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Article

Analysis of The Effect of Soundproofing on Ship Engines Based on Composite Materials Made from Tofu Dregs *(Glycine Max L Merill)*

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Abstract. Minimizing ship noise and vibrations is crucial due to the potentially severe consequences, such as communication problems, sleep disturbances, stress, and structural damage. To address this, effective dampers are necessary. Many soundproofing materials now utilize natural fiber waste to replace synthetic materials, which are harmful to the environment. One such underutilized natural fiber is tofu dregs, which contain fibers suitable for sound absorption. This study investigates the use of tofu dregs as a composite material in sound dampening applications. Composites are materials engineered from two or more substances with different properties to create a heterogeneous mixture. In this research, sound-dampening composites were developed using tofu dregs combined with carbon black and talc duco. The study found that the composite containing 60 grams of tofu dregs, 60 grams of talc duco, and 50 grams of resin achieved a sound absorption coefficient of $\alpha = 0.19$. Meanwhile, the composite with 60 grams of tofu dregs, 50 grams of carbon black, and 50 grams of resin achieved a higher sound absorption coefficient of $\alpha = 0.24$. These results indicate that the tofu dregs and carbon black composite offers superior sound absorption compared to the tofu dregs and talc duco composite, demonstrating the potential of tofu dregs as an eco-friendly soundproofing material.

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1. Introduction

A ship is a transportation medium that consists of several rooms that have noise and temperature that need to be handled because it will disturb the comfort and safety of passengers if the dampening is not regulated. Many studies have attempted to create insulation for rooms on ships that need noise reduction or heat insulation. So far, the dampening for the interior of ships has used synthetic materials that are not environmentally friendly, so researchers have started to use environmentally friendly materials from natural fibers that can be used on ships. Some synthetic materials used as insulation materials to reduce noise in a room, namely rockwool, glasswool and polyurethane-based mineral wool, are not environmentally friendly so efforts need to be made to utilize natural fibers [1-2].

Natural fibers are widely used as insulation materials, such as in Tristiandinda P's (2021) research entitled "Utilization of Bagasse and Sawdust As Bio-Based Insulation on The Walls Of The Ship's Accomodation Ceiling" by using bagasse fiber and sawdust as heat insulation in storage spaces. ship accommodation [2]. Research conducted by Vikha Agustiarini (2023) which uses coconut fiber as an insulating material for ship wall structures which is useful for maintaining the temperature in fish holds [3].

Natural ingredients can be found in materials that contain fiber such as bagasse, coconut fiber, corn fiber, banana stems. There are several studies that use natural materials as sound-absorbing insulation, including research on sound-absorbing composites using banana stems which found the effect of variations in composition on the best sound absorption coefficient found in variations in the composition of banana stem fiber, namely 70%:30% with a sound absorption coefficient of $\alpha = 0.29$ [4-5]. Apart from that, use palm frond fiber as noise reduction by being able to absorb sound waves of 0.15 [6-7].

One natural fiber that is not widely used is tofu dregs waste. Tofu dregs are waste from the tofu making industry that has not been widely used. The use of tofu dregs as an insulating material is because tofu dregs contain natural fibers which can be used as sound absorbers [8-9]. Research on tofu dregs which can be used as a sound dampener is the Absorption and Impedance Characteristics of Natural Fiber Acoustic Tofu Dregs *(Glycine Max)* using the Tube Method, finding that tofu dregs have the ability to absorb sound with the greatest absorption. The coefficient value is 0.99 which is found at a frequency of 8000 Hz, it is necessary to make a composite using tofu dregs fiber which will be applied to the ship's engine room to find out how effective this tofu dregs fiber composite can reduce the sound of the engine in the engine room ship.

Figure 1. Tofu dregs

Sound dampeners on ships are placed in parts of the ship that have high sound intensity, one of which is the engine room. Local standards for engine noise that cause noise have been determined through Threshold Limit Values (NAV), namely Regulation of the Minister of Manpower and Transmigration Number PER.13/MEN/X/2011 concerning Physical and Chemical Threshold Limit Values [10]. Workplace Factors and Indonesian National Standards (SNI 16-7063-2004) Regarding the Threshold Value for Work Climate (Heat), Noise, Arm Vibration and Ultra Violet Rays in the Workplace is 85 decibels A (dBA) and the Resolution of the International Maritime Organization MSC. 337(91) [11].

The application of the Code On Noise Levels On Board Ships discusses ships weighing 1,600 to 10,000 GT and exceeding 10,000 GT, the limit is 110 dBA, however, because the size of the engine used on small ships is equivalent to a Diesel engine in a workshop, the standard machine used in the workshop is 85 dBA, under certain conditions, noise can increase to more than 85 dBA [12] so it is necessary to install insulating material in the engine room. Based on this problem, it is necessary to make an insulation material made from a composite of natural materials in the form of tofu dregs fiber combined with Black Carbon and Talack Duco as soundproof insulation for ship parts, one of which is applied to the engine room. This is due to pollution from engine noise. Under certain conditions, the noise can increase beyond 85 dBA, so it is necessary to have a device to reduce the sound produced by an object or room.

By using the acoustic tube method as a simulation medium so that from the damping obtained the damping coefficient will be calculated, the sound absorption efficiency of a material at a certain frequency is expressed by the Sound Absorption coefficient (sound adsorption coefficient) [13-14]. So it is hoped that this research can be a solution for using natural materials as sound attenuation in ship engine rooms.

2. Experimental Section

2.1. Materials

In making composite material specimens made from tofu dregs, it is necessary to calculate the composition of the combination of fiber and matrix composite materials as composite materials. At this stage is the calculation of the number of specimens needed with the aim of knowing the composition ratio to make the specimens to be tested in sound absorption.

Table 1. Composite Material Specimen Variations

Specimen type	Specimen Comparison	Composite Variation			Resin (gr)
		Tofu Dregs	Black Carbon	Talak Duco	
A	45:30:25	90	-	60	50
B	30: 45: 25	60	-	60	50
C	45: 30: 25	90	60	-	50
D	30:45:25	60	60	-	50

Based on specimen testing according to ASTM E1050 standard using specimen size a in the form of a round bar with a diameter of 85 mm and a thickness of 20 mm. In the variation of the composition for making specimens for filler and matrix, the comparisons are made according to Table 1.

2.2. Methods of Experimental

At this stage is the noise testing of the specimens that have been made. This noise test was carried out according to the ASTM E1050 standard, namely by using a tube which was divided into 2 parts. This test can be carried out with a prepared tube given a silencer for the specimen being tested and then

measured using a sound level meter. Measurement of the normal incident sound absorption coefficient was carried out using the impedance tube method. Effects of thickness involving fiber-filled and air-fiber specimens as well as effects of bulk density have been discussed. For sound absorption coefficients that appear randomly, the test is carried out in an echo chamber [15-16].

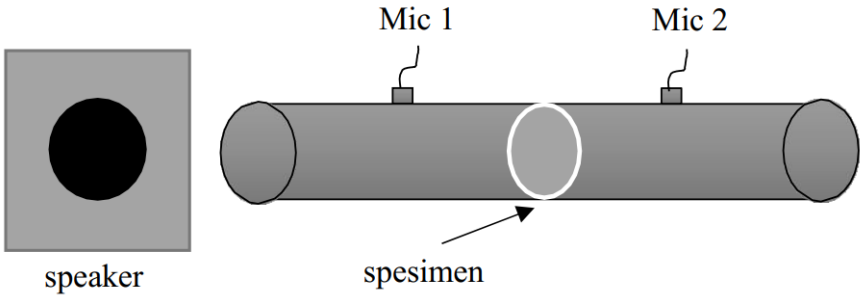

Figure 2. Testing technique using the tube method

The process of making and testing is carried out in stages and according to the condition of the ship. The following will display a research flowchart which can be seen in Figure 3.

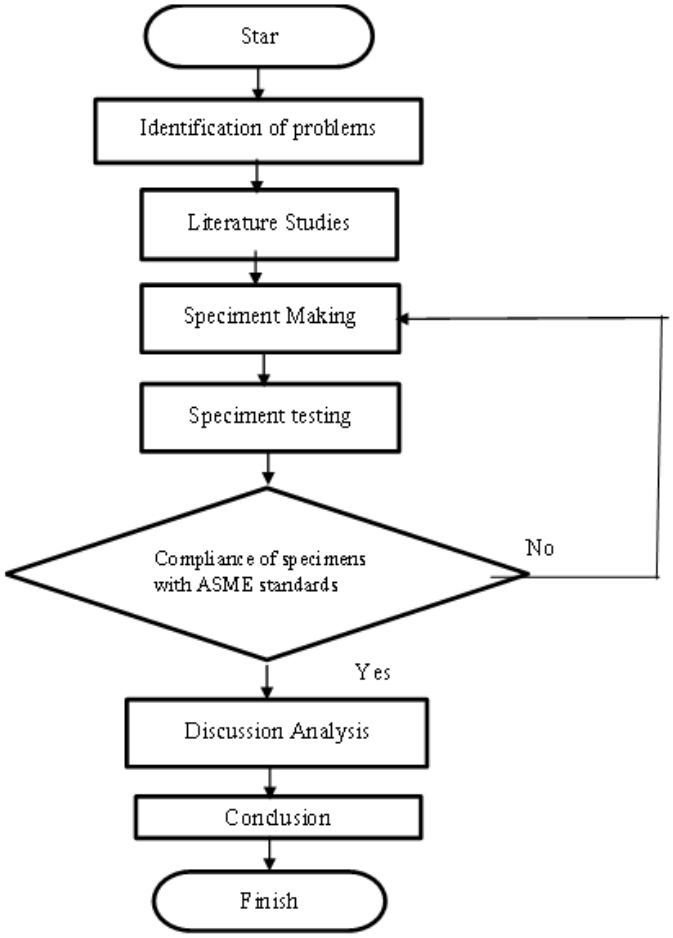

Figure 3. Schematic/flowchart of research

The attenuation characteristic is often used as a measurement tool for the theoretical basis which describes a physical phenomenon reduction in the intensity of a sound [17]. Change the intensity of a diminishing wave sound is as follows:

$$I = I_o^{e-a}.t \quad (1)$$

with:

I = Sound intensity after pass through the particleboard(dB)
I_o= Initial intensity (dB)
a= Sound absorption coefficient
t = Sample thickness (cm)

so that from equation (1) in finding the sound absorption coefficient it can be simplified using equation (2)

$$a = \frac{\ln I_o - \ln I}{x} \quad (2)$$

3. Results and Discussion

Natural fibers, apart from having a number of advantages, also have several weaknesses such as low interfacial adhesion, poor moisture resistance, and low microbial resistance that need to be overcome so that they can be used for effective insulation applications [18-19], so it is necessary to add additional composites from other materials and make variations to get the appropriate composition. Before making specimens, it is necessary to have appropriate concentrations suitable for this experiment. Several tests have been carried out to obtain a comparison of composite variations as shown in Table 2.

Table 2. Trial and error results of making composite variations

Trial and Error	
Specimen Comparison	Result
80% Tofu dregs, 20% Resin	Easy to break, easy to mold
40% Tofu dregs, 20% talk duco, 40% Resin	The specimen resembles glass
50% Tofu dregs, 40% talak duco, 10% Resin	Specimens are not attached to each other

From the trial and error results shown in table 2, the variations of specimens that are suitable for making this composite can be seen in table 1 in the methodology and are formed according to the tube method in the experiment. The specimen results are shown in figure 4.

(a) (b) (c) (d)

Figure 4. The results of making specimens with a comparison of the composition between tofu dregs, black carbon and talack duco (a) 45:30:25 (b) 30: 45:25 (c) 45: 30:25 (d) 30:45:25

In recent years, noise pollution has become one of the most critical environmental problems for mankind. This has a negative impact on people's health and their work efficiency. Therefore, porous materials receive great attention due to their excellent sound absorption properties, low density, high specific strength, mechanism and type of sound absorption [20-22]. Porosity is one of the most

important factors in the sound absorption properties of a material. Sound noise testing on ships is carried out in accordance with the ASTM E 1050 standard [23-25]. This test is carried out in an echo-free room on the test material. This data is used as a reference for noise levels in the engine room of the KM Pandelangan ship. KM Pandelangan is a type of traditional fishing boat used to catch fish in Branta. This boat has an engine room that does not have sound attenuation. From the results of the field analysis, it was found that noise in each room on the ship can be seen in Table 3.

Table 3. Noise Testing Data From KM. Pandelangan

No	Testing Point	Noice (Dba)
1	After Peak	94.2
2	Starboard	93.7
3	Portside	92.6
4	Engine Room	101
5	Collision Bulkhead	99.2
6	Fore Peak	80.7

From the data from Table 3 above, it can be divided into several sound source ranges, namely 70-80 Dba, 81-90 Dba and 91-100 Dba. This noise test is carried out in accordance with ASTM E 1050 standards. This test is carried out in an echo-free room on the test material.

Table 4. Test results for each specimen

Specimen	Sound Range	Testing 1		Testing 2		Testing 3		Average	
		Sound Level Meter	(α)	Sound Level Meter	(α)	Sound Level Meter	(α)	Sound Level Meter	(α)
A	70 – 80	57.5	0.18	70.6	0.15	67.5	0.16	65.2	0.16
	80 – 90	70.8	0.17	77.6	0.14	70.5	0.06	72.9	0.12
	90 – 100	77.5	0.09	83.5	0.14	77.1	0.06	79.3	0.09
B	70 – 80	63.3	0.19	64.5	0.14	62.8	0.16	63.5	0.16
	80 – 90	72.4	0.14	68.6	0.14	71.1	0.07	70.7	0.11
	90 – 100	82.9	0.11	78.7	0.12	78.1	0.08	79.9	0.10
C	70 – 80	58.2	0.16	63.1	0.13	47.1	0.10	56.1	0.13
	80 – 90	65.2	0.11	68.3	0.14	56.8	0.05	63.4	0.10
	90 – 100	79.7	0.20	77.2	0.13	67.7	0.05	74.8	0.12
D	70 – 80	63.1	0.24	67.5	0.15	62.9	0.09	64.5	0.16
	80 – 90	69.4	0.18	72.8	0.11	71.8	0.06	71.3	0.11
	90 – 100	77.2	0.13	77.7	0.10	75.4	0.04	76.7	0.09

In Table 4 it can be seen that there is an influence of variations in fiber composition on the sound absorption coefficient in each noise range which can be explained in Figure 5.

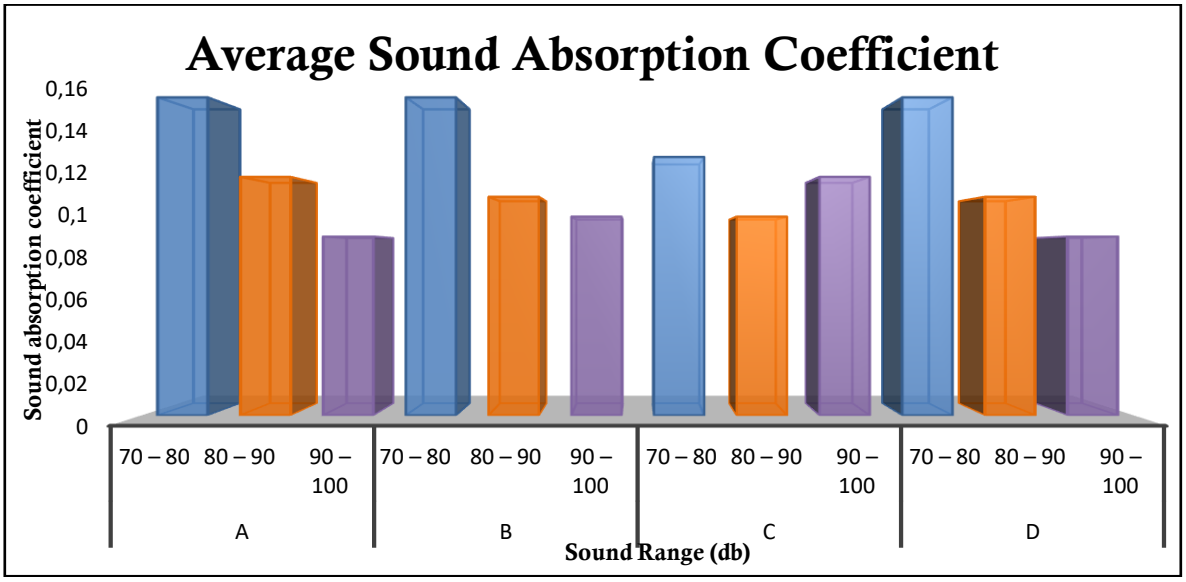

Figure 5. Sound Absorption

From the test results it is known that the noise attenuation value is of course the highest in the low noise range, namely 70-80 db, and obtained based on the graph in Figure 5, the highest sound absorption coefficient value α = 0.16 in test objects A and D in the noise range 70-80 db, but the average comparison result of effective sound attenuation is that Test A is the best, because if the noise range is 80-90 db, specimen D is still lower than specimen A in terms of the damping coefficient results. The quality of a material as a sound absorbing material can be determined by looking at the α value or what is called the sound absorption coefficient [26-28]. Based on the ISO 11654:1997 standard, the higher the sound absorption coefficient (α), the better the material is as a sound absorber [29-30].

4. Conclusion

The test results and composite calculations, it can be concluded that the best results are found in the composition variation of test object A with an average sound absorption coefficient α = 0.16 in the noise range of 70-80 db. So the most effective in absorbing sound is a composite of tofu dregs and talak duco. This is because the porosity of the composite is better than the composite mixture of bagasse and carbon black.

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