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A Review of Synthetic Fiber Panel for Acoustic Properties

Mohd Mustafa Md Radzi[1], **Mohd Arif Rosli**[1]*, **Kamarul Aini Mohd Sari**[1]

[1]Department of Civil Engineering Technology, Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, Pagoh, 84600, MALAYSIA

*Corresponding Author Designation

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Abstract: The use of synthetic fibers has increased significantly since the 1960s, causing the natural fiber industry to lose most of its market share. A review on, synthetic fiber materials have been studied focusing on sound absorption coefficient. The objective of this study are to identify the previous research on acoustic panels based on synthetic fibers, to analyze the data of sound absorption coefficient based on density and thickness and to propose the best synthetic fiber applied as an acoustic panel. There are ten articles with ten synthetic material being summarize and analyze. The result found that sound absorption coefficient of synthetic material increased with the increasing of density and thickness. The good sound absorber was polymer foam fiber mixed with natural fibers with sound absorption coefficient of 0.830 and 0.970 at low and high frequency. This synthetic material were proposed as the best materials to apply as acoustic panel and sound absorber.

Keywords: Acoustic Panels, Synthetic Fibers, Sound Absorption, Density, Thickness

1. Introduction

Acoustic panels are special boards made of sound-absorbing materials. It has been used as a sound insulation tool. The material used for this panel acoustics can be used from natural or synthetic materials. Sound absorbent panels are usually made from expensive synthetic materials and are usually petrochemical based [1]. However, panels made from natural materials are taken from trees or plants and from animals. Absorbent materials have been widely made from natural fibres, which are more environmentally friendly to use [2].

Natural fibers grow or appear in the form of fibers, including those produced by plants, animals and geological processes. Natural fibers can be plants (kenaf flax, wood), animals (feathers, fur) or plants; Minerals (asbestos); while synthetic mineral fibers (fiberglass, mineral fibers, fiberglass) or acrylic (polyester). The main component of vegetable fiber is cellulose [17]. Natural fiber is an attractive material with low density, strong mechanical properties, easy processing, high durability, occupational

*Corresponding author: mohdarif@uthm.edu.my

safety benefits, reduced fog behavior, quality in high quantity, low price and reduced environmental impact for its production [18].

Synthetic fibers are fabricated fibers by chemical synthesis, as opposed to natural fibers derived directly from living organisms. According to Saba [3], synthetic fibers are made from polymers that do not exist naturally, and are produced entirely in the laboratory, usually from petroleum by-products. This method of synthetic fiber production is known as polymerization, which involves mixing monomers to produce long chains or polymers. Azahari [4] states that polymers have a useful application of sound-absorbing materials. The use of synthetic fibers has increased significantly since the 1960s, causing the natural fiber industry to lose most of its market share [5]. In this study, synthetic fiber materials have been studied about its acoustic properties i.e. sound absorption coefficient. These materials should be used on wall panels to provide a sound balance that absorbs in the enclosed space.

The noise phenomenon is now adversely affecting the population affecting the health and behavior of individuals. According to, Gupta. A. [6] that noise pollution affects the physical and mental health of people. Noise has been a major threat in recent times and can have lasting biological and psychological effects on humans and other animals in the wild [7]. Noise pollution affects schools, hospitals and certain commercial buildings. Examples include external noise pollution caused by railroads, airports, busy roads, and highways. Therefore, all these buildings need appropriate acoustic engineering facilities to overcome the problem. Next, sunlight, moisture, as well as sweat from human skin cause all the fibers to break down and wear out. Natural fibers tend to be slightly more sensitive than synthetic blends. This is mainly due to the biodegradability of natural products. Natural fibers are more susceptible to pests, but synthetic fibers are not a good source of food for insects that cause tissue damage.

Sound absorption is the loss of sound energy when sound waves are exposed to absorbent materials such as ceilings, walls, floors and other objects, so that sound is not emitted back into space. Sound absorbers absorb most of the sound energy that reaches them, making them very useful for noise reduction [19]. Sound-absorbing materials can be used to create an appropriate acoustic atmosphere in the space by minimizing echo time. According to Arenas, J.P & Crocker, M.J [19], the main uses of absorbent materials include almost reducing the level of resonant sound pressure and thus reducing the time of echoing in the enclosure or room. Therefore, sound absorbing material is found to be very useful for controlling sound [20].

This review are done to identify the previous researchers who studied synthetic fiber-based acoustics panel. It also to analyze sound absorption coefficient data based on density and thickness of the sample and to propose the best synthetic fiber applied as an acoustic panel.

2. Materials and Methods

There are various ways of research methods, testing and procedures in testing the panel, but to achieve the objectives of this study, only one method has been focused that is by using case study methods. Therefore, in this part, it will explain about the process used along with an overview so that it is more detailed. Figure 1 shows the methodology chart for this study.

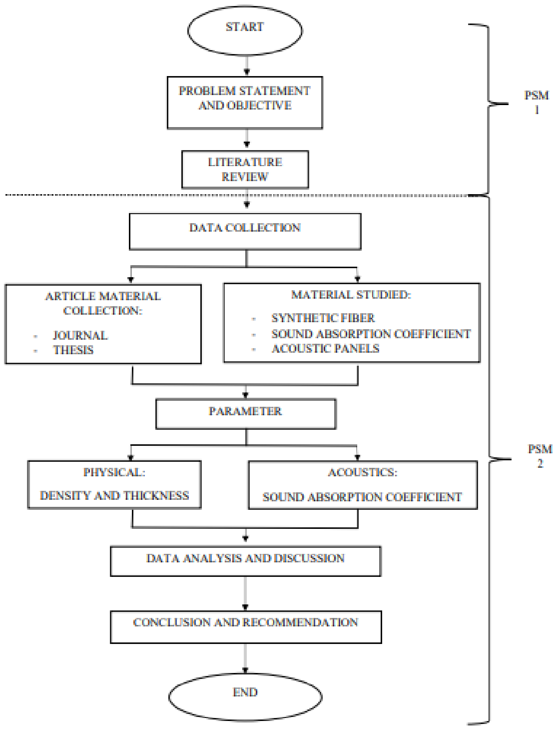

Figure 1: Methodology chart

In this study, it includes data collection, test data and results. In order to obtain data in this scientific study, two important things need to be there such as the collection of ten article material and the material studied. Among the article materials used are journals and thesis. Then, through the objectives and scope of the study that has been made, there are three parameters was studied such as synthetic fibers, sound absorption coefficients and even acoustic panels.

According to Figure 1, the parameters that have been summarize from previous scientific studies such as density, thickness and the value of the sound absorption coefficient. Then, to obtain the data of the sound absorption coefficient, ASTM E1050-09, using a two-way microphone is carried out. The test is performed at low frequency as well as high frequency, which ranges from 100 Hz- 6000 Hz. Figure 2 shows the experimental testing Impedance tube used to obtain the sound absorption coefficient.

Figure 2: Instrument tube impedance

3. **Results and Discussion**

Discussion of data related to parameters that is comparison in terms of total sound absorption coefficient, density and material thickness. Most of the synthetic fibers in the last study were mixed with other materials such as natural fibers, material residues such as textiles and others. The combination of these materials is to achieve the objective of the study, which is the sound absorption coefficient of synthetic materials. Table 1 shows a summary of synthetic fibers from previous researchers that include the coefficient of sound absorption at high and low frequencies, density and even thickness of the material.

Table 1: Summary of ten types of synthetic fibers from previous researchers

Synthetic fibre	Sound Absorption Coefficient, α		Density, kg/m^3	Thickness, mm
	High frequencies, Hz	Low frequencies, Hz		
Inorganic fiberglass	1.00 (4000 Hz)	0.51 (1000 Hz)	160	-
Polymer foam is mixed with natural fibers	0.999 (5000 Hz)	0.83 (1000 Hz)	868	30
Polyester fiber	0.91 (6000 Hz)	0.65 (1500 Hz)	40	40
Polyurethane foam is mixed with Electrospun Nylon-6 Nanofibre Mat and Polyurethane	0.39 (4000 Hz)	0.60 (1000 Hz)	-	-
Glass fiber mixed with flax fiber	-	0.16 (2000 Hz)	-	3
Porous metal fiber material	0.53 (6000 Hz)	0.06 (1500 Hz)	-	3
Polyurethane foam is a mixture of textile residues	0.42 (3100 Hz)	0.87 (1000 Hz)	55	40
Polymer microparticles	-	0.54 (1600 Hz)	-	20
Fiberglass installation with sandwich panel	0.27 (5000 Hz)	0.62 (1000 Hz)	-	-
Non-woven polyester fiber.	0.88 (5650 Hz)	0.8 (1125 Hz)	148	5.09

3.1 Sound Absorption Coefficient

According to Peng. L [11], the material sound absorption coefficient is used to determine the sound absorption efficiency and it is the energy ratio used for energy occurrence, and is determined by α. The sound absorption coefficient is a major factor used to calculate the sound absorption of a material [12]. α ranges from 0 (total reflection) to 1.00 (total absorption). If acoustic energy can be fully absorbed, then α = 1 [11].

Figure 3 shows the result of the sound absorption coefficient, α for porous metal fiber material is 0.060 at low frequency, while sound absorption coefficient, α at high frequency is 0.53. In addition, fiberglass with sandwich panels showed lower α result at high frequencies where at a frequency of 6000 Hz it was 0.210 and at a frequency of 2000 Hz it was 0.750 [8].

Polymer foam materials mixed with natural fibers studied by Azahari [4] show the results of sound absorption coefficients, α at low and high frequencies are 0.830 and 0.970. Figure 3 also shows the results α respectively for inorganic fiberglass where at low and high frequencies (0 Hz-4000 Hz) are at

0.700 and 1.00. Based on the overall comparison that has been made for each of these synthetic fibers, it has been shown that these inorganic fiberglass fibers have the highest α results at a frequency of 4000 Hz compared to other materials.

Zhou [9] reported on polymer micro particles show the highest coefficient of sound absorption coefficient at low frequency of 0.88 at 900 Hz. Meanwhile, Tiuc [15] shows the reading of the sound absorption coefficient for polyurethane foam is 0.87 at 1000 Hz. Another study done by Prabhakaran [10] with glass fiber mixed with flax fiber shows the highest sound absorption coefficient reading at 1000 Hz which is 0.37.

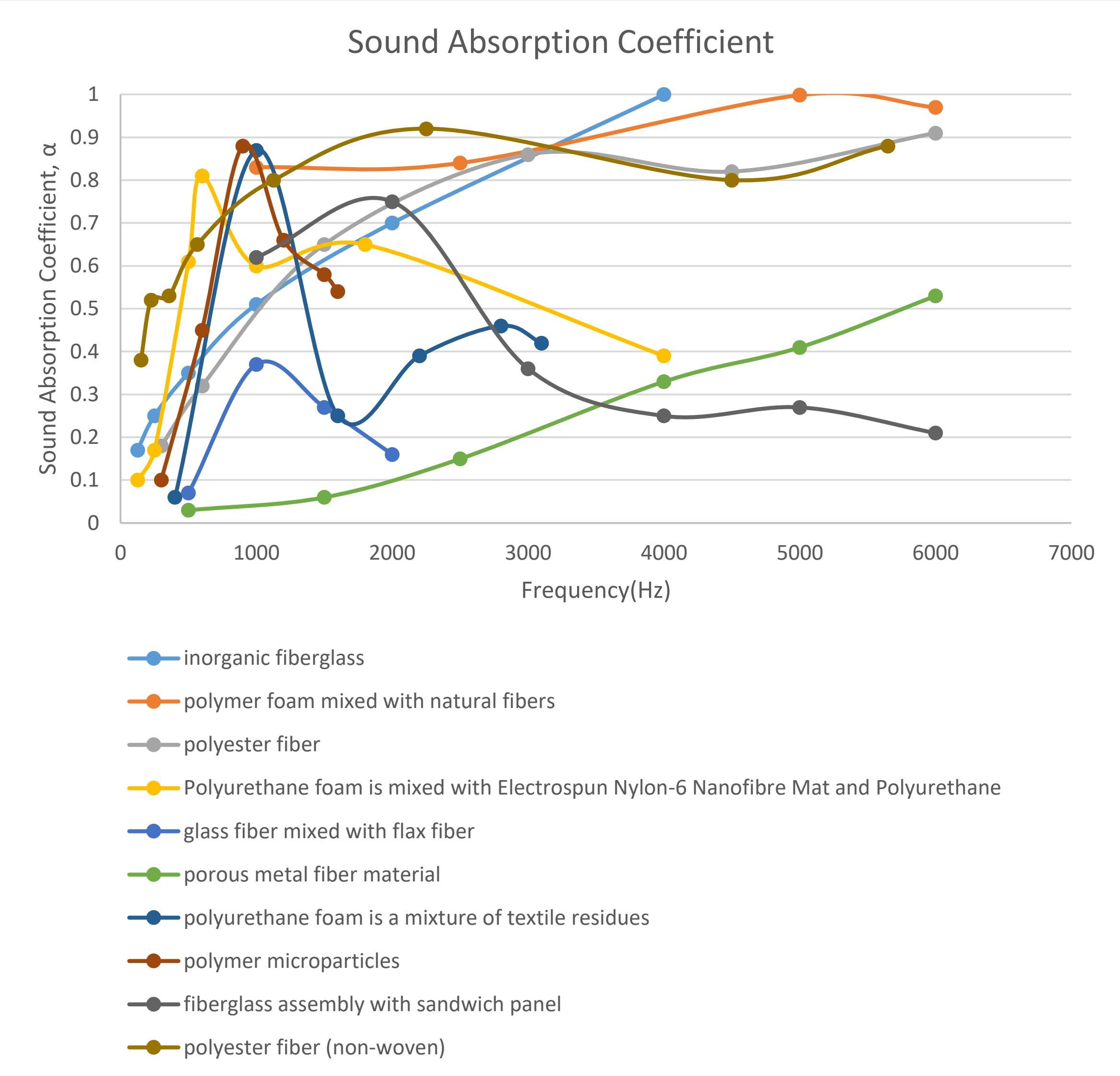

Figure 3: Sound Absorption Coefficient of ten types of synthetic fiber

3.2 Density

Figure 4 shows the result readings for the total density for five types of materials. Such as inorganic fiberglass, polymer foam mixed with natural fibers, polyester fibers, polyurethane foam mixed textile waste and nonwoven polyester fibers. Graphs show that polyester fibers have the lowest material density of 40 kg/m^3. Materials other than these polyester fibers have shown an increase in density values of 55 kg/m^3, 148 kg/m^3, 160 kg/m^3 and 868 kg/m^3 respectively. According to [4], polymer foam mixed with natural fibers has a greater effect on the density value where the percentage of filler loading were 20.00 % compared to polyurethane foam. It stated that the number of fiber increases per unit area when the density is increasing and makes more sound energy losses as the surface friction increase, thus makes the sound absorption coefficient, α also increases [16].

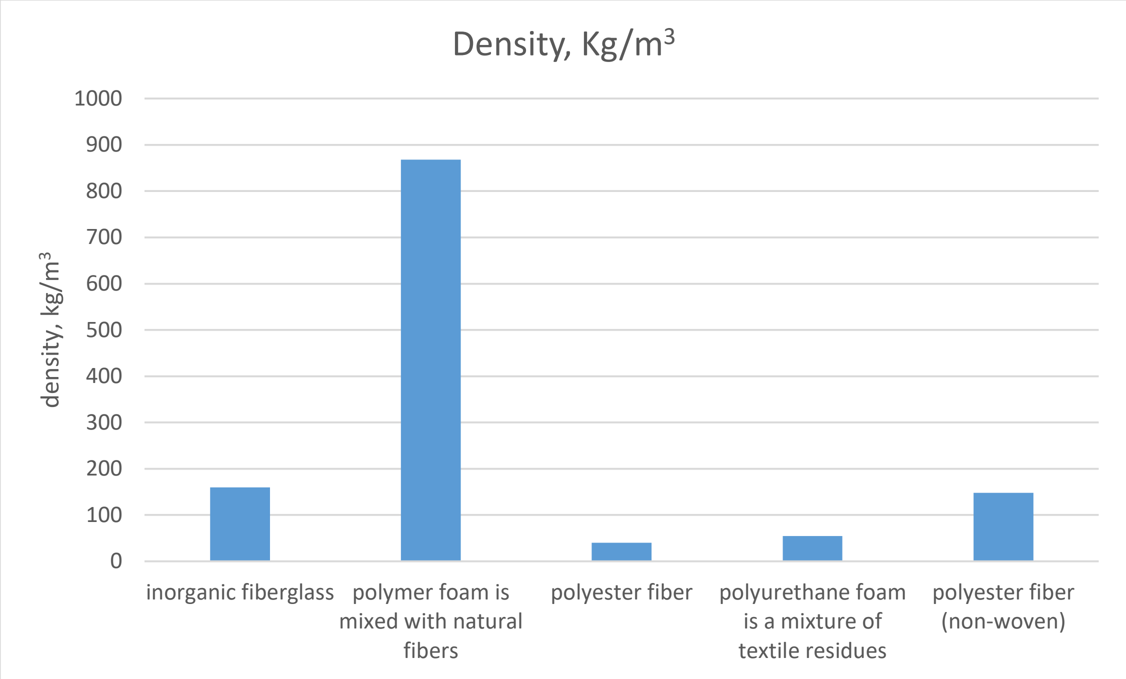

Figure 4: Density of five types of synthetic fiber

3.3 Thickness

Figure 5 shows the thickness results for the seven types of synthetic materials used in this study. Among them are polymer foam mixed with natural materials, polyester fibers, glass fiber mixed with flax fiber, porous metal fiber material, polyurethane foam mixed with textile waste, polymer micro particles and even non-woven polyester fibers. Graphs show that polyester fibers as well as polyurethane foam mixed with textile waste have the same material thickness of 40 mm. Furthermore, for materials such as polyester (non-woven) fibers, polymer micro particles as well as polymer foam mixed with natural materials showed an increase in thickness of 5.09 mm, 20 mm and 30 mm respectively. Meanwhile, the rest of the material is glass fiber mixed with flax fiber and porous metal fiber material shows the smallest and equal amount of thickness, which is 3 mm. According to [11] wavelength of wave transmission is determined by the thickness of the fibrous material. The thicker the material, the longer the transmission strip, and the acoustic energy is weakened. It conclude that thickness is directly proportional to the sound absorption coefficient. However, adding thickness can increase sound absorption at low frequencies, but there is not much difference in high frequency noise [11].

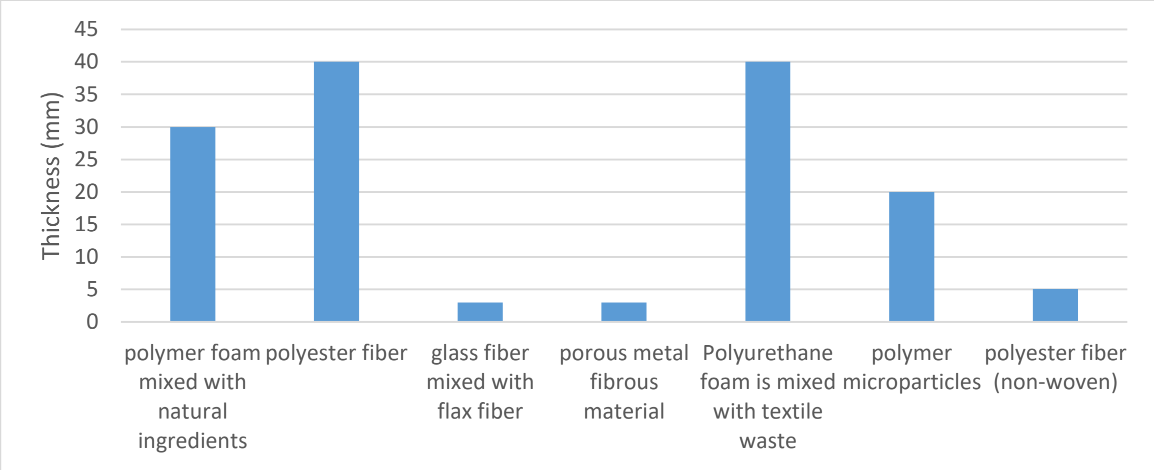

Figure 5: Thickness of seven different types of synthetic fibers

3.4 Polymer Foam Fibers mixed with natural fibers.

Review from ten articles found that polymer foam fibers mixed with natural fibers [4] are the best material to propose as acoustic panel. Figure 6 shows the values of the best sound absorption coefficients for the study at low and high frequencies. Due to the material has a very high density because of mixing between two fiber materials. Even such a high density also leads to better sound absorption. In a study conducted [4] he proved that by increasing the density of this material, it would increase the ability to absorb more acoustic energy. The density increases and reduce sound energy as the surface friction increases, thus making the sound absorption coefficient, α also increases.

However, for good absorption material is also due to the porosity of the material. The porosity size of a material is one cause where the sound absorption coefficient or sound absorption of the material increases better. Azahari [4] reported there are four materials that differ from their average porosity size, among which are 134.86 µm, 168.82 µm, 175.22 µm and 185.21 µm. For the fibers discussed in this section, the average porosity size of the material is 134.86 µm as shown in Figure 7, which shows that the material has the smallest value of the fiber. He concluded that by increasing the loading percentage of fillers, it would reduce the size of the polymer-shaped composite pores. As a result, smaller pore sizes cause further collisions between sound waves and cell walls, longer reflection times, and greater energy absorption, thus providing greater sound absorption coefficients [13]. This statement can be further strengthened by a study conducted by Puchka [14] where materials with a smaller pore size will have a high sound absorption coefficient.

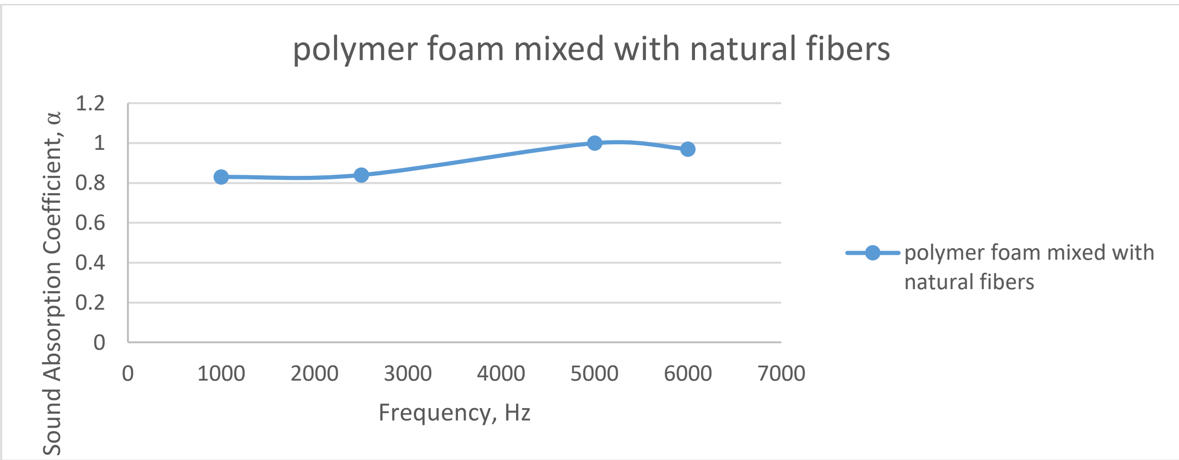

Figure 6: Sound absorption coefficient of polymer foam mixed with natural fibers

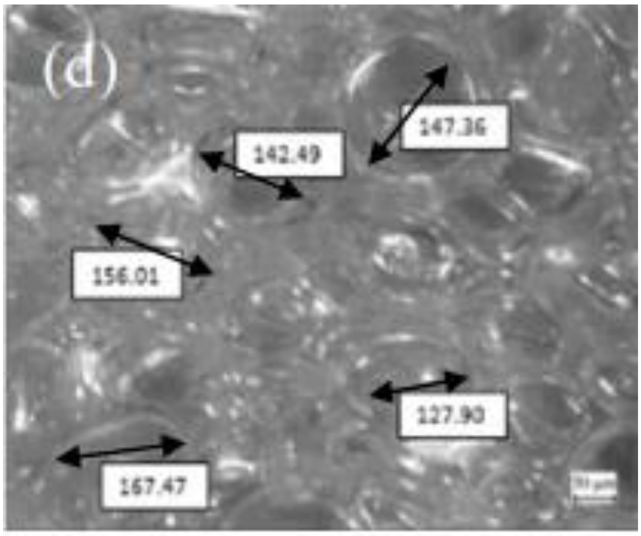

Figure 7: Microstructure image of the material

4. Conclusion

Based on the study, three objectives were set to be achieved to complete this review. The first objective of this study was to identify the previous researchers who studied synthetic fiber-based acoustics panel. To achieve the first objective, ten previous studies have been taken and applied. The study material was taken from the journal as well as the thesis. It has ten different types of materials in terms of fiber material as well as arrangement.

The second objective is to analyze the data of sound absorption coefficient based on density and thickness. In the study conducted, the acoustic properties were determined by taking the value of the sound absorption coefficient of the material. The value of this sound absorption coefficient is very important and should be taken into account in determining the use of synthetic fibers as acoustic panels. These values have been associated with the density and thickness of the synthetic fibers. Therefore, through the data and analysis performed, the higher the density of a material the higher the value of the sound absorption coefficient. However, the thickness of the material also affects the value of the sound absorption coefficient. As the thickness of the material increases, so does the value of the sound absorption coefficient for the material also increases.

Finally, the third objective is to propose the best synthetic fibers to be applied as an acoustic panel. With the data from the previous study, comparisons can be made, and the selection of the best fiber material has been found. From the ten data collected, polymer foam fibers mixed with natural fibers was selected as the best material. This is because the data of the sound absorption coefficient for the material at low and high frequencies has approached 1.00. This has shown that the material is able to absorb sound at low and high frequencies very effectively.

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