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UTILIZATION OF OIL PALM TRUNK (ELAEIS GUINEENSIS) AS FOAM COMPOSITE FOR SOUND ABSORPTION

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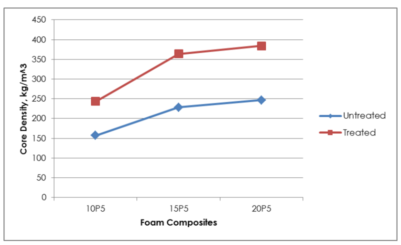
Graphical abstract



Abstract

Oil Palm Trunk (OPT) act as a filler for polymer foam composite has been investigated and proved to have ability to absorb sound. In this study, treatment of wood untreated and treated with acid hydrolysis named as UP5 and TP5 was use as filler. This study was developed to compare the ability of sound absorption based on different composition of filler in polymer foam composite. By choosing the size of <500 μm, three different percentage has been selected which is 10 %, 15 % and 20 % for both conditions. These samples has been tested by using Impedance Tube test according to ASTM E-1050 for sound absorption coefficient, a measurement and Scanning Electron Microscopy (SEM) for determine the porosity for each samples. 20 % filler loading of UP5 gives highest sound absorption coefficient of 0.97 at 4728 Hz. Meanwhile for 20 % loaded of TP5 gives 0.99 at 3371 Hz. When comparing the sound absorption coefficient for both sounds absorbing materials, TP5 polymer foam composite showed higher value of sound absorption coefficient, a at lower frequency level (Hz) as compared to UP5 polymer foam composite which gives better results in sound absorption.

Keywords: Oil palm trunk, sound absorption, polymer composite, pore structures

Abstrak

Batang Kelapa Sawit (OPT) bertindak sebagai kayu isian untuk polimer busa berkomposit dikaji dan terbukti mempunyai keupayaan untuk menyerap bunyi. Dalam kajian ini, kayu yang tidak dirawat dan dirawat dengan hidrolisis asid dinamakan UP5 dan TP5 digunakan sebagai pengisi. Kajian ini telah dilakukan untuk membandingkan keupayaan penyerapan bunyi berdasarkan komposisi kayu isian yang berbeza dalampolimer busa berkomposit. Dengan saiz <500 μm, tiga peratusan yang berbeza iaitu 10%, 15% dan 20% untuk kedua-dua UP5 adan TP5. Sampel ini telah diuji dengan menggunakan ujian Tiub Bergalang mengikut ASTM E-1050 untuk pekali penyerapan bunyi, a dan Mikroskopi Pengimbas Elektron (SEM) untuk menentukan saiz liang bagi setiap sampel. 20% kayu isian bagi UP5 menunjukkan pekali penyerapan bunyi tertinggi 0.97 pada 4728 Hz. Sementara itu, bagi 20% kayu isian bagi TP5 menunjukkan 0.99 pada 3371 Hz. Apabila membandingkan pekali penyerapan bunyi untuk kedua-dua bahan-bahan penyerap bunyi, TP5 polimer busa berkomposit menunjukkan nilai pekali penyerapan bunyi, α yang lebih tinggi pada tahap frekuensi yang lebih rendah (Hz) berbanding UP5 polimer busa berkomposit yang memberikan menyerap bunyi dengan lebih baik.

Kata kunci: Batang kelapa sawit, penyerapan bunyi, polimer berkomposit

1.0 INTRODUCTION

As the problem of hazardous noise has become serious, the demand of better environment and residential safety is increased and becomes a major requirement. From previous study, polyurethane foams composites made from palm oil were synthesized, crosslink and doped with eco natural filler of rubber waste or sawdust powder [1-2]. As natural resources become scarce, many researchers and industries are beginning to investigate and utilize various renewable resources such as the abundant and cheap vegetable oils, which represent a major potential source of chemicals [3-4].

In the recent years, a number of studies have been carried to develop new materials and technologies improving the sound absorption properties [5-6]. The sound of an industrial waste developed by using processed bamboo and oil palm frond has been tested for its sound absorption properties [7-8]. Sound absorbing materials absorb most of the sound energy striking them and reflect very little. Therefore, sound-absorbing materials have been found to be very useful for the control of noise [9]. Materials that have high value of sound absorption coefficient are usually porous [10]. The absorption coefficient is a useful concept when using geometrical acoustic theory to evaluate the growth and decay of sound energy in a room [11].

Impedance tube measurement of the bamboo, fiber samples reveal similar properties to the glass wool. Bamboo material formed into fiber board yield a superior sound absorption as compared to plywood material of similar density [7].

Nowadays, Malaysia is one of the major countries that produce oil palm tree. The life of the oil palm tree can last up to 25 to 30 years which suitable and long lasting to gain a lot of profit. In this study Oil Palm Trunk (OPT) was used because it is renewable, nonabrasive and abundance sources [12]. The acoustical properties (sound absorption coefficient) of the composite were determined to investigate the possibility of OPT as filler of polymer composite foams. The acid hydrolysis treatment of wood mainly produces xylose from hemicelluloses, leaving a solid residue containing the cellulose and lignin fractions almost unaltered in controlled condition [13]. The remaining OPT containing acidic cellulose-lignin and OPT before acid hydrolysis treatment were tested as filler.

In this present study, a comparison between untreated and treated acid hydrolysis treatment of OPT as filler polymer foam composite to study the sound absorption ability and understanding the quality of fibrous material in composite foam.

2.0 EXPERIMENTAL

2.1 Preparation Of Samples

The woods were sundried for a day to remove humidity. The woods are then being grinded into fine wood by using heavy duty blender to get desired fine particle size. Wood dust with <500 µm in size, untreated and treated with acid hydrolysis named as UP5 and TP5 with percentage of 10 %, 15 % and 20 % were used as filler in polymer foam composites. Treatment of wood with diluted sulfuric acid extracts the hemicelluloses in a liquid form and leaving a solid residue of cellulose and lignin. The pore size and structures of composites during the cross linking with polyol and isocyanate was also monitored. Specific designed of close mold with 100 mm diameter and 28 mm diameter was used to fabricate the samples.

2.2 Determination Of Acoustic By Impedance Tube Test

The sound absorption coefficient can be measured by two different methods - the room method and the tube method. For room method, when a sound wave strikes one of the surfaces of a room, some of the sound energy is reflected back into the room and some penetrates the surface. Parts of the sound wave energy are absorbed by conversion to heat energy in the material, while the rest is transmitted through. As for tube method, the impedance tube was used. The impedance tube consists of a adjustable filter, propagation tube, large sample tube 100 mm diameter, small sample tube 28 mm diameter and two-microphone method and a digital frequency analysis system for the measurement of normal incidence sound absorption coefficient and normal specific acoustic impedance ratios of materials.

2.3 Scanning Electron Microscope (SEM)

The morphology is conducted to identify the structure of filler loaded in FC. This study is considered important because the effect of filler loading in FC may affect the mechanical as well as acoustic properties of polymer foam composites. The surface of polymer composite foam samples were gold coated at 25 mA plasma current and 2 Pa of chamber pressure to make them conducting samples. Cellular structure images were examined by using SEM of JEOL-JSM6380LA operates at 15 kV at 30 µm magnifier under high vacuum

3.0 RESULTS AND DISCUSSION

3.1 Sound Absorption Coefficient (SAC) For UP5 And TP5 Polymer Foam Composite

All samples with different percentages of polyurethane have been tested for sound absorption coefficient. Fig. 1(a) and (b) shows the sound absorption coefficient at different frequency level of all samples treated and untreated with 10 %, 15 % and 20 % of OPT filler.

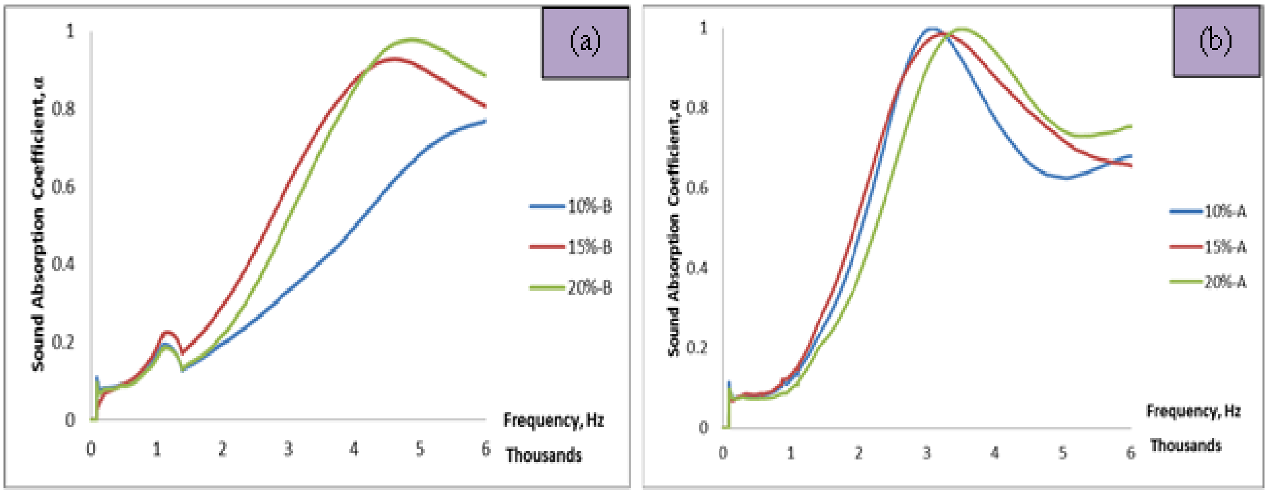


Figure 1 (a) and (b) Sound absorption coefficient (a) and frequency level of UP5 and TP5 polymer foam composite of 10 %, 15 % and 20 % filler loading.

In general, both treated of sample demonstrated higher absorption coefficients for medium to high frequency range of 3000 - 6000 Hz. This wider range of frequencies highlights the potential of OPT polymer foam composites for sound absorbent material. However, TP5 polymer foam composites with all percent of filler demonstrate better performance to its counterpart, which most samples gives maximum absorption coefficient at higher frequency level of 3000- 3700 Hz. Meanwhile, the sound absorption coefficient for UP5 polymer composites approaches to 1 at with at frequency level of 4500 – 6000Hz.

3.2 Scanning Electron Microscope (SEM) For UP5 And TP5 Polymer Foam Composite

For Fig.1 (a), graph for 10 % filler-loading-polymer foam composites shows high sound absorption coefficient, a at highest frequency as compared to the other percentage of filler. The maximum a for UP5 is 20 % loaded with OPT of 0.97 at 4728 Hz, as for Fig. 1 (b) the maximum a for TP5 is 20 % loaded with OPT of 0.99 at 3371 Hz. It may be due to the changes of wood structure after acid treatment which affects the size of porosity as refer to Fig. 2 resultants in higher sound absorption coefficient at lower frequency level. Fig. 2 also shows the porosity structure of UP5 and TP5. For Fig.2 (a), the small particle of OPT wood was observed as compared to Fig.2 (b). Acid treatments of OPT influence the pores structure of OPT-polymer foam composites. In Fig. 2 (b), the TP5 was loaded in polymer foam composite gives smaller pore sizes of the foam and approach to 1 for a at lower range of frequency level. As compared to Fig. 2 (b), the large size of porous cell approach to 1 in a at higher range frequency level. The physical condition of TP5 polymer foam composites is scattered as compared to UP5 polymer foam composite.

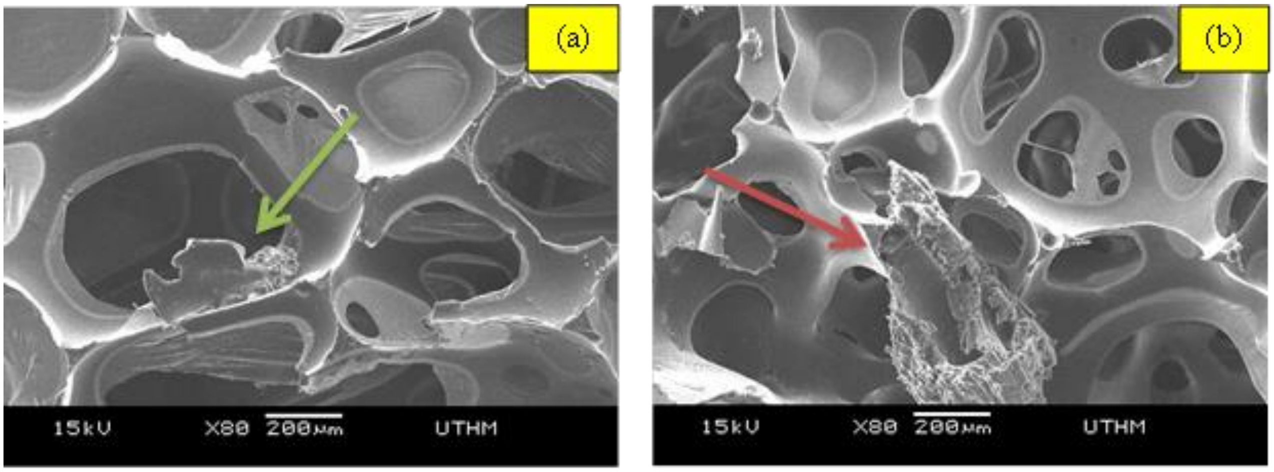


Figure 2 (a) and (b) SEM images of UP5 and UP5 of polymer foam composite which consist of different percentage of filler loading (a) UP5-polymer foam composite, while (b) TP5 polymer foam composite.

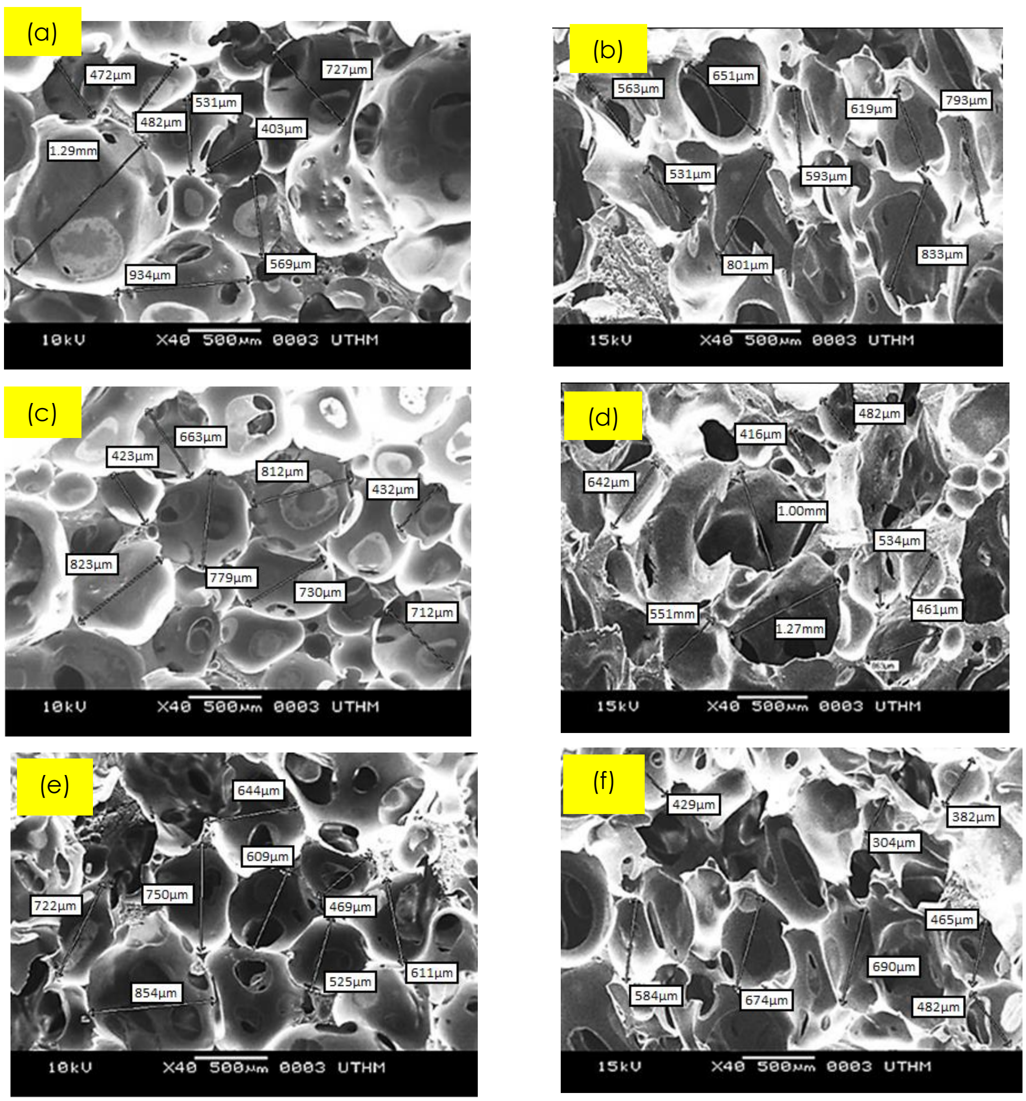


Figure 3 SEM images for UP5 and TP5: (a) 10UP5, (b) 10TP5, (c) 15UP5, (d) 15TP5, (e) 20UP5 and (f) 20TP5-FC.

Based on Fig. 3 (a) to Fig. 3 (f), the FC were found to have interconnected and open-cells cellular structures. All figures showed the cellular structures of untreated and treated FC. The 10TP5, 15TP5 and 20TP5-FC were observed have uniform structures compared to 10UP5, 15UP5 and 20UP5. Furthermore, the average values for each FC were shown in Table 1.

Table 1 Average pore size of untreated and treated P5

Foam samples	1	2	3	4	5	6	7	8	Average
U10P5	472	531	727	403	482	1290	934	568	676
T10P5	563	651	619	793	833	801	593	531	673
U15P5	566	663	812	432	712	730	779	823	690
T15P5	642	416	482	534	461	1270	551	1000	670
U20P5	722	750	644	609	469	611	525	854	648
U20P5	429	304	382	465	690	482	674	584	501

As referring to the Table 1, all the fabricated foams, the untreated FC cellular structures were found larger for all the FC. Meanwhile, for treated FC, the cellular structures were found smaller which give the better sound absorption compared to untreated FC. The variety of the cellular structure is due to the present of the acidity of the wood filler affect the cell structure.

As study proved by [14], during sulfuric acid hydrolysis, esterification of cellulose hydroxyl groups to sulfate groups occurs which can introduce negative charges to the wood and this provides improved suspension stability. The present of sulfate group in cellulose hydroxyl group has affected the foam production as refer to Fig. 4. The increasing of sulfate group is directly increase the molecular weight of the cellulose hydroxyl which resulting the increasing of the density of the foam. This can be proven by the cell sizes measurement carried out by analytical SEM software.

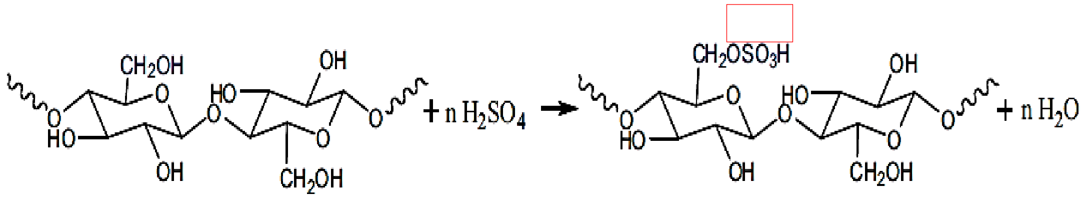


Figure 4 Esterification of cellulose hydroxyl groups during sulfuric acid hydrolysis.

3.3 Density values of wood FC

One of the important parameter in conjunction with application for light-weight materials is density. It is known that, the higher the density, the higher the weight of the FC obtained. Fig. 5 shows the core density for UP5 and TP5- FC developed. Furthermore, the effect of the ratio and different condition will also affect the density value for each FC.

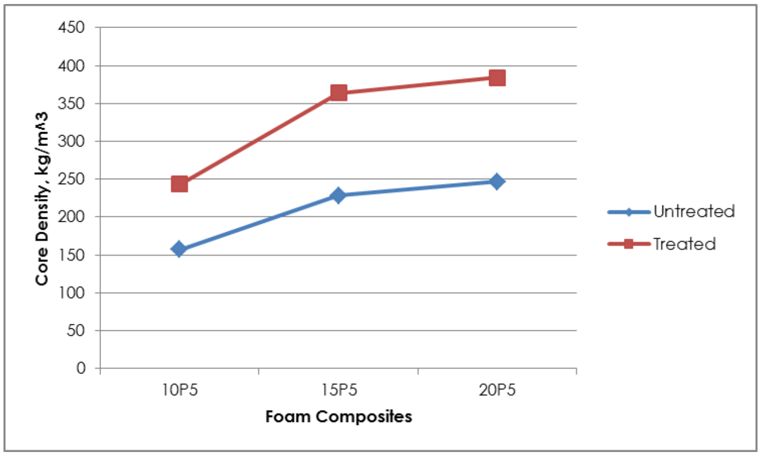


Figure 5 Density for FC all percentage filler loading for UP5 and TP5

Based on Figure 4, the core densities of foam composites with 10 %, 15% and 20 % of M3 and P3 of treated fillers were slightly increased as compare with untreated wood fillers-FC. . The pores structure for treated M3, P3, M5 and P5 were observed smaller than untreated wood indicates that the smaller the pores structures resulting higher densities. The present of acid treatment also contribute to higher density results.

3.4 Porosity measurement of UP5 and TP5-FC

The porosity of a porous material is defined as the ratio of the volume of the voids in the material to its total volume. Good absorbers tend to have high porosity. Table 2 (a) and table 2 (b) shows the average porosity for UP5 and TP5-FC respectively for all percentage filler loading.

Table 2 (a) Average porosity measurement for UP5-FC.

UP5 filler Percentage (%)	No. of Sample	Mass of Air Dried Specimen (Wd)	Mass of Immerse and Suspend Specimen in Liquid (Ws)	Mass of an Immersed and Suspended Specimen in Air (Ww)	Porosity
10	1	86.4	-354.3	229.1	24.46
	2	75.8	-275.9	170.8	21.27
	3	67.6	-608.7	143.8	10.13
	4	70.2	-543.3	147.2	11.15
Average					**16.75**
15	1	87.8	-277.6	181.7	20.44
	2	80	-393.7	173.9	16.54
	3	81.4	-220.8	171	22.87
	4	80.4	-181.6	156.5	22.51
Average					**20.59**
	1	69.5	-272.1	141.3	17.37
	2	81.7	-262.9	181.5	22.46
	3	71.7	-289.7	137.9	15.48
	4	76.9	-205.1	152.4	21.12
Average					**19.11**

Table 2 (b) Average porosity measurement for UP5-FC.

TP5 filler Percentage (%)	No. of Sample	Mass of Air Dried Specimen (Wd)	Mass of Immerse and Suspend Specimen in Liquid (Ws)	Mass of an Immersed and Suspended Specimen in Air (Ww)	Porosity
10	1	139.6	-729.2	302.5	15.79
	2	142.7	-488.6	258.4	15.49
	3	114	-227.1	222.9	24.20
	4	103	-329.8	188.4	16.48
Average					**17.99**
15	1	189	-217.4	341.7	27.31
	2	180.5	-235.3	313.8	24.28
	3	155	-433.1	263.1	15.53
	4	218.3	-525.7	382.7	18.10
Average					**21.30**
	1	216.7	-295.2	373.7	23.47
	2	188.2	-354.5	315.7	19.02
	3	190.8	-391.2	346.6	21.12
	4	235.8	-299.9	396.9	23.12
Average					**21.68**

For table 2(a), the average porosity shows inconsistent throughout the percentage, unlike the average porosity from table 2 (b). TP5-FC shows increasing in average porosity with the increasing of percentage filler loading in FC. Both tables show average value at range 16 to 21%. Among all the values, 20TP5-FC shows the highest porosity value. Higher porosity values tend to be good absorber as the pores can absorb more sound energy.

3.5 FTIR spectroscopy for UP5 and TP5-FC

FTIR is one of complementary techniques which can be used to evaluate structure of the hard domains flexible polyurethane foams. Fig. 6 shows the FTIR spectra for UP5 and TP5 FC.

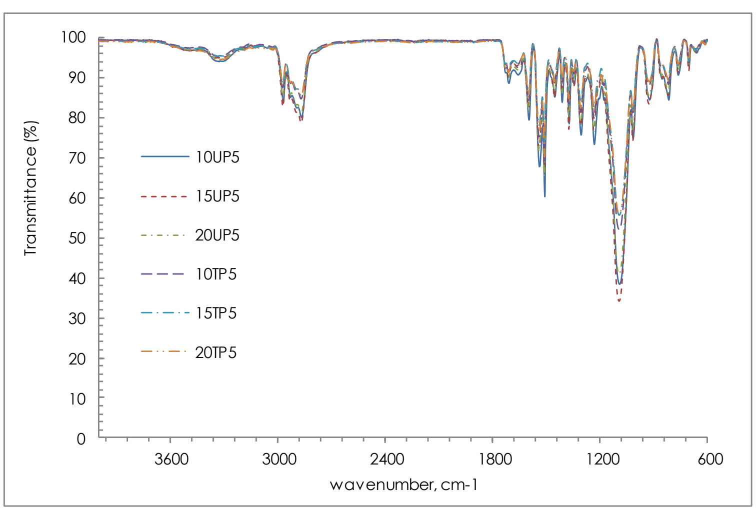


Figure 6 FTIR spectra for all percentage filler loading for UP5 and TP5-FC.

The IR spectrum of the FC clearly shows the characteristic band of the alkanes group in the regions of 2984-2900 cm^{-1} due to C-H stretching and the regions 1715 cm^{-1} due to carbonyl stretching. The IR spectrum of the wood fiber shows the absorption band at 1735 cm^{-1}. This absorption band is due to the carbonyl group of acetyl ester in hemicellulose and carbonyl aldehydes, C=O stretch bond in lignin [15]. The appearances of N-H and O-H absorption band at 3000-3660 cm^{-1} were observed. Presence of expected peaks implies that the reaction was completed as the PU was formed. The N-H stretching modes at 3375 cm-1 were observed. Aliphatic C-H stretching mode of 2972-2874 cm^{-1} and carbonyl (C=O) stretching absorption band at 1717-1690 cm^{-1} were also observed due to stretching bending vibration group of urethane linkages, used to identify the PU. N-H bending vibrations at 1600 cm^{-1}, O=C-O stretching vibrations corresponding to the ester at 1300-1050 cm^{-1} were observed due to strong intensity of absorption band. These vibrations are strong evidence for the formation of PU because the esters chains were formed after the polymerization reaction of isocyanate and polyol.

4.0 CONCLUSION

The OPT-polymer foam composite samples show the ability to influence the absorption coefficient of polymeric foam at different frequency levels (Hz). 20TP5-FC polymer foam composite was achieved the highest sound absorption coefficient at lower range of frequency level (Hz); meanwhile 20UP5 was able to absorb the sound at the highest sound absorption coefficient at higher range of frequency level (Hz). Meanwhile 20UP5-FC filler was able to absorb the sound at the highest sound absorption coefficient at higher range of frequency level (Hz). This type of polymer composite can be applied for cushion, sound-proof wall or building structure. Oil Palm Trunk can be used as a sound absorption material and the effectiveness of samples was determined by the condition and the percentage filler added and the porosity if the samples itself. The two condition of the wood which is untreated and treated with acid treatment gives different result in sound absorption coefficient at different frequency level.

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