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Investigation of Eichhornia crassipes as a natural fibre in PMC for noise controller

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Abstract. This paper investigated the Eichhornia crassipes as fibers in polymer matrix composite (PMC) for sound absorption. The polyester resin R-108 was mixed with the fibers with the variation percentage. The fibers were varied with three different variations: 20%, 25%, and 30%. The Methyl Ethyl Ketone Peroxide catalyst was added to accelerate the solidification. The sound absorption experiment used a simple insulated box with a sound level meter. After the experiment, the noise absorption coefficient (NAC) result was calculated and analyzed. The maximum noise absorption was obtained at 25% of fibers, indicated by the NAC value of 0.384. In addition, the tensile strength was also obtained for the supplementary data for this study.

1 Introduction

Noise pollution has become one of the unsolved problems in the capital city, especially for the developing country. Indonesia, as one of the developing countries, has contributed to noise pollution on the roadway. The noise source mainly comes from the racing type of motorcycle since this type has become popular recently [1]. The noise is becoming worse when the muffler has been modified. The incorrect material for the muffler's silencer made the vibration because the exhaust gas flow could not be adequately silenced. One of the materials used for silencers is fibre glass. However, it has been investigated that manufactured fibreglass can be toxic to human health [2]. The fibreglass produced styrene that can be neurotoxic. An alternative material, such as organic material, may be proposed to replace the fibreglass, such as Eichhornia crassipes, known as water hyacinth.

Generally, Eichhornia crassipes can be planted or overgrown without any special treatment. It can be found easily in a tropical country such as Indonesia. Even in some areas in Indonesia, it is thought of as Weed. The Eichhornia crassipes have yet to be processed correctly. Instead of applying it as organic material to replace synthetic or inorganic material, many ways were carried out to destroy this plant manually or chemically. The massive growth of Eichhornia crassipes can be seen in Figure 1.

Tang and Yan have reported that sound absorption could be controlled with the fibrous material. The fibrous material can be classified into inorganic, synthetic, natural, and

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nanofibers [3]. Inorganic and synthetic materials have commonly been used for many sound absorption components.

Fig. 1. The Eichhornia crassipes.

Several examples of inorganic and synthetic materials were glass wool, fibreglass, carbon fibre, polyester fibre felts, polypropylene, etc. Some of those materials have many issues with human health. An alternative fibre that is environmentally friendly must be developed to replace them. Natural fibre is an appropriate choice. However, there was limited investigation that has been reported about the use of natural fibres for sound absorption. Several natural fibres developed for sound absorption components are listed in Fig. 2.

In this study, Eichhornia crassipes were applied as the fibres in polymer matrix composite (PMC). The fibres were dried and mixed with the polyester resin with the lay-up method. The composition between fibres and resin was varied. The fibres were varied into 20%, 25%, and 30% with the polyester resin. After the PMC had been manufactured, the sound absorption experiment was conducted. The noise absorption coefficient (NAC) result was then obtained and discussed. In addition, several data on mechanical properties were also obtained for supplementary data.

No.	Fibers	Key findings
1	Bamboo fiberboard	Better noise reduction properties than plywood with similar density
2	Tea-leaf fiber felts	Tea-leaf fiber exhibits better sound absorption than polyester and polypropylene nonwovens
3	Ramie fiber reinforced poly (L-lactic acid) composites	Composites with short ramie fiber have better sound absorption property than the ramie fabric reinforced composites
4	Coir fiber	Coir fiber has naturally good acoustical absorption in medium and high frequency range
5	Bamboo fiber	Bamboo fiber has good absorption properties
6	Goose fiber felts	The fractal phenomenon of down fiber for sound absorbing
7	Jute composite materials	Jute shows better acoustical attenuation and flammability properties than glass fiber
8	Coir fiber felts	Natural coir fiber had an average acoustic absorption of 0.8 for f > 1360 Hz, f > 940 Hz and f > 578 Hz at thicknesses of 20, 30 and 45 mm
9	Polyurethane foams loaded with tea-leaf fiber and luffa cylindrica	The incorporation of tea-leaf-fibers into polyurethane can improve the acoustic absorption properties significantly
10	Natural fiber mixed nonwoven composites	The samples including 70% cotton and 30% polyester resulted in excellent absorption in the mid-to-high frequency ranges
11	Ramie, flax and jute fibers	Acoustic absorption properties of these natural fibers were calculated by the *Delany-Bazley* and *Garai-Pompoli* models, the results showed good agreement with the experimental data
12	Hemp fiber	Alkalization at higher temperature and higher

Fig. 2. Natural fibres for sound absorption [3].

2 Methods

The Eichhornia crassipes fibres were dried before mixing with the resin. The drying process was conducted under the sunlight for several days. The fibres were then brushed with a wire brush into the finer fibres, as shown in Figure 3. The alkaline process was applied by soaking the dried fibres in the 5 % NaOH solution for 2 hours. All fibres were cut uniformly with 1 Cm of length. The type of resin and catalyst were polyester and Methyl Ethyl Ketone Peroxide, respectively. The resin, fibre, and catalyst were mixed into the container. All the components were stirred in the container to ensure that the resin, fibre, and catalyst were distributed uniformly. The process was conducted repeatedly for different variations of fibres. The resin composition varied by 20%, 25%, and 30% with the resin. Before pouring the mixing components, the mould was coated with a release agent to prevent the PMC from becoming sticky to the mould surface.

Fig. 3. The finer fibres after being brushed.

After the PMC freezing, the solid PMC was formed into the dimension of 23 × 23 × 0.5 Cm, following the apparatus used for the sound absorption experiment. For the supplementary data, the tensile specimen was manufactured for the tensile test by following the ASTM D3039 [4].

Figure 4 shows the schematic illustration of the sound absorption apparatus. The apparatus was a simple box consisting of a sound source area and measured sound area. The sound was generated from an audio frequency generator and connected to the amplifier. The amplified sound was entered into the sound source area and passed through the PMC partition. The sound is measured by a sound level meter after passing through the PMC partition. The sound frequency was varied for each fibre percentage to determine the NAC value [5]. The frequency range applied to the apparatus's inside was from 100 to 7000 Hz.

3 Data and analysis

In this study, the fibre is stirred with resin and catalyst in the container and poured into the mould. The orientation of fibre in solid PCM is randomly oriented. The solid PCM is in plate form, as shown in Figure 5 (a)-(c). Each plate was then placed in the middle of the box as a partition.

Figure 6 shows the measurement result of sound intensity for each partition type. The maximum sound intensity was measured at a frequency of 3500 Hz. The sound intensity was measured around 85 dB for the box without partition. The sound intensity becomes lower with the box with partition. For all fibres composition, the sound intensity can be absorbed on average about 30%. This sound absorption quantity is performed by NAC value, as shown in Figure 7. The 25% of fibre shows the highest sound absorption. This fibre composition has an optimal number of pores to reduce the sound intensity. An additional percentage above

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25% of fibres may produce overlapped pores, decreasing the number of pores. It also relates to the dimension of partition used in this study. If the dimension of the partition is made more significant, the percentage of fibres may be optimal above 25%. It has also been reported by Tang and Yan that there is a maximum value of NAC at a critical fractal dimension and sound frequency [3].

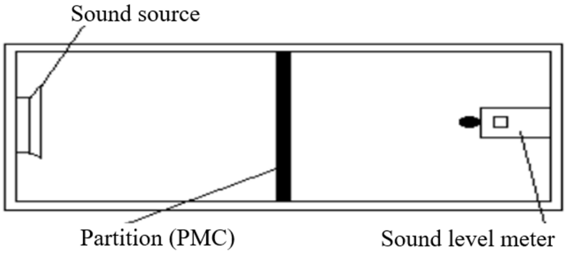

Fig. 4. The sound absorption apparatus.

Figure 8 shows the tensile test result for PMC under various percentages of fibres. It shows that both tensile strength and modulus elasticity decrease with the increase of fibre percentage. The Eichhornia crassipes will have a high tensile property if loaded parallel with the load direction. However, the PMC used in this study has a random orientation due to its manufacturing process. The perpendicular orientation of fibres may be found in a higher percentage. Hence, the tensile strength and modulus elasticity of PMC will decrease. The high percentage of fibres may also reduce the binding force between the resin and fibre [6]. Moreover, the natural fibres are generally having a low interfacial strength due to hydrophilicity to the matrix [7,8]. Fibres may experience debonding with the resin. It becomes worse when the specimen is being cut or deformed. The methods have been reported to increase the bonding between the natural fibres and the matrix were by controlling the alkali treatment and hydrolysis method [9,10].

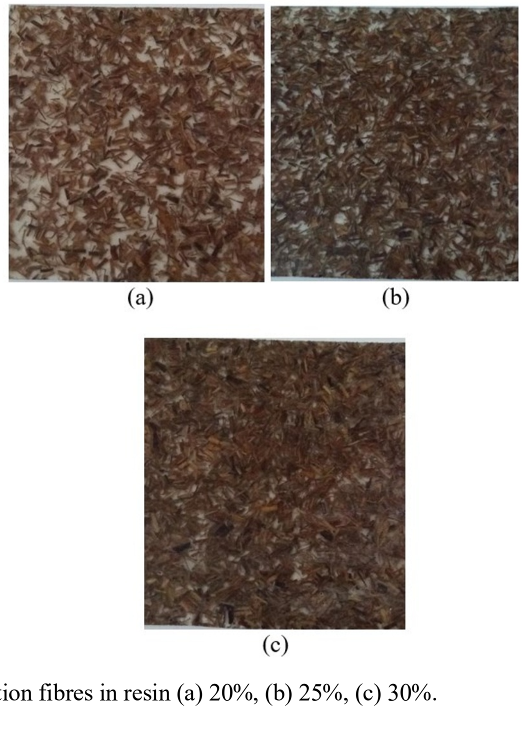

Fig. 5. Random orientation fibres in resin (a) 20%, (b) 25%, (c) 30%.

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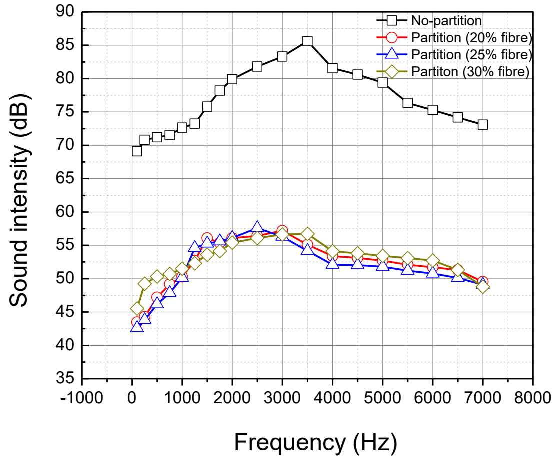

Fig. 6. Sound intensity in various partition.

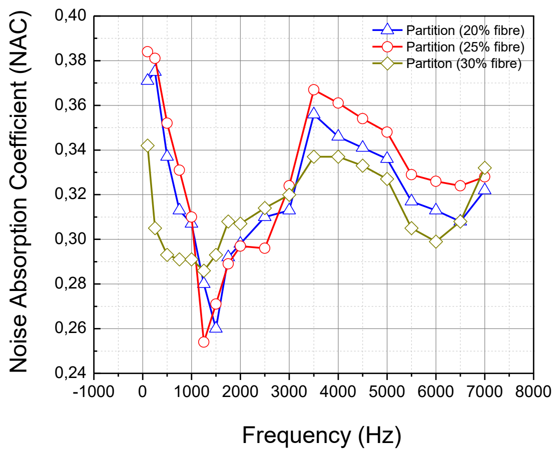

Fig. 7. Noise absorption coefficient for different fibre percentages.

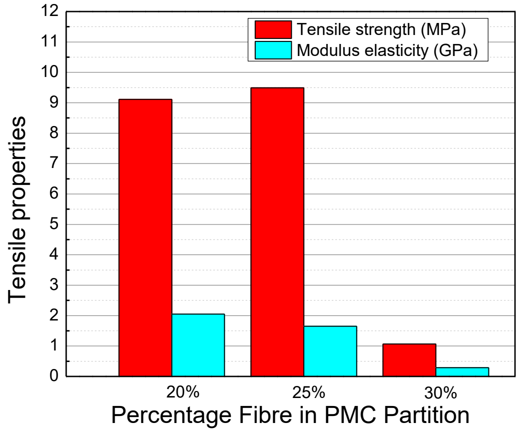

Fig. 8. Tensile stress result for different fibre percentage.

4 Conclusions

This preliminary study obtained the sound absorption value for PMC at various percentages of Eichhornia crassipes fibres. The PMC with 25% of fibres performed an optimum sound absorption indicated by the highest value of NAC. For the design purposes, the simple tensile characteristic was also calculated. The tensile test showed that the strength and modulus elasticity of PMC decreased with an increase in the percentage of fibres. Several issues during the machining process of PMC must be solved in future research to provide a high bonding between the resin and fibre.

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