Utilisation of polyurethane composite with 50% composition of roystonea regia fiber as noise reduction panel on car hood

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Abstract. The objective is to get the characteristics of noise reduction, noise reduction level, variety of measurement spaces, and knowing the process in making acoustic material of natural fiber becomes noise reduction on a car hood. The process of making noise reduction material used casting method and pressed by using molded press. The composition of noise reduction material consist of 50% roystonea regia by 32 mesh and 50% combined by gypsum and polyurethane. The result shows that the average result of noise reduction at X₁- side is 5,7% and X₂- side is 3,9%, X₁+ side is 0,9% and X₂+ side is 6,2%, Z₁- side is 8,9% and Z₂- side is 10,1%, Z₁+ side is 9,7% and Z₂+ side is 10,01%. The main conclusion of the study shows that a noise reduction which made of roystonea regia with 32 mesh mixed by matrix of polyurethane and gypsum is appropriate for noise reduction on car hood.

1. Introduction

The development of automobile production in Indonesia increase annually. Each car has capability in reducing a noise that resulted from engine running system. The material for noise reduction has different noise reduction level depends on its brand and type. The higher noise reduction level in cabin space, the lower noise comes in the car. Most of the noise resulted from outside of the car as the engine other vehicles, crowded street, raindrop on the roof of a car, even the sounds of an engine running is still very noisy from the inside of cabin. The noise resulted from outside of the car can reduce the feeling of comfortable and damn distracting the driver while the driver is driving a car. The noise points that come to cabin of car resulted from: (1) door trim that reduce resonance on the license body plate, (2) cabin wall to reduce the noisy engine running that enter to cabin, (3) spakbor (the wheels space) to reduce a rumbling of road noise when the car runs, (4) engine hood to reduce noise of a machine and detain heat to prevent the hood paint not faded quickly, (5) the cabin floor to maximize noise reduction of wheel and power train derived from the bottom of the car, (6) the car roof to reduce heat and minimize noise of raindrop [1,2].

Basically, noise reduction has the same theory, namely reduces the ability of sound waves to do penetration in the panels of vehicles. Based on reduction material used, there are solid and liquid material. The solid materials are asphalt, foam, and butyl rubber. But now there are a variation experimented, there are distinction of noise reduction thickness, the aluminum foil layers, and the
difference in the contours of noise reduction. The advantages and disadvantages of every material such as: (1) asphalt, the advantages are reachable price, the ability of reduction is very good, many of the variation thickness, easy in installing and good in heat resistant. The disadvantages are very heavy (for one sheet by a size 60x60 cm needs 2 mm thickness and by weighed 2 pounds, while for 1 panel of the door at least needs two sheets). (2) Foam, the advantage is low price, it has many thickness variations, and light. The disadvantages is difficult in installment, the ability of noise reduction is low, thick, and cannot be used for wet. (3) Butyl rubber, the advantage is the ability of noise reduction is good, the mass is lighter until 80% than asphalt at the same thickness, easy in installment but the price is expensive [3].

As long as the expansion of science and technology, it is found that a noise reduction from porous material, fibrous material, resonators and panels. Many of porous and fibrous material can be used as a composite of noise reduction. Recent decades, the use of natural fibers have many demands because the quality of low density, low price, renewable, low costs production, good in mechanical and physical properties and abounding [4]. The use of natural fibers initially by the utilization of waste long-lived plants such as areca and coconut, which can reduce the effects of global warming. One of a natural fiber which become an objective of research is the fibers of roystonea regia or in the world trade known as Areca Catechu L. This plant comes from South Asia and Southeast Asia and some of them grew up in India [5].

Roystonea regia has researched with variations mesh 10, 14, and 32 with contained 30%, 40%, 50%, 60%, and 70% of fibers. The result of the experimental got the best noise reduction coefficient obtained in composition of 50% fiber and 32 mesh [6]. By the experimental, researchers want to canvass the utilization of roystonea regia fibers with composition 50% fiber and 32 mesh to be a noise reduction on Daihatsu Xenia car hood. In this study the noise reduction will be investigated experimentally by influencing variation of measurement distances. The main objective is to explore the decline of noise reduction to get information about noise reduction characteristic of 50% roystonea regia by 32 mesh.

2. Method
In this study a mini bus which is used for human transportation will be used as a tested car. The specifications of the car are presented in Table 1. It is three cylinders four stroke engine fueled by gasoline.

| No | Parameter                        | Value                        |
|----|----------------------------------|------------------------------|
| 1  | Commercial name/model            | Daihatsu Xenia 1.0           |
| 2  | Number of cylinder/stroke        | Three-cylinder/four strokes engine |
| 3  | Cooling system                   | Water cooled                 |
| 4  | Bore × Stroke                    | 72 × 81 mm                   |
| 5  | Maximum output                   | 65 PS/ 5600 rpm              |
| 6  | Engine weight                    | 995 kg                       |

2.1 Experimental Apparatus
In this study the making of noise reduction material on car hood for xenia used fibers of roystonea regia as a filler, gypsum and milionate MR-200 of polyisocianate and JKR-7631L of polyol as composite of matrix polymeric foam material. The process of making specimens started from making fiber, as shown in figure 1. Where the first process is cutting down the roystonea regia, making it in a part of cutting, placing to an oblique position for drying process, after the roystonea regia totally dry, blend it to be a fiber. After becomes a fiber, it sieves by using screen mesh to get roystonea regia fiber by 32 mesh.

The next step after produced roystonea regia fiber by 32 mesh, furthermore it is added by matrixes (gypsum and polyurethane gradually). Gypsum mixed into roystonea regia fibers and stirred until
evenly distributed, then added the milionate MR-200 of polyisocianate and stirred until evenly distributed, then added JKR-7631L of polyl alternately into a mixture until evenly distributed. The combination of filler and matrix is poured to a mold of xenia car hood. The technique of making specimen used hand lay-up method and pressed by lock mold. It is like shown as figure 2.a. The drying process needs about 20 minutes minimum and 30 minutes maximum, then the product detachable from the mold. And the result of molding process produces an acoustic material as shown in figure 2.b.

**Figure 1.** Preparation process in making roystonea regia fiber to be meshed 32

In this study the method of measurement is directly measured by digital sound level meter (SPL) instrument to get the values of noise reduction. In order to perform the study, an experimental apparatus has been designed and developed as shown in figure 3.

In measurement process, the SPL moved by the distance as 10 cm, 20 cm, 30 cm, 40 cm, 50 cm, 60 cm, 70 cm, 80 cm, 90 cm, and 100 cm sequentially for each side. It moved for X- as front car hood side, X+ as behind car hood side, Z- as left car hood side, and Z+ as right car hood side.
Figure 2. car hood as lock mold to produce acoustic material

The measurement condition is devided by four kinds of measurement, firstly is without engine load and noise reduction, secondly is without engine load but with noise reduction, thirdly is with engine load and without noise reduction, fourthly is with engine load and noise reduction. The engine load is the condition when the air conditioner and the body electrical is turned on. All the measurement process is in stationary engine run condition. The datas got from the sides that measured will be shown as a grafic to get the conclusion for the experiment.

Figure 3. The measurement side of hood
2.2 Noise Reduction Analysis

Sound intensity is the flow of energy carried by sound waves in a region per unit area, the Intensity of Sound is very important to understand the total of radiation from a sound source and the pressure. It can be calculated by using the following equation:

$$I = \frac{P^2}{\rho \cdot c}$$  \hspace{1cm} (1)

Where $I$ is Intensity [J/m$^2$s] a function of square pressure ($P^2$), it can develop an equation for sound pressure level (SPL) as follows;

$$PWL = 10 \log \frac{P_1^2}{P_0^2}$$  \hspace{1cm} (2)

Or:

$$SPL = 20 \log \frac{P_1}{P_0}$$  \hspace{1cm} (3)

Where:

- $P_0$ = reference pressure as pressure the noise incapable of being heard on a frequency 1000 Hz.
- $P_1$ = working pressure;

3. Result and Discussion

The results will be discussed in two subsections; they are coefficient of 50% fiber of roystonea regia and distance variation of measurement.

3.1 Coefficient of 50% fiber of roystonea regia

From the eksperiment obtained the data of noise reduction coefficients ($\alpha$) with frequency variations in using impedance tube and the results shown on Table 2.

| Frequency (Hz) | A    | B    | X1  | X2  | k    | $\alpha$ |
|----------------|------|------|-----|-----|------|---------|
| 125            | 0.448| 0.239| 0.275| 0.2 | 2.289| 0.716   |
| 250            | 1.232| 0.768| 0.275| 0.2 | 4.579| 0.611   |
| 500            | 0.586| 0.383| 0.275| 0.2 | 9.159| 0.572   |
| 1000           | 0.502| 0.308| 0.275| 0.2 | 18.318| 0.623  |
| 1500           | 0.052| 0.038| 0.275| 0.2 | 27.477| 0.453   |
| 2000           | 0.667| 0.403| 0.275| 0.2 | 36.637| 0.635   |

The result of Table 2 changed to a chart will shown as Figure 4. Where it apparently increase the coefficients at the frequency of 125 Hz namely 0.7162 and when the frequency of 125 Hz to the frequency of 250 Hz experienced reduction in the value of the coefficients employ the namely 0.6017. The noise reduction coefficients at the frequency of 500 Hz is 0.5719 and deriving from the frequency of 250 Hz, but increasing at the frequency of 1000 Hz namely 0.623. The noise reduction coefficients at the frequency of 1500 Hz derive from frequency 1000 Hz namely 0.4532 and at the frequency of 2000 Hz namely 0.6346. So the noise reduction coefficient produced of material 50% fibers of roystonea regia with mesh 32 and 50 % gypsum and polyurethane with the impedance tube methods is an average number of experiment by frequency variations of 0.6016.
3.2 Distance variation of measurement
In this discussion will be noted on car hood sides by the symbols below:
1. Front car hood side in stationer condition without engine load and without noise reduction (X1-).
2. Front car hood side in stationer condition without engine load and with noise reduction (X1-\*).
3. Front car hood side in stationer condition with engine load and without noise reduction (X2-).
4. Front car hood side in stationer condition with engine load and with noise reduction (X2-\*).
5. Behind car hood side in stationer condition without engine load and without noise reduction (X1+).
6. Behind car hood side in stationer condition without engine load and with noise reduction (X1+\*).
7. Behind car hood side in stationer condition with engine load and without noise reduction (X2+).
8. Behind car hood side in stationer condition with engine load and with noise reduction (X2+\*).
9. Left car hood side in stationer condition without engine load and without noise reduction (Z1-).
10. Left car hood side in stationer condition without engine load and with noise reduction (Z1-\*).
11. Left car hood side in stationer condition with engine load and without noise reduction (Z2-).
12. Left car hood side in stationer condition with engine load and with noise reduction (Z2-\*).
13. Right car hood side in stationer condition without engine load and without noise reduction (Z1+).
14. Right car hood side in stationer condition without engine load and with noise reduction (Z1+\*).
15. Right car hood side in stationer condition with engine load and without noise reduction (Z2+).
16. Right car hood side in stationer condition with engine load and with noise reduction (Z2+\*).

Figure 5 shows that on stationary condition with and without engine load and noise reduction material, the waves current of noise flows descently from near of noise source. The best noise reduction percentage is on Z2 side. It is 10.11% by average noise reduction 6.81 dB. And the lowest noise reduction percentage is on X1 side. It is 0.89% by average noise reduction 0.5 dB. For comparing the data, it is shown as Table 3 and Table 4 below.
**Figure 5.** Result of SPL Measurement

### Table 3. Data of SPL measurement at right and left side of car hood

| Distance (cm) | \( Z_1^- \) | \( Z_1^+ \) | Intensity of Noise Reduction | Percentage of Noise Reduction | \( Z_2^- \) | \( Z_2^+ \) | Intensity of Noise Reduction | Percentage of Noise Reduction |
|---------------|-------------|-------------|-----------------------------|------------------------------|-------------|-------------|-----------------------------|------------------------------|
| 10            | 64.3        | 58.1        | 6.2                         | 9.642                        | 63.7        | 57.1        | 6.6                         | 10.361                       |
| 20            | 63.3        | 56.8        | 6.5                         | 10.268                       | 63.0        | 56.3        | 6.7                         | 10.635                       |
| 30            | 62.6        | 56.0        | 6.6                         | 10.543                       | 62.3        | 56.1        | 6.2                         | 9.952                        |
| 40            | 62.1        | 55.5        | 6.6                         | 10.628                       | 61.9        | 55.8        | 6.1                         | 9.855                        |
| 50            | 61.5        | 55.1        | 6.4                         | 10.406                       | 61.6        | 55.2        | 6.4                         | 10.389                       |
| 60            | 59.7        | 54.7        | 5                           | 8.375                        | 59.6        | 54.7        | 4.9                         | 8.221                        |
| 70            | 58.5        | 54.1        | 4.4                         | 7.521                        | 59.2        | 54.0        | 5.2                         | 8.784                        |
| 80            | 57.9        | 53.8        | 4.1                         | 7.081                        | 58.9        | 53.3        | 5.6                         | 9.507                        |
| 90            | 57.3        | 53.2        | 4.1                         | 7.155                        | 58.4        | 52.8        | 5.6                         | 9.589                        |
| 100           | 57.1        | 52.6        | 4.5                         | 7.881                        | 58.1        | 52.2        | 5.9                         | 10.155                       |
| Number of Average | 5.44       | 8.950       |                             |                             | Number of Average | 5.92       | 9.745                       |

| Distance (cm) | \( Z_2^- \) | \( Z_2^+ \) | Intensity of Noise Reduction | Percentage of Noise Reduction | \( Z_2^- \) | \( Z_2^+ \) | Intensity of Noise Reduction | Percentage of Noise Reduction |
|---------------|-------------|-------------|-----------------------------|------------------------------|-------------|-------------|-----------------------------|------------------------------|
| 10            | 71.0        | 63.8        | 7.2                         | 10.140                       | 69.9        | 63.3        | 6.6                         | 9.442                        |
| 20            | 70.0        | 63.5        | 6.5                         | 9.285                        | 69.2        | 62.0        | 7.2                         | 10.404                       |
| 30            | 69.1        | 61.7        | 7.4                         | 10.709                       | 67.5        | 61.9        | 5.6                         | 8.296                        |
| 40            | 67.6        | 61.4        | 6.2                         | 9.171                        | 67.3        | 61.4        | 5.9                         | 8.766                        |
| 50            | 66.5        | 61.0        | 5.5                         | 8.271                        | 66.3        | 59.9        | 6.4                         | 9.653                        |
| 60            | 66.3        | 59.7        | 6.6                         | 9.955                        | 65.9        | 59.3        | 6.6                         | 10.015                       |
| 70            | 66.0        | 59.3        | 6.7                         | 10.155                       | 65.4        | 58.8        | 6.6                         | 10.092                       |
| 80            | 65.8        | 58.8        | 7                           | 10.638                       | 65.2        | 58.2        | 7                           | 10.736                       |
| 90            | 65.7        | 58.4        | 7.3                         | 11.111                       | 65.0        | 57.7        | 7.3                         | 11.231                       |
| 100           | 65.6        | 57.9        | 7.7                         | 11.737                       | 64.9        | 57.4        | 7.5                         | 11.556                       |
| Number of Average | 6.81       | 10.117      |                             |                             | Number of Average | 6.67       | 10.019                       |
From Table 3 can be concluded that the ratio of the right and the left side of car hood got the highest value of average percentage at the right side with engine load without noise reduction $Z_2$ is 10.1% (6.81 dB). It is caused by sound that generated by alternator and power steering pump. Furthermore, Table 4 shows the ratio of inside and outside car hood. The highest value of noise reduction average at outside (front side) of car hood by engine load with noise reduction is 6.2% (4.2 dB). It is caused of car hood reduction.

Table 4. Data of SPL measurement at inside (behind) and outside (front side) of car hood

| Distance (cm) | $X_1^+$ | $X_1^{+\prime}$ | Intensity of Noise Reduction | Percentage of Noise Reduction | $X_1^-$ | $X_1^{-\prime}$ | Intensity of Noise Reduction | Percentage of Noise Reduction |
|--------------|---------|-----------------|-------------------------------|-------------------------------|---------|-----------------|-------------------------------|-------------------------------|
| 10           | 57.5    | 57.4            | 0.1                           | 0.174                         | 66.3    | 62.9            | 3.4                           | 5.128                         |
| 20           | 57.4    | 57.2            | 0.2                           | 0.348                         | 65.5    | 62.3            | 3.2                           | 4.885                         |
| 30           | 57.2    | 57.0            | 0.2                           | 0.349                         | 64.9    | 61.9            | 3                             | 4.622                         |
| 40           | 56.5    | 56.3            | 0.2                           | 0.354                         | 64.8    | 61.4            | 3.4                           | 5.246                         |
| 50           | 56.4    | 56.1            | 0.3                           | 0.532                         | 64.3    | 60.5            | 3.8                           | 5.909                         |
| 60           | 56.2    | 55.7            | 0.5                           | 0.889                         | 62.9    | 59.1            | 3.8                           | 6.041                         |
| 70           | 55.8    | 55.4            | 0.4                           | 0.716                         | 62.7    | 58.4            | 4.3                           | 6.858                         |
| 80           | 55.5    | 55.0            | 0.5                           | 0.901                         | 61.2    | 57.6            | 3.6                           | 5.882                         |
| 90           | 55.4    | 54.1            | 1.3                           | 2.346                         | 60.8    | 57.1            | 3.7                           | 6.085                         |
| 100          | 55.1    | 53.8            | 1.3                           | 2.359                         | 60.6    | 56.8            | 3.8                           | 6.271                         |
| Number of Average | 0.5     | 0.897           |                               |                               | 62.9    | 59.1            | 3.8                           | 6.041                         |
|               |         |                 | Number of Average             | 3.6                           |         |                 |                               | 5.693                         |

| Distance (cm) | $X_2^+$ | $X_2^{+\prime}$ | Intensity of Noise Reduction | Percentage of Noise Reduction | $X_2^-$ | $X_2^{-\prime}$ | Intensity of Noise Reduction | Percentage of Noise Reduction |
|--------------|---------|-----------------|-------------------------------|-------------------------------|---------|-----------------|-------------------------------|-------------------------------|
| 10           | 69.8    | 65.7            | 4.1                           | 5.874                         | 76.7    | 73.5            | 3.2                           | 4.172                         |
| 20           | 69.4    | 65.4            | 4                             | 5.764                         | 74.9    | 72.7            | 2.2                           | 2.937                         |
| 30           | 68.7    | 65.0            | 3.7                           | 5.385                         | 73.9    | 71.3            | 2.6                           | 3.518                         |
| 40           | 68.3    | 63.7            | 4.6                           | 6.735                         | 73.2    | 70.4            | 2.8                           | 3.825                         |
| 50           | 67.7    | 63.3            | 4.4                           | 6.499                         | 72.5    | 69.4            | 3.1                           | 4.275                         |
| 60           | 67.3    | 63.1            | 4.2                           | 6.241                         | 71.3    | 68.8            | 2.5                           | 3.506                         |
| 70           | 67.2    | 62.9            | 4.3                           | 6.398                         | 71.1    | 68.2            | 2.9                           | 4.078                         |
| 80           | 67.0    | 62.6            | 4.4                           | 6.567                         | 69.7    | 66.8            | 2.9                           | 4.161                         |
| 90           | 66.4    | 62.3            | 4.1                           | 6.174                         | 68.8    | 65.8            | 3                             | 4.360                         |
| 100          | 66.2    | 61.8            | 4.4                           | 6.646                         | 68.5    | 65.6            | 3.9                           | 4.233                         |
| Number of Average | 4.22    | 6.228           |                               |                               | 68.5    | 65.6            | 3.9                           | 4.233                         |

4. Conclusion
From the experimental data with 50% roystonea regia fibers used impedance tube got the average results of noise reduction coefficient ($\alpha$) namely 0.6 and the experimental data of noise reduction used SPL such as 6.81 dB for Maximum average on $Z_2$ and minimum 0.5 dB on $X_1^+$. The decline of noise reduction level by variations of measurement distances used SPL stated that the results of noise
coefficients produced noise reduction level linearly. However, the longer measurement distances, the result of measurement will be smaller. The highest noise level was on \(X_2^{-}\) and the lowest on \(X_1^{+}\).

5. References

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