

CHARACTERIZATION OF PERFORMANCE ACOUSTIC SANDWICH COMPOSITE WITH A CORE OF POLYURETHANE FOAM-AGAVE SISALANA FIBER REINFORCED POLYESTER FOR NOISE ABSORPTION

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ABSTRACT

Absorber material has characteristic of acoustic that reflect and absorb sound wave. Absorption by porous material is very useful to reduce the sound power level that occurs so as to reduce the noise in the room. The sound absorption coefficient of the Acoustic Sandwich Composite (ASC) was determined by a two-microphone impedance measurement according to international standard ASTM 1050-98. Dimension of The ASC consist of 1 core and 2 skin with diameter 100 mm. Skin on front side designed has 5 hole ($d=10$ mm) and used 4 different thickness of polyurethane foam (PU-Foam) that is 10, 20, 30 and 40 mm used as core of ASC. The skin on both sides of sandwich composite made from continuous and chopped agave sisalana fibre reinforced polyester with thickness 5 mm. Value of Noise Absorption Coefficient (NAC) is given from 0 to 1, which means sound absorption is none in value 0, and sound absorption reaches the maximum in value 1 on frequency range 0 Hz -1.6 kHz. This case, it is shown on the foam with thickness 30 mm is good in the low frequency range with the highest value of NAC is 0,46. The ASC designed of thickness 30 mm foam core can raise reach value of the NAC in the low frequency (400 Hz-1000 Hz), highest value 0.80 at frequency 800 Hz. The ASC of thickness 10 mm foam core to be optimum for middle frequency (1000 Hz-1600), highest value 0.89 at frequency 1200 Hz.

Key Words : Foam, Acoustic Sandwich Composite, Noise Absorption Coefficient

INTISARI

Bahan penyerap memiliki karakteristik akustik yang memantulkan dan menyerap gelombang bunyi. Penyerapan oleh bahan berpori sangat berguna untuk mengurangi tingkat kekuatan bunyi yang terjadi sehingga dapat mengurangi kebisingan di dalam ruangan. Koefisien Penyerapan Bunyi (NAC) dari *Acoustic Sandwich Composite* (ASC) diuji dengan menggunakan tabung *Kundts Tube* impedansi dua mikrofon sesuai dengan standar ASTM 1050-98. Dimensi ASC terdiri dari 1 inti dan 2 kulit dengan diameter 100 mm. Kulit di sisi bagian depan didisain memiliki 5 lubang ($d = 10$ mm) dengan variasi 4 ketebalan yang berbeda dari busa poliuretan (busa-PU) yaitu 10, 20, 30 dan 40 mm yang digunakan sebagai inti dari ASC. Kulit atau skin di kedua sisi komposit *sandwich* terbuat dari poliester yang diperkuat bahan serat alam agave sisalana acak dan panjang dengan tebal 5 mm. Nilai Koefisien Penyerapan Bunyi (NAC) diberikan nilai 0-1, yang berarti penyerapan bunyi tidak ada akan bernilai 0, dan penyerapan bunyi mencapai maksimum apabila bernilai 1 pada rentang frekuensi 0 Hz -1,6 kHz. Pada penelitian ini terlihat sifat busa polyurethane dengan ketebalan 30 mm baik pada rentang frekuensi rendah dengan nilai NAC tertinggi adalah 0,46. ASC dengan ketebalan busa PU 30 mm memiliki kenaikan harga NAC di frekuensi rendah (400 Hz-1000 Hz), nilai tertinggi 0,80 di frekuensi 800 Hz. ASC dengan ketebalan busa PU 10 mm baik untuk frekuensi menengah (1000 Hz-1600), nilai tertinggi 0,89 pada frekuensi 1200 Hz.

Kata Kunci : Busa PU, *Acoustic Sandwich Composite*, Koefisien Penyerapan Bunyi

INTRODUCTION

Noise according to *McGraw Hill Dictionary and Technical Terms* is a sound that doesn't wanted (sound which is unwanted) (Parker, 1994). Noise was always associated with impact exceed the high pressure voice heard man. In closed spaces,

when the sound spread to bend a walls and the sound will be absorbed or reflected. So, in a pool a sound that happened to be heard in fact is a combination of the original sound and sound reflection. Knowledge about how to disseminate the sound in their room will

provide any benefits on anticipated noise that emerged on room (Mediastika C.E, 2005).

Polyurethane usually abbreviated PU is polymers that consists of a chain organic unit connected by uretana (karbamat). This type of polymer initially liquid form at the same time as a catalyst mixed so that they formed a task force isocyanate that form of solid as foam rigid low density and spongy (PU-Foam) (Hull D, 1981). Foam rigid and porous structure as seen in Figure 1a is a core in sandwich that serves as a device to reduce noise. By doing design acoustic cell was then PU *foam core* can function device to reduce noise in the wall so that it was able to create a space that are qualified health as well as comfort (Doelle L.L, 1986).

Agave Sisalana Perrine (*Agave SP*) is one of the kinds of plant fibers from the leaves that are classified as fiber plant leaves. This Fiber used their ropes and to also be used for making bags, ropes, fish nets, a clean sweep, furs and handicraft products that other commercial because his nature is strong, not flexible and sea water resistant (Sastrosupadi A, 2006). Fiber agave sisal attempted in madura known with the title fiber pineapple fiber is white and strong, its area around 670-728 ha with production of fiber average 208,106 Kg/year as seen in Figure 1b. Using fiber agave sisalana in sector reduce sound engineer is seldom carried out. This Research involves the use fiber was in a *Acoustic Sandwich Composite* (ASC) that is as skin with the thickness of 5 mm. Composite sandwich is a composite is composed of three the layers of skin consists of skin over designed holes with a diameter 10 mm as much as 5 (five) of the hole that is expected to function as resonator in ASC and skin under the closed not hollow with core in the middle of sandwich composite is made with the aim to economize weight or raw materials very light but have stiffness and the high strength and able to be used for absorbing the sound on room.

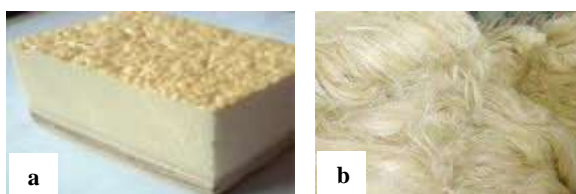


Figure 1. a) Polyurethane foam and
b) Agave sisalana fibre

LITERATURE REVIEW

Several Researchers have succeeded in developing perforated material. Han F *et al*,

2003 have a study on of Al-cell foam made from non-ferrous metals with the infiltration process to form with form as metal foam porous. Material *acoustics Al foam cell* that has a small pores will have value on the *Sound Absorption Coefficient* (SAC) more optimal in absorb sound that materials that have big pores. Acoustic cells without air gap has a good SAC value at the high frequency that is in the devastated landscape reach 1500-3500 Hz and optimum in frequency 2000 Hz. Additional air gap of 30 mm shift the SAC toward a lower frequency with frequency range 400-1500 Hz.

For study of the multi layer acoustic absorber on article, Yudhanto F, 2012 present an experimental study for sandwich composite with three part assembly consisting two skin and the middle of sandwich as core. Core of sandwich has square shape from particle wood material designed like as Helmholtz resonator. Cell Acoustic *Helmholtz* was designed by a variation without hole ($d=0$), hole 4 mm ($d=4$ mm) and the hole 10 mm ($d=10$ mm). Additional diameter holes in a cell Acoustic resonator caused NAC value shift to the low frequency with the range 400 Hz-800 Hz. Additional *acoustics fill* coconut fiber density coconut fiber that small effected number of many porous and the density to cavities resonator gases that will increase the value NAC in low frequency.

Mustika C. Fitriani *et al*, 2014 make synthesis and testing performance absorbed the sound powder bamboo composite with adhesive sago flour, which was created by a heat pressure mechanism at temperatures 80°C and by design modification perforation ratio as well as resonance technique by wearing the cavity air obtained test result NAC powder composite bamboo good to be used at the average frequency in range 1000Hz-1600 Hz.

Study of acoustic research focus on the structure and configuration of the air cavity variations in the samples tested make from gedeg woven fibre and enceng gondok composite with perforated cell. Testing of Noise Coefficient Absorption will be done by the method of tube impedance according to the standard ASTM E-1050-98. Testing result shows that the response accumulative insertion panel holes and additional air cavities variations of 25 mm in front and rear panel can be effective in improving performance of acoustic instrument panel gedek being examined by 0.68 in landscape low frequency that is wide range 200 Hz - 800 Hz (M.Wijayanti *et al*, 2015).

Resonator Helmholtz

Resonator Helmholtz can analogize as a system resonator gases such as seen in Figure 2. The mass element (m), the existence pressure to cavities acoustic resonator function as a stiffness element (s), and the resistance in the neck resonator that are absorbed and air cavities porous material (PU-Foam) behind cell front panel working as a resistance element (R_m), (Kinsler E.L. *et al*, 1982)

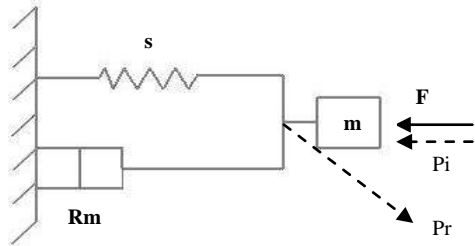


Figure 2. A damped, forced harmonic oscillator

By the analogy above so that Helmholtz resonator has a common point that is often called as a *single degree of freedom system (Single DOF)* that formulated as follow;

$$m \frac{d^2 \zeta}{dt^2} + R_m \frac{d\zeta}{dt} + s\zeta = Fe^{j\omega t} \quad (1)$$

note :

$$m = \rho_0 SL' \quad (2)$$

with :

- m = total effective mass
- ρ_0 = kind air mass
- L = long effective neck hole
- S = area neck hole

RESEARCH METHODOLOGY

Testing of Noise Absorption Coefficient (NAC) with Kundts Tube Impedance two microphone

When the waves sound of a material and a part of the energy sound wave will be absorbed and some will be reflected back. The enormous pressure from the sound waves come can be declared in the equation below:

$$p_i = A \cos 2\pi f t \quad (3)$$

While pressure sound waves that reflected (*reflection*) can be declared in its equation below:

$$p_r = B \cos 2\pi f \left(t - \frac{2y}{c} \right) \quad (4)$$

- P_i = pressure sound waves come (mPa)
- P_r = pressure sound waves refracting (mPa)
- f = frequency of source sounds (Hz)
- y = distance location that is observed to material surface (m)
- v = speed of sound (m/s)
- t = time (s)

Specimen trial was made according to the standard ASTM E-1050-98 with a diameter specimen tests 100 mm as seen in Figure 3 and Figure 4.

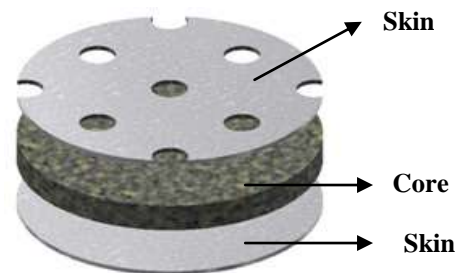


Figure 3. The Specimen of NAC with diameter 100 mm and resonator hole 10 mm

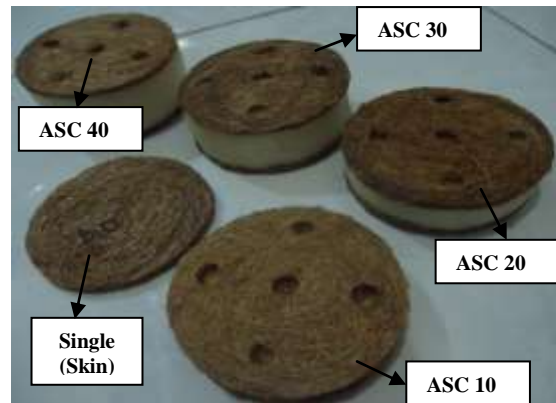


Figure 4. The Specimen of NAC with diameter 100 mm and resonator hole 10 mm

The variables used in *acoustic sandwich composite* is a variation thickness *Pu-Foam* as core from sandwich composite is 10, 20, 30 and 40 mm. Adding a hole resonator that are planned as much as 5 hole with a diameter 10 mm on front of skin cells acoustics. Optimization additional holes will be made to the thickness skin 5 mm and this was aimed to find out the influence holes and thick PU-Foam to the sound.

The sound coefficient absorbed or absorption coefficient (α) a material is defined as a comparison between the absorbed energy material with total energy that the material constraints. Because energy has a proportion value by the square to pressure from the sound, then:

$$\alpha = 1 - (r)^2 \quad (5)$$

note :

r = comparison waves came with refracting waves

The equipments in *kundts tube impedance two mikrophone* that is used, a tube used is type 4206, microphone type 4718, computers with software *Pulse System* type 7700 v.16 *Sound, Vibration and Material Testing Measurement*, generator type 3160, and amplifier type 2716 C (*Brüel & Kjaer*) as seen in Figure 5.

According to the standard ASTM E-1050-98 sample trial diameter 100 mm were placed on back side tube impedance while *loudspeakers* in the other side that transmit random noise. The Second mikrophone tube impedance used to perceive the sound pressure in two different positions that are used to calculate components wave came and waves refracting to specimens trial.

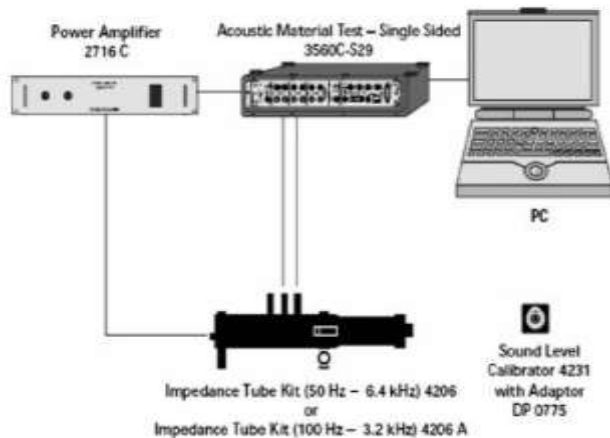


Figure 5. Testing of *Noise Absorption Coefficient (NAC)* by using kundts tube impedance two mikrophone (*Brüel & Kjaer*)

RESULTS AND DISCUSSION

Testing result of Noise Absorption Coefficient (NAC) in PU-Foam and Acoustic Sandwich Composite (ASC)

Testing PU-Foam, designed as core ASC function to shock absorbers resistance in ASC. Testing PU-Foam obtained by the NAC is good in that range 200 Hz-800 Hz with the

highest values 0.46 on 450 Hz. As a whole PU-Foam have average value NAC of 0.41 as seen in Figure 6.

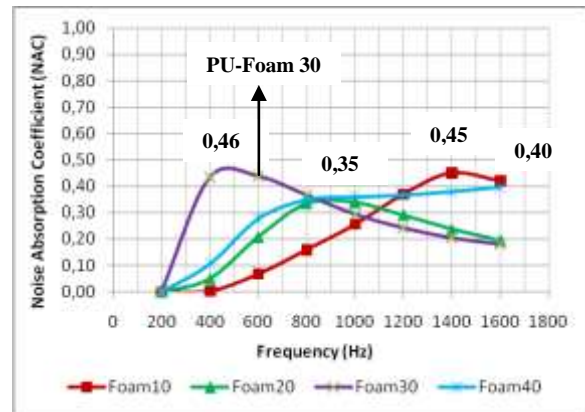


Figure 6. The Testing result of *Noise Absorption Coefficient (NAC)* in Pu-Foam with thickness variation 10 mm, 20 mm, 30 mm and 40 mm

Design result acoustics by using fiber agave sisalana (*absorber material*) reinforced polyester as *skins* at ASC, then an additional resonator holes that are expected can affect to stiffness attenuation (s).

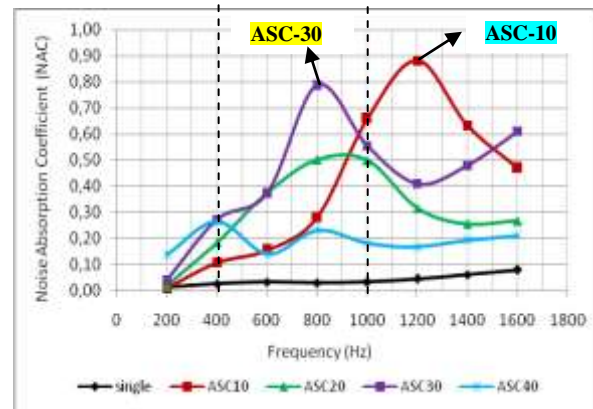


Figure 7. The testing result of *Noise Absorption Coefficient (NAC)* in *Acoustic Sandwich Composite (ASC)*

The ascension NAC that can be seen the highest, is in ASC-30 in low frequency range (400-1000 Hz) with the value 0.80 at 800 Hz and ASC-10 for middle frequency range that is 1000 Hz-1600 Hz with the highest values 0.89 at 1200 Hz (Figure 7). This was strengthened by testing reflected sound or *Reflection Coefficient (RC)* from PU-Foam and ASC have rates that low so that it is very optimal used as the sound absorbed in Low frequency .

Testing result of Reflection Coefficient (RC) in PU-Foam and Acoustic Sandwich Composite (ASC)

Outcome of the test RC obtained PU-Foam 30 mm have the best absorption 0.73 compared PU-Foam 10, 20 and 40 mm of 0.80. In a broad outline characteristic PU-Foam in *low frequency* (400 Hz-1000 Hz) have reflected value a great or in other words the absorbed a small one.

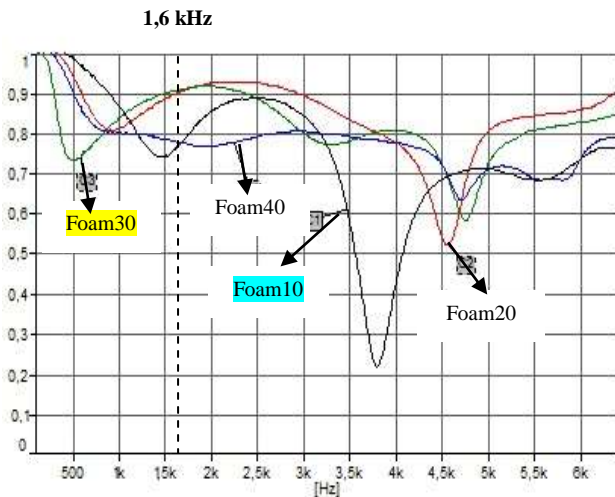


Figure 8. The testing result of *Reflection Coefficient (RC)* in Polyurethane or PU-Foam with variation thickness 10 mm, 20 mm, 30 mm and 40 mm

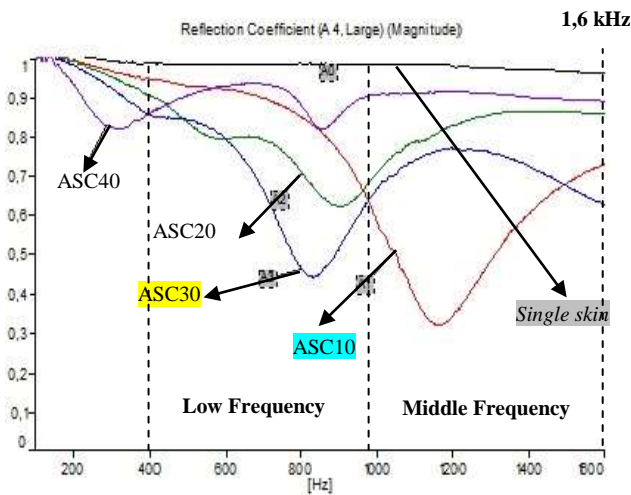


Figure 9. The testing result of *Reflection Coefficient (RC)* in Acoustic Sandwich Composite (ASC) with variations ascension the thickness PU-foam

The Reflections average value of 0.7 stable at the high frequency at reach 3000 Hz-6000 Hz. In reach 1600-3000 Hz the reflection value or

average reflection 0.9 and this means almost perfect reflected, this is most likely be natural resonance of PU-Foam and happen resonance wave length $3/4 \lambda - 5/4 \lambda$ as seen in Figure 8.

In testing single skin from agave sisalana reinforced polyester show the value of RC close to 1 this mean that the sound waves reflected off almost. ASC method characteristic reflected foam after designed with a helmholtz resonator concept that add skins from absorb material to reach low frequency with value of reflected sound to be smallest 0.42 for ASC-30. ASC-10 has a good pattern absorbed in reach middle frequency with smallest value of 0.30 means that sound wave as a reflection the noise on 1150 Hz as seen in Figure 9.

ASC 40 tend to be reflected sound these things happen because natural resonance among the distance 40 mm between PU-Foam and skins ASC is considered not to make a resistance close up. The structure big pores, a little oval and regular form from Polyurethane-Foam with thick 40 mm make that NAC less optimal in low frequency and middle frequency.

Testing of Density on a Acoustic Sandwich Composite (ASC)

Mass of ASC specimen with variations ascension the thick foam have weight almost the same the average 38 gram while material volume biggest. This was described porous or hollow in PU-Foam the bigger along with the ascension thick PU-Foam.

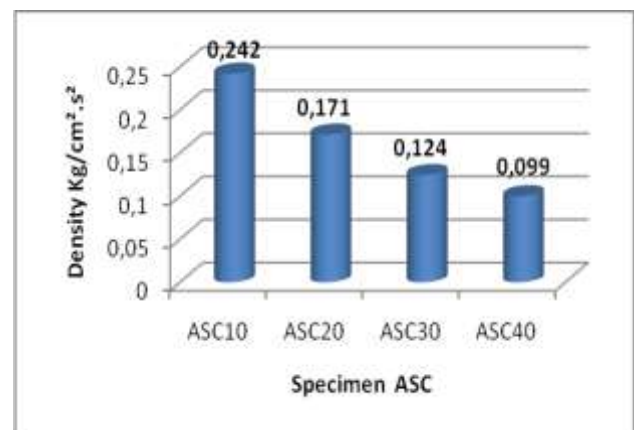


Figure 10. Density in Acoustic Sandwich Composite (ASC)

From preliminary data, every increase thick so that cavities or porous from volume cavity PU Foam will rise to more than early volume (Figure 10).

This was the cause that the air entered among the two skins more increasing rates viscous near from attenuation sound especially on ASC30. The big pores and pill up make the sound wave be caught in that sturcture of polyurethane foam and has good viscous damping for low frequency (600 Hz-1000Hz) as seen Figure 11.

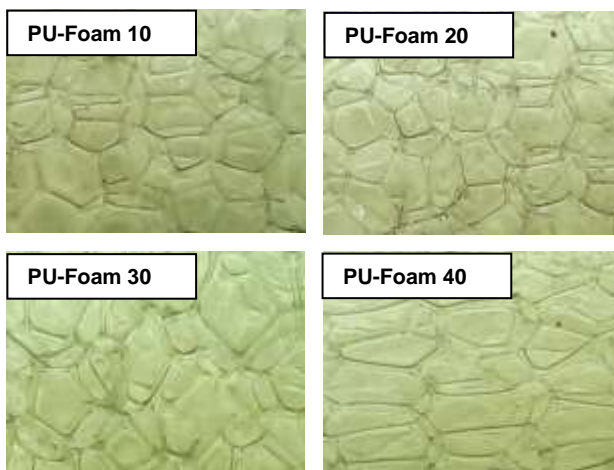


Figure 11. Photos the structure at macro level PU-Foam

CONCLUSION AND SUGGESTION

1. Acoustics Sandwich Composite (ASC) with thickness PU-Foam 30 mm have characteristics absorb sound optimally at reach low frequency (*Low Frequency*) with the highest values *Noise Absorption Coefficient* (NAC) is 0.8 at 800 Hz. For ASC-10 in both frequency range (*middle frekuensi*) with the NAC value 0.89 at the frequency 1200 Hz.
2. Reflections at the sound may lead to the collision between the sounds come and the sound refracting. Results RC (*Reflection Coefficient*) that low in ASC-20 and ASC-30 means that the design has a value sound reflection that small in low *frequency*. While ASC-10 as a reflection is lower in *middle frequency*, this can lead a buzzing in a room at the frequency can be overcome.
3. PU-Foam is hard foam material is light density $0.029 \text{ Kg/cm}^2 \cdot \text{s}^2$. PU-Foam with 30 mm thickness optimum resistance as shock absorbers vibration or viscous damping because the sound or voice through the structure foam with holes and overlap so that the sound refracting that

will be changed to heat energy more and more. While PU-Foam 40 has the structure big pores, little oval and regular form so have less value on Noise Absorption Coefficient (NAC) at low and middle frequency.

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