams of catalyst, and 2.5 gams of lead acetate. The calculation results of the attenuation coefficient and absorption obtained in this study, when compared with previous research that has been done on testing materials that can be used as radiation shields, can be said that composites in composition VI can be developed and become one of the latest innovations in X-ray radiation shielding.

Under the provisions of PERKA BAPETEN Number 8 of 2011 concerning radiation safety in diagnostic and interventional radiology X-ray aircraft, the screen must be coated with a material equivalent to 1 mm Pb. The most optimal composition in absorbing radiation in this study is composition VI, which has a density of 1.120 g/cm^3, while the thickness of lead is 11.34 g/cm^3. By using equation (2.3), it is known that 1 mm of charge (Pb) is equivalent to 10.125 mm or 1.0125 cm of the composite sample (composition VI). In composition VI, the thickness of the sample obtained is 2.21 cm which met the minimum thickness limit of radiation shielding recorded in PERKA BAPETEN. So it can be said that the thickness of the piece is following the standard.

CONCLUSION

Based on the research conducted, it can be concluded that the most optimal composition of radiation shielding samples with hemp fiber and lead acetate epoxy resin is composition VI, which uses 12 grams of hemp fiber, 160 grams of epoxy resin, 80 grams of catalyst and 2.5 grams of lead acetate because the composition has the highest density and thickness. Samples with this composition can absorb 71.22% (1.24580 cm^{-1}) of radiation at 40 kV, absorb 66.91% (1.10621 cm^{-1}) at 60 kV, and 60.22% (0.92191 cm^{-1}) of radiation absorbed at 81 kV voltages. Composites based on hemp fiber epoxy resin matrix and lead acetate can be used as alternative radiation shielding by adding resin, hemp fiber, or lead so that the sample can absorb radiation more optimally up to 100%.

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