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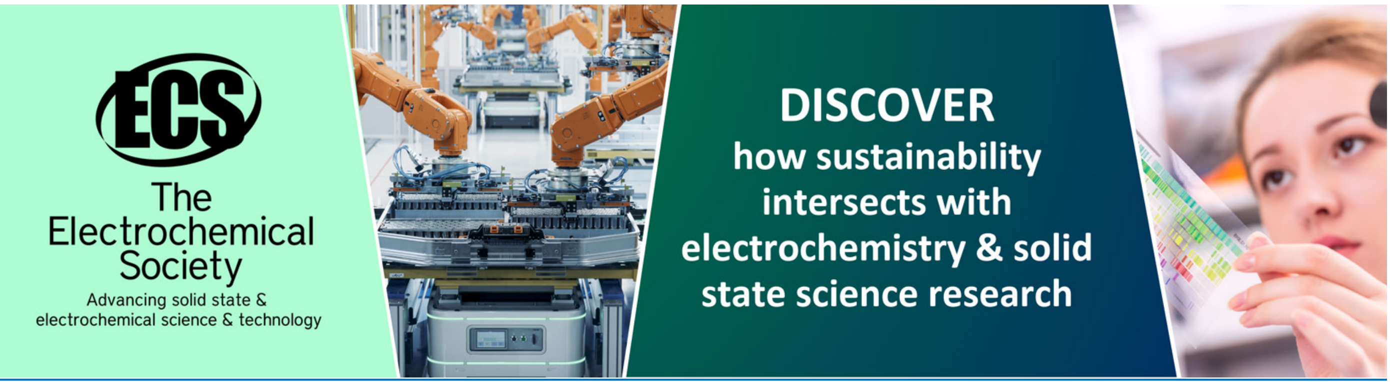

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A Review: Characteristics of Noise Absorption Material

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Abstract. Noise is always treated as a nuisance to human and even noise pollution appears in the environmental causing discomfort. This also concerns the engineering design that tends to cultivate this noise propagation. Solution such as using material to absorb the sound have been widely used. The fundamental of the sound absorbing propagation, sound absorbing characteristics and its factors are minimally debated. Furthermore, the method in order to pertain sound absorbing related to the sound absorption coefficient is also limited, as many studies only contributes in result basis and very little in literature aspect. This paper revolves in providing better insight on the importance of sound absorption and the materials factors in obtaining the sound absorption coefficient.

1. Introduction

Noise is obviously related as nuisance endured by humans from the machineries and appliances of daily activities [1]. Sound is a propagation of disturbance in fluid or in solid, principally; a wave motion is set off when an element sets the nearest particle of air into motion, which then creates difference in pressure in the medium where the wave travels [2]. Noise and sound carries the same definition, however denoted with different perception and definition. Depending on the medium the sound wave travels, sound propagates at different speeds, related to the pressure difference [4]. Normally, the static air pressure is about 105Pa in which the audible sound pressure variations are minor ranging from 20µPa to 100Pa [5]. Such in that, the sound pressure of 20µPa corresponds to the average human's threshold of hearing, making it the par. As for principle of the sound detection, theory notes the vibrations caused by the sound pressure hits a surface and travels to been detected by the human ear [6] as in figure. 1. The normal static pressure appears hits the object causing pressure change in the air thus propagating a sound wave through the vibration back and forward by the object [7]. The sound being emitted in terms of sound waves in a longitudinal manner, which eventually calculated using frequency, f measured in Hertz, Hz. As researched

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by [3], frequency as the physic quantity can be used as the sound wave and enables calculation of the sound pressure level and also

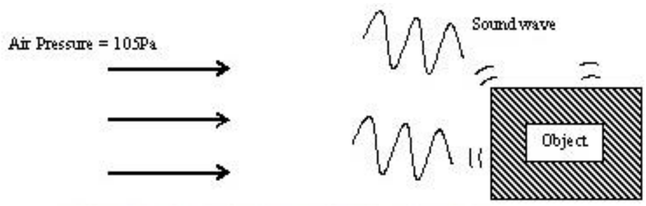

Figure 1. Schematic diagram of reflected sound wave.

sound absorption coefficient. Theoretically, the frequency is produced by the vibration of the particles upon the travelling through the pressure wave or the sound wave [8]. Subsequently the particles moves in parallel direction to the wave movement, the reason of the sound wave being a longitudinal wave. These longitudinal waves occurs because of the creation of compressions and rarefactions within the air. As the sound wave travels through the air, two regions are formed, one of it at where the air molecules are crowded together in the high pressure regions making compression between the molecules in the air. Such action makes the molecules to push each other and enter another region of low pressure, where the rarefactions occur [9]. During the compression, individual molecule moves side to side, making the speed at which a compression propagates through the medium to be known, which is actually the wave/sound speed [10]. Closely related to the speed of sound is the wavelength denoted as ʌ, used to calculate the frequency. The air experiences in norm its own normal pressure, termed as P_0, and then as the sound waves travels through the air, the differences in the pressure occurs aforementioned, denoted as ΔP. Changes in the pressure can be determine by taking the reference pressure of P_0 which appears at the initial point, which can also be related to the pressures at other points. These changes in pressure can be at maximum P_{max} or at minimum P_{min} and these are the pressures that will be detected by human [11], where P_{max} or P_{min} are primarily the amplitudes. Apparently, as the wave travels, a certain cycle will be occurred due to displacement. The instantaneous displacement waveform is the cycle taken, and each cycle can be represented by period, which the time needed to complete one cycle [12] and knowing the time taken for the one cycle, *t*, the frequency, *f* can be determined [13].

2. Sound Absorption Coefficient (SAC)

Sound absorption coefficient is defined as ratio of absorbed energy to incident energy noting the amount of sound being absorbed by a material [14]. The higher the percentages, the better the absorption is, indicating most of the sound being absorbed and less is being reflected back and is portrayed in the work of [15]. As presented in figure 2, it is observed that there are three types of waves encountered by a certain material which are the incident, reflected and transmitted sound waves. Incident waves are those waves that are being projected to a certain material which then can either be reflected or transmitted [16]. This principally contributes in finding a material's capability of absorbing sound wave. With aid of equations 1, 2, 3, and 4 the sound absorption coefficient, α can be calculated [4].

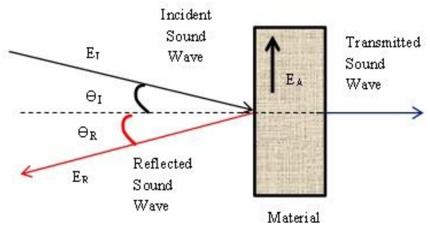

Figure 2. Schematic diagram of a material's absorption.

$$\alpha = E_A/E_I; \quad (1)$$

$$\alpha = 1 - E_R/E_I. \quad (2)$$

$$\alpha = 1 - |\, r \,|^2. \quad (3)$$

$$\alpha = I_{Abs}/I_I. \quad (4)$$

α = sound absorption coefficient E_I = incident energy, E_R = reflection energy, E_A = absorbed energy, r= incident reflection factor I_{Abs} = Sound intensity absorbed, I_I = Incident sound intensity

3. Sound Absorbing Material and Influencing Factors

Sound absorbing materials are classified on the ability of the material to absorb as much as sound wave and reflect as minimal as it could and at the same time transmit more of the waves. A material that could absorb and transmit more sound waves than it reflects, is considered a good sound absorbing material [17]. Factors such as the thickness, density and porosity influences a material's capability to absorb sound and will be discussed in this paper to provide better insight [18].

3.1. Material's Thickness

One of the factors that influence a material's sound absorption is the thickness. Though, the thickness of the materials is only relevant or has direct relationship at low frequency range (100-2000Hz) and is insignificant for high frequency (>2000Hz) [19]. Increase in the thickness provides better absorption of the wave and reflect less energy [20] Study by [21] shows that as the thickness of the samples increases, the sound absorption coefficient increases too as in table 1. The reason is at low frequency, waves have higher wavelength, which means the thicker material contributed in better absorption [22].The result shows that the thickness influences better sound absorption and is the reason of the high wavelength mentioned [23]. In that study, biopolymer foams were coated with three different materials comprising cotton fabric, single knitted jersey fabric and polyester fabric that been layered with four panels. It was found that taking the result at 2000Hz, the sound absorption coefficient increases by an average 58% comparing the first and fourth panel. This indicates that as the thickness increases, the absorption increases [24]. Findings by [25] also proved that thicker elastomeric foam based on synthetic rubber produces better absorption. Obvious trend of increase was noted upon increase in the thickness of the material. Comparing different thicknesses, the thicker elastomeric foam produced better sound absorption from the frequency to higher frequency. Although thicker material does not prevail at higher frequency due to the coincidence dip phenomenon, it was still noticeable that at 2000Hz, the 50mm material had almost 20% better absorption than the 10mm material. Higher wavelength by a low frequency needs a thicker material to ensure contact and making the absorption better [26]. Crucial point to be noted is the materials thickness should be one tenth of the wavelength in order to act as an effective sound absorber [27] and is on the recommended condition for the lower frequency (<2000Hz). Further study providing by [28] using polyurethane resin added with fire retardant was used with four different thicknesses, as the data plotted in figure. 3.

Thicker polyurethane resin added with fire retardant produces better sound absorption coefficient similarly reported by [21], nevertheless, shift in better absorption occurs towards thinner material as frequency increases. This provides clarification that thicker material contributes better sound absorption for low or medium range frequency (<2000Hz), supported [29]. Reason for this observation is because standards clarified that the thickness of the materials should be at least one tenth of the wavelength for that particular frequency in order to obtain better absorption [30]. Thus, if the frequency of a material is at 1000Hz, the wavelength will be 0.34m, which then the thickness shall be about one tenth of the wavelength and in this study, it is 0.03m. Such that, the thickness must be about 0.03m and if higher it would have no profound effect to absorption.

Table 1. Sound absorption coefficient influenced by thickness of plywood panel and fibreglass board.

Material	**Frequency (Hz)**					
	125	250	500	1000	2000	4000
Wood: Plywood panel(10 mm thick)	0.28	0.22	0.17	0.09	0.1	0.11
Fibreglass board(25 mm thick)	0.06	0.20	0.65	0.9	0.95	0.98

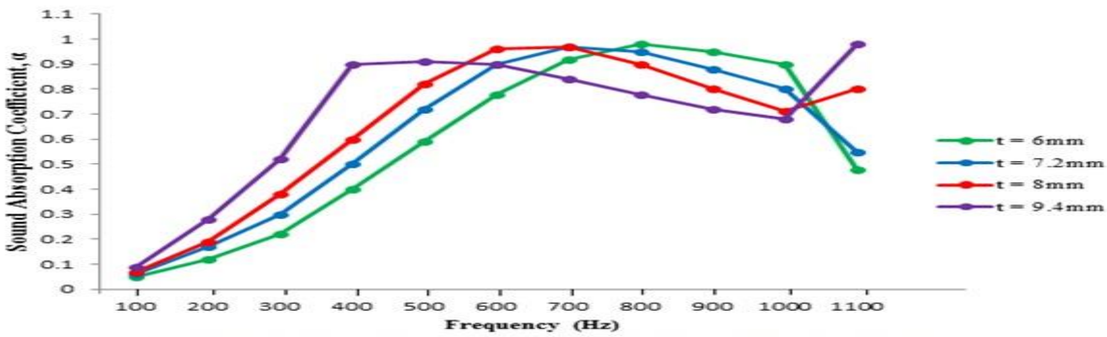

Figure 3. Sound absorption of polyurethane resin added with fire retardant with various thicknesses.

3.2. Material's Density

The density of the material is another factor and is defined as mass per unit volume. Density influences the acoustic impedance as the impedance determines the reflection of materials, equation 5. It was stated by [31] that a high density material due of mass increase increases the sound absorption and provided by [32] in table 2, the reason is justified.

$$Z = \rho cs \ \frac{A+B}{A-B} \quad (5)$$

ρ = density of material, c = speed of sound, s = cross sectional area of material, A + B = maximum of wave pattern, A - B = minimum of wave pattern.

Research by [33] compared the 25% percentages rice husk mass added to polyurethane with the bare polyurethane and concluded the prior had better absorption of sound with a frequency ranging 200-1000Hz that later decreases at 2000Hz as in figure 4. Contribution of this 25% rice husk in of increase in mass subsequently increasing the density. However, as for the decrease in the absorption at a higher frequency is related to the thickness of material that will be the dominant factor at higher frequencies. Demonstrated also by [34], this occurrence of decrease in the sound absorption at higher frequency is known as coincidence dip phenomenon. Critical frequency (1 kHz-4 kHz) strictly limits the sound absorption ability of a material and when the incident sound wave is in phase with the reflected wave, the coincidence dip phenomenon occurs, similarly reported by [35]. A material with high density has

Table 2. Sound absorption coefficient on different densities (RW = Rockwool).

Material	**Densities (kg/m^3)**	**Frequency (Hz)**					
		200	250	500	1K	2K	4K
RWA45	45	0.20	0.50	0.85	1.00	1.00	1.00
RW3	60	0.11	0.60	0.96	0.94	0.92	0.82
RW5	100	0.10	0.40	0.80	0.90	0.90	0.90

a larger surface are per unit volume and is effective in sound absorbing associating with fibre containing porous materials [37]. The increase in fibres surface area prompts more energy loss due to high friction loss, making more incident waves being converted to heat energy [19]. Research by [37] clarified that as the fibre size decreases, it is easier for the fibres to move among them making the airflow resistance higher contributing in increase of friction [38]. Few recommendations in the size by stating that 1.5 to 6 denier per filament (dpf) produces better sound absorption than coarser fibres. Similarly, 1.25dpf nonwoven fibres produces better sound absorption coefficient than 7dpf.

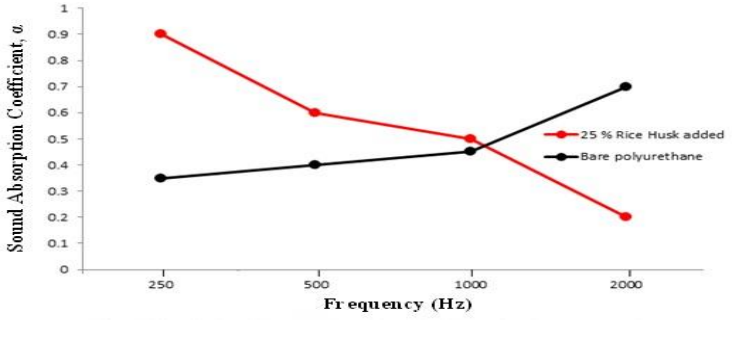

Figure 4. Sound absorption of 25% husk rice added with polyurethane and pure polyurethane [33].

Figure. 5 shows the result based on the nonwoven fabric's density and its influence in sound absorption, and it was evident that increase in density increases the absorption coefficient. Primarily, the increase in the density increases the thickness of the fibre. Henceforth, this contributes in more contact of the sound wave and the fibre, increasing the friction of airflow resistance and released as heat energy [34].

3.3. Material's Porosity

This factor is closely related with material's configuration involving the volume of the voids/holes to the total volume [39] shown in equation 6. The presence of pores or voids plays a crucial part as they act as the medium of sound wave dissipation. Figure 6 shows a schematic diagram of types of voids present in the material as porous material's configuration are such containing pores, granular, fibrous or cellular types. However, the principle of sound wave reaching the pores is similar for each type and this influenced by the existing voids. Upon contact, the channels or pores contains air molecules will vibrate and losses energy due to energy of the air molecules by the sound wave being converted to heat due to thermal and viscous losses at the walls of the interior pores and channels. The isothermal changes are noted as domain at low frequencies while at high frequencies, adiabatic acts as domain factor [39].

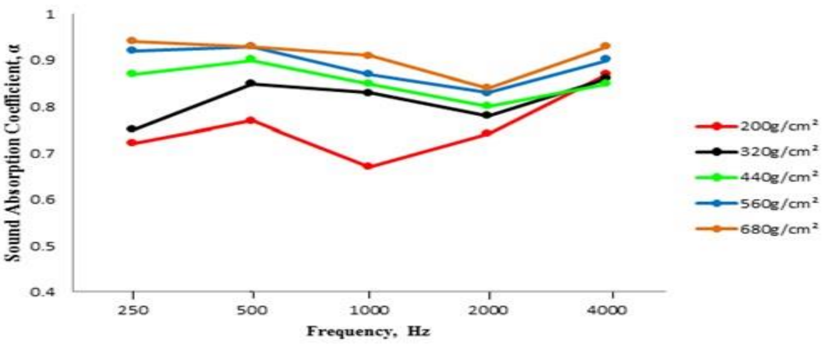

Figure 5. Sound absorption of nonwoven fabric.

Ultimately, there must be a sufficient transfer of energy with an acceptable range of porosity, meaning an open pores with continuous channels prevails better sound absorbing, because of the multiple reactions between the sound wave and the walls of the pores. Eventually more energy will be transformed in to heat energy [31]. As found out by [8], micro-perforated panel (MPP) were used with different cavity/pores diameters and upon two different diameters of 30 and 60mm, the later the as better sound absorption coefficient. Different air gaps diameter behind the sample of polyurethane foam (fixed diameter = 25mm) was tested as air gaps behind the sample acts as cavities that allows sound that has been transmitted to flow and hit the rigid back plate and encounter the sample after reflection[40]. In other word, the cavity acts as open pores. The diameter of 25mm gap produces better sound absorption than the smaller gaps almost 25% better comparing to the 5mm diameter. This is only applicable up to 1250Hz of frequency which later had reduction in absorption for the 25mm diameter gaps as the frequency increases. The reason is at high frequency, the wavelength is short and the diameter of the gaps has no profound effect. This proves that as the increase in frequency occurs, the wavelength becomes shorter needing thicker of materials to absorb more incident energy [17]. Contradicting to that, studied that the perforation panels should be having smaller diameters to allow better absorption [41]. However, the perforations are usually panels that act as backing for absorbent material and is applicable for a low frequency range only.

$$\textit{Porosity (H)}: \frac{Va}{Vm} \tag{6}$$

Va = Volume of air in voids, Vm = Total volume of material

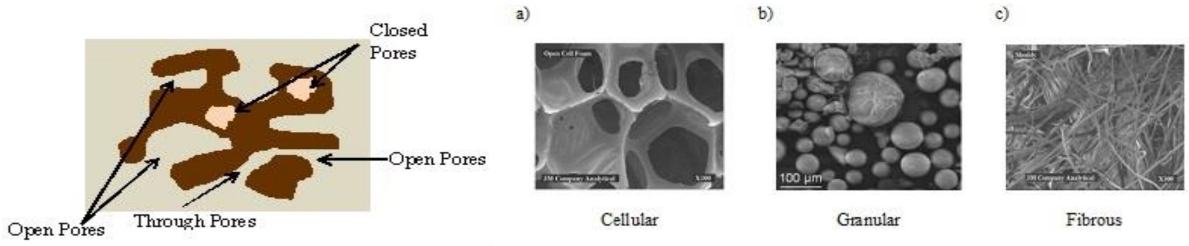

Figure 6. Schematic diagram of porous materials with pores/voids [39].

4. Conclusion

This paper aims to provide information as a literature study as the concept of sound and noise were deliberated. Adding to that, the material's characteristics were further explained which then linked to the test method to figure or obtain the sound absorption coefficient. Obtaining such information will provide better understanding of the parameter needed to select a material based on the sound absorption criteria. Conventionally, the major confusion arises in this area of study is to link each parameter and combine them to produce or even study the acoustical aspects. Nevertheless, this paper solves such problem and provides simpler yet sufficient linkage of information in this field of study with the method of solving the sound absorption coefficient.

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