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Article

# High sound absorption of polyester composites / fiber hemp / nanocellulose for automotive interior materials

Mohammad Farid [1,*], Agung Purniawan [1], Diah Susanti [1], Vania Mitha Pratiwi [1], Mohammad Ilham Yoessa [1]

[1] Department of Materials Engineering, Institut Teknologi Sepuluh Nopember (ITS), Surabaya, Indonesia

* Correspondence: mofaredo@gmail.com; Scopus ID: 55898969200

**Abstract:** Human health and environmental comfort are disturbed by the presence of noise, especially in cars, so that effective sound-absorbing materials are currently being developed. To answer the problem of noise in car interiors, polyester composite materials with local hemp fiber and nanocellulose reinforcement were developed. Natural fiber is biodegradable and renewable, and acts as an alternative to the use of synthetic fibers. The method used for the composite material manufacturing process was the casting method. The matrix of the composite material was polyester, while the reinforcement was a combination of local hemp fiber and nanocellulose fiber. Alkalization and non-alkalization processes have been carried out on hemp fiber. The composition of nanocellulose was 0%, 1%, and 3%. The characterization applied in this research were SEM test, FTIR test, sound transmission loss test, and density test. Optimal results were obtained on hemp fiber reinforced polyester composite materials without alkalization and without nanocellulose. Sound transmission loss (STL) was 61.91 dB up to 68.52 dB for the frequency range of 630 Hz to 125 Hz. The standard noise limit on 8-passenger passenger's four-wheeled vehicles is 77-80 dB. Based on the results obtained, the sound absorption is good. The density of this composite material was obtained at 0.989 gram/cm$^3$. This composite material has the potential for developing dashboard material.

**Keywords:** composite; nanocellulose; hemp; polyester; acoustic; automotive.



## 1. Introduction

Nanocellulose is thixotropy, which has a high viscosity under normal conditions but with continuous stirring, the viscosity can be reduced (thinner). Cellulose nanocomposite is widely discussed in its processing techniques by Kristiina Oksman [1] including solution casting, resin impregnation, melt-processing of thermoplastic cellulose nanocomposites. The process of making sound absorption material in this study uses the casting process. This casting process is used to make sound absorption material specimens such as composites using unsaturated polyester resin (UPR) matrices and the fillers are hemp and nanocellulose fibers.

Characterization of sound absorption material based on natural fibre was carried out by many



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researchers [2,3,4]. Nanocellulose has become the attention of researchers and industry circles. The advantage of nanocellulose is its mechanical strength, besides it also has a high surface area so that it can be used as nanofiller reinforcing on composite materials. Nanocellulose is also biodegradable so it is environmentally friendly.

Nanocellulose can be applied as a reinforcing ingredients in composites. Farid et al [5,6], have shown that the addition of nanocellulose to composites can increase the sound absorption value of a material over a wide frequency range or in other words be able to make the material as a type of wideband absorber material. This study focuses on developing automotive interior materials based on natural fibers and polymers.

## 2. Materials and Methods

The filler material is derived from hemp fiber and is obtained from areas around Yogyakarta, Indonesia. Hemp fibers are prepared by mashing using a chopper. Figure 1 is a micrograph of hemp fiber. Separation of sizes is done mechanically using a sieving machine. Hemp fibers are sieved at 280 μm in size and alkalised. Hemp fiber is soaked in 2% NaOH solution for 24 hours. The fiber is dried in an oven at 100 0C for 4 hours. The nanocellulose fiber used has thesize of about 20 nanometers. The manufacturing process of composites is done by mixing unsaturated polyester resin (UPR) with a catalyst in a ratio of 199: 1. UPR matrices are mixed with hemp fiber which has been calcified in a 4: 1 ratio. The nanocellulose fraction is 0%, 1%, and 3%. UPR is mixed with flax fiber without alkalization using nanocellulose fractions of 0%, 1%, and 3%. Unsaturated PR, hemp fibers, and nanocellulose are carefully mixed.

This material was prepared for the sound transmission loss test specimen carried out with reference to the ASTM E413-16 standard using the impedance tube method. The diameter of the specimen is 10 cm and the height is 10 mm. Density testing is carried out with reference to the ASTM D2395 standard.

The functional group of UPR / Fiber Hemp / Nanocellulose composite material has been characterized by using Fourier transform infrared spectroscopy (FTIR) Thermo Scientific Nicolet iS 10 (Thermo Fisher Scientific, Inc., MA, USA). The morphological analysis of this composite material uses scanning electron micrograph (SEM) type FEI INSPECT S50 and PHENOM G2 Pro.

## 3. Results and Discussion

Figure 1 shows the results of SEM observations on flax fiber before alkalization with a magnification of 250x. Hemp fiber diameter is 125-135 μm. The surface of natural fiber that has not been alkalised consists of a layer of wax, pectin, lignin, fatty substances and impurities [7].

Figure 1b shows the results of SEM observations on hemp fibers after the alkalization process. The diameter of the hemp fiber has decreased to 62-65 μm. Figure 1 (c) is an alkalised hemp fiber with a magnification of 500x. Figure 2 shows the sound transmission loss specimens.

The use of hemp fibers and nanocellulose fibers has been implemented as a filler in the manufacture of polyester Composite / Fiber Hemp / Nanocellulose. In general, the transmission loss value of the six specimens fluctuates in increase and decrease, this is because each frequency has a characteristic in reducing sound energy which is stated that the reduction in sound energy for each frequency is logarithmic so that it is not always directly proportional to the others [8]. Shi [9], also investigated the existence of different sound transmission loss values in each frequency.

Figure 3, it is shown that frequencies of 4000 Hz and 1600 Hz, there was an increase in the value of sound loss transmission from polyester composites with the addition of nanocellulose by 1% and 3% at frequencies of 4000 Hz and 1600 Hz. Even at the addition of 3% nanocellulose at the frequency of 4000 Hz and 1600, the STL value reached 42 dB. According to Kargarzadeh [10], the addition of nanocellulose to alkaliised hemp fiber composites is capable of producing pores in the material.

According to Howard [11] porous material will change the sound energy that comes into heat energy in the pores, then the energy will be absorbed and the rest of the energy will pass through the barrier and the sound that made it through the barrier is the sound that is transmitted.

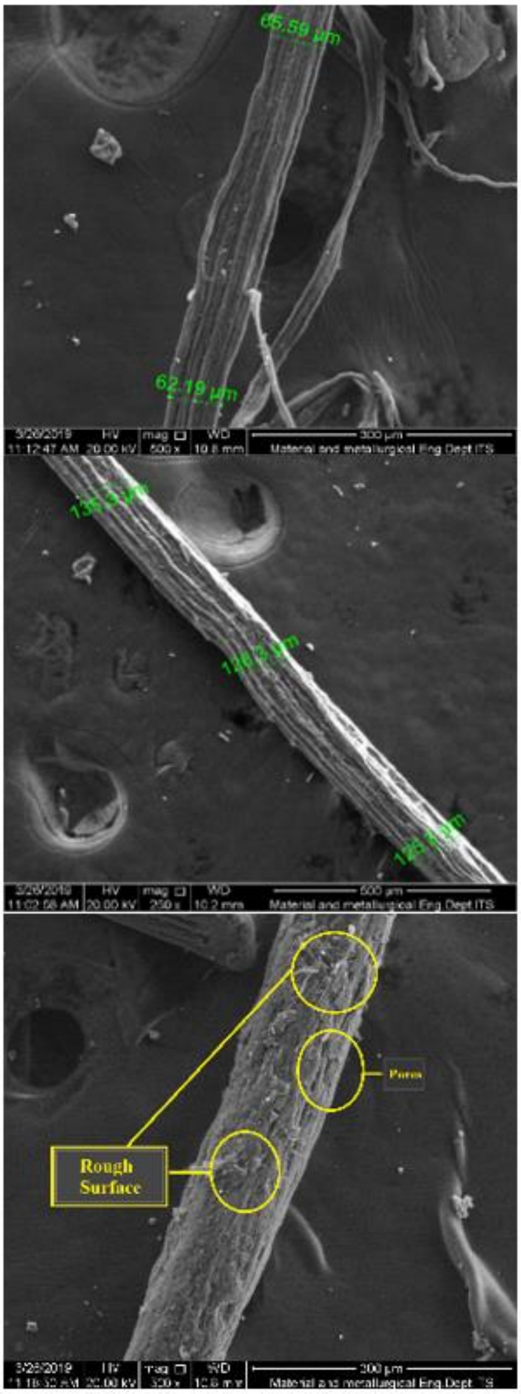


**Figure 1.** SEM hemp fibre (a) Before alkalization process; (b) After alkalization process; (c) After alkalization process (in higher magnification).

**Figure 2.** Sound tranmission loss specimens.

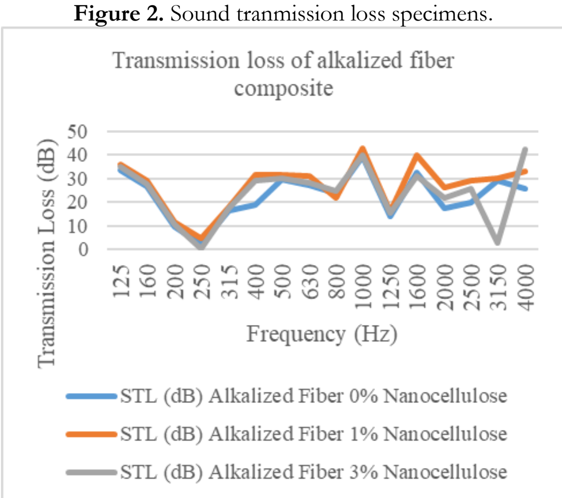


**Figure 3.** Sound tranmission loss of alkalized fiber composite.

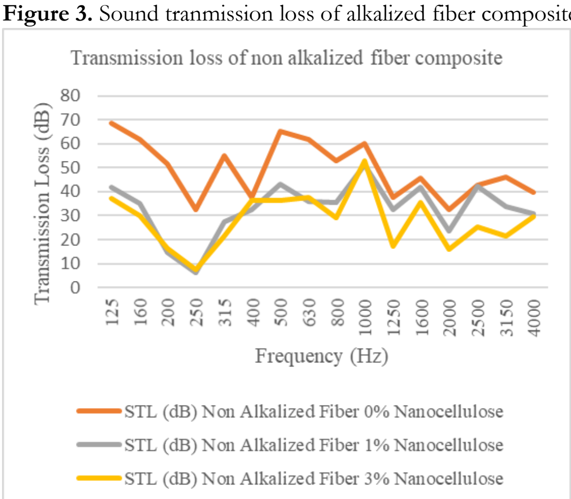


**Figure 4.** Sound transmission loss of non alkalized fiber composite.

In Figure 4, it shows the STL values in the frequency range 125 - 4000 Hz of non-alkalised hemp fiber reinforced composites. It can be seen that the composite STL value without the addition of nanocellulose has a peak STL value at low frequencies (below 1000 Hz), ie at a frequency of 125 Hz with STL values up to 69 dB, while for composites with the addition of nanocellulose 1%

and 3% have peak values STL at a frequency of 1000 Hz with a STL value of 51-52 dB

According to Siano[12], for M1 type cars or diesel-engined passenger vehicles with capacities below or equal to 8 people, the sound intensity value that can be heard in the car reaches 80 dB at frequencies below 350 Hz. The sound intensity is found when the engine speed is at 1100-1500 rpm and 2200-2700 rpm, or when the car is traveling at low speeds and driving at high speeds.

It can also be seen that at frequency (1000-4000 Hz) the STL value of the composite has decreased compared to the STL value at low frequencies. The interface area between the fiber and the matrix that has debonding causes many pores in a narrow space, so that the air in the pore cannot move freely so that it is able to reduce the sound waves (9).

To support research on sound transmission loss, the basic properties of UPR / hemp / nanocellulose composites are related to their functional groups, morphology, and density.

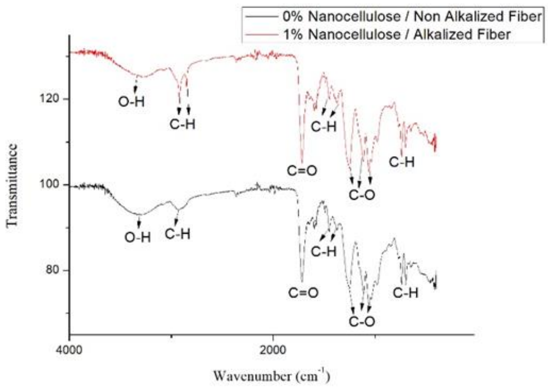


**Figure 5.** FTIR Spectroscopy of the composite.

Figure 5 shows a graph of FTIR test results. The absorption peaks of 3289.78 cm-1 and 3294.33 show the O-H stretching bond. At the peak of absorption 2918.69 cm-1 shows stretching C-H bonds. At the peak of absorption 1717.73 cm-1 and 1716.41 cm-1 shows the C = O bond representing the ester group. Whereas the peak absorption of 1597.96 and 1589.88 cm-1, and 1578.60 cm-1 and 1579.88 cm-1, showed the C = C bond representing the Aromatic group. In the absorption area of 1490.06 cm-1 and 1491.25 cm-1, 1448.52 cm-1 and, 1448.65 cm-1 as well as 1371.28 and 1374.66 cm-1 showed C-H bonds representing Alkane groups. Whereas in the absorption areas 1062.40 and 1062.95, 1112.55 and 1115.17, as well as 1253.83 and 1252.84 cm-1 showed C-O bonds representing the Esther group. The absorption area of 740.81 cm-1 and 740.33 cm-1 shows stretching of the C-H bond, while at the peak 702.59 cm-1 and 700.16 cm-1 indicates the deformation of the C-H bond.

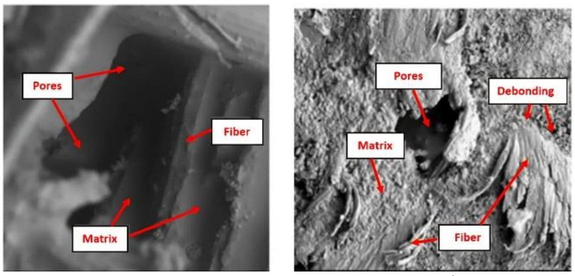


**Figure 6.** Morfology of (a) 1% Nanocellulose / Hemp Fibre Alkalisasi, (b) 0% Nanocellulose/ Non Alkalized Hemp Fibre.

Figure 6, it appears that many matrices are attached to or bound to the fiber. The increase in bonding is also aided by the presence of pores and rough surfaces owned by the fiber by alkalization treatment. The picture also shows that the cavity formed has a fairly large size. This happens because the nanocellulose itself has the ability to form cavities to produce porous material. The presence of impurities, lignin and waxy coatings that exist on the surface of the fiber effect to the sound absorption.

## 4. Conclusions

A number of experiments have been carried out on polyester composite materials with hemp and nanocellulose fillers. Optimal results were obtained on hemp reinforced polyester composite materials without alkalization and without nanocellulose. Sound transmission loss (STL) was 61.91 dB up to 68.52 dB for the frequency range from 630 Hz to 125 Hz. The standard noise limit on 8-passenger passenger's four-wheeled vehicles is 77-80 dB. The density of the composite material is 0.989 gram / cm3, while the size of the powder is 280 µm. The addition of 280 µm hemp fibers and nanocelluloses of 1% and 3% gives STL values at frequencies of 1000 Hz each of 51 dB to and 52 dB.

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## Conflicts of Interest

The authors declare no conflict of interest.

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