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Studies on Some Mechanical Properties of Pvc-Wood Fibre Composite

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ABSTRACT

In this study some mechanical properties of PVC-Wood fibre composite were investigated. The wood fibre was gotten from a mahogany tree. The sample was moulded and shaped at a temperature of 150^{o}C using a hadraulic hot press and pressure of 3bar for 5mins and the mechanical properties were studied base on varying the wood fibre contents from 0% to 50%. The hardness test carried out using the durometer hardness tester show a decrease in the hardness of the composite as the wood fibre is varied from 0%, 10%, 20%, 30% 40% and 50% and the impact strength of the composite decreases as well in that order. The tensile strength conducted using the Mensato Tensometer show a decrease at 10% wood fibre, while an increase in the wood fibre to 20% show an increase in the tensile strength on further addition of the wood fibre a decrease is noticed. This decrease in tensile strength decreases the strain of the PVC-wood fibre composite and hence increasing the modulus of elasticity of the PVC-wood fibre composite as the wood fibre is been added.

1. Introduction

In the last 20 years, natural organic fillers have been regularly applied in the global market. Polyvinyl chloride–Wood composite are recently popular in many applications, such as construction industries [1]. The reason is the desirable properties of the composite, such as the relative low cost and the abrasiveness [2]. Furthermore, the composites are environmentally friendly and recyclable [1]. Studies have pointed out the main problems, the strength of the composites decrease, the leaching of the additives and the deterioration of the physical properties of the blend [3]. The wood additives are susceptible to thermal degradation; therefore it was only suitable for some type of plastic, such as PVC, PE and PP. But in this case it was very difficult to reach strong adhesion between hydrophilic cellulose and hydrophobic polymer (PVC). Studies have used three general opportunities to enhance dispersion and compatibility of cellulose with polymers: fiber, matrix and interface treatment. The advantages of wood are: low density, excellent mechanical properties and good biodegradation. But unfortunately, it has negative aspects; UV radiation, biological attack, degradation from high temperatures and the air moisture content. Therefore the service lives of the composites are needed to be extended [4]. However, current levels of their usage and disposal generate several environmental problems. A major portion of plastic produced each year is used to make disposable items of packaging or other short-lived products that are discarded within a year of manufacture. These two observations alone indicate that our current use of plastics is not sustainable [5]. Recycling is one of the most important actions currently available to reduce these impacts and represents one of the most dynamic areas in the plastics industry today. Recycling of packaging materials has seen rapid expansion over the last decades in a number of countries. Advances in technologies and systems for the collection, sorting and reprocessing of recyclable plastics are creating new

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opportunities for recycling, and with the combined actions of the public, industry and governments it may be possible to divert the majority of plastic waste from landfills to recycling over the next decades [6]. Wood–PVC composites (WPCs) are a form of composite combining wood-based elements with PVC. The processes for manufacturing WPCs include extrusion, injection molding, and compression molding or thermoforming (pressing). Newer manufacturing processes for WPCs include additive manufacturing via fused layer modeling and laser sintering. An important constraint for PVC used in WPCs is requiring process conditions (melt temperature, pressure) that will not thermally degrade the wood filler. Wood degrades around 220°C.Wood fibers are inherently hydrophilic because of the hydroxyl groups contained in the cellulose and hemicellulose molecular chains. Thus, modification of the wood fiber via chemical or physical treatments is very critical to making improved WPCs [7]. It is important to note that we need to protect tropical forests from deforestation and degradation if we want to reduce emissions to the levels needed to protect the planet against the worst global warming impacts. Ending deforestation will not solve global warming by itself [8], of course urgent action is needed to cut the other 90 percent of emissions. But the problem cannot be solved if the role of tropical deforestation is ignored. And reducing deforestation has other benefits beyond reducing global warming pollution [9]. In addition, tropical forests are crucial sources of food, medicine, and clean drinking water for people in developing countries. Tropical forests help regulate regional rainfall and prevent both floods and droughts. Reducing deforestation is not only a beneficial action against global warming [10, 11]; it also can make important contributions to saving biodiversity and supporting sustainable development. Wood plastic composite materials are such materials which are used mainly in the building industries [12]. Due to its compatibility with natural fibers, ductility, chemical and flame resistance Polyvinylchloride (PVC) has been suggested more appropriate material to build structures such as furniture, automobile parts and in other construction works.[13] reported that the worldwide Natural Fiber Reinforcement Polymer Composite Industry sector reached U$ 2.1 billion in 2010. Landfilling has usually been used to dispose of plastic waste but has proved inefficient since it fills up the site quickly. Also, incineration of the plastic waste and wood dust leads to pollution and environmental hazards. Therefore, there is the need for effective and sustainable method to manage the menace. The widespread application of Natural Fiber Polymer Composite in polymer composites due to its low specific weight, relatively high strength, relatively low production cost resistance to corrosion and fatigue [14]. Based on reviewed literature, it is necessary to further investigate alternative mode of recycling plastic wastes.

2. Results and Discussion

The result for the Hardness study of PVC-Wood fibre composite conducted according to the method stated earlier in the work is presented as;

Table 1: Hardness result for PVC-wood fibre composite

S/No	PVC: Wood fibre	Hardness (J)
1	100:0	66.50
2	90:10	62.00
3	80:20	61.33
4	70:30	59.87
5	60:40	62.00
6	50:50	49.57

From the above table a gradual decrease in the hardness of the composite is noticed this decrease could be due to the decrease in the rigidity of the PVC as the wood fibre is added. Below is a figure showing the variation of hardness with % composition.

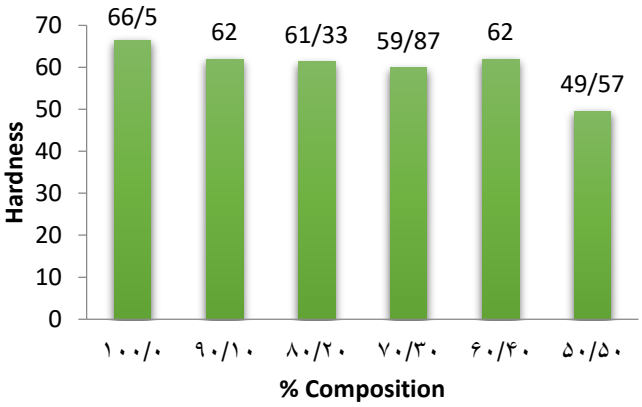

Figure 1: Variation of hardness with % composition

The result for the Impact study of PVC-Wood fibre composite is represented as

Table 2: Impact test result for PVC-wood fibre composite

SAMPLE	COMPOSITION(PVC:WOOD)	IMPACT(J/mm)
CONTROL	100:0	0.148
A	90:10	0.206
B	80:20	0.232
C	70:30	0.258
D	60:40	0.222
E	50:50	0.192

Table 2 above show a gradual increase in the impact strength as the wood fibre is added where it is 0.148(J/mm) at 0% wood fibre, at 10% wood fibre it yield an impact of 0.206(J/mm). A serious decrease is observed as the % composition of the wood fibre is increased from 30% to 40% and from 40% to 50% where a decrease in the impact strength is seen. The decrease in the impact strength could be probably due to the dilution effect whereas the increase could be due to the low content of the wood fibre. This is in contrast to the findings of [15] where a decrease is noticed. The trend in the variation of Impact strength of the PVC-Wood fibre composite is illustrated in figure 2

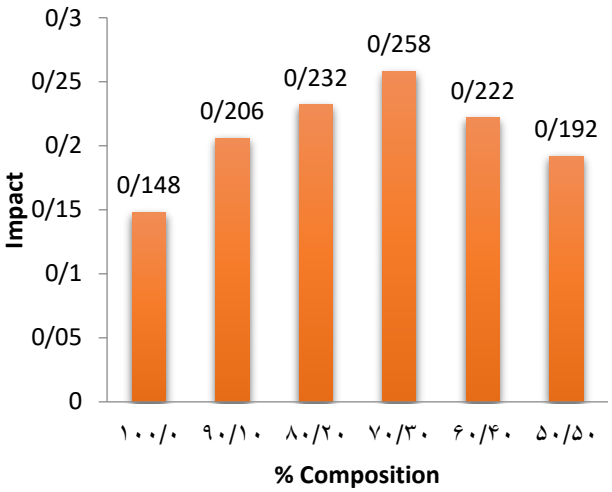

Figure 2: Variation of Impact strength with % composition

The result for the Tensile strength, Strain and Young modulus studies of the PVC-Wood fibre composite done according the method stated earlier, is represented as;

Table 3: Tensile Strength, Strain and Young modulus test result for PVC-wood fiber composite

S/No	Composition(PVC:wood)	Tensile strength(N/mm^2)	Strain	Young modulus(N/mm^2)
1	100:0	38.67	0.204	189.56
2	90:10	28.67	0.165	173.76
3	80:20	39.00	0.138	282.61
4	70:30	38.67	0.144	268.54
5	60:40	34.00	0.099	343.43
6	50:50	26.67	0.087	306.55

The table 3 above show a decrease in the tensile strength as the wood fibre is added from zero % to 10 % with the tensile decreasing from 38.67 to 28.67.Whereas on addition of the wood fibre an increase in the tensile strength is noticed. On further addition of the wood fibre to the PVC a gradual decrease is shown where the tensile strength decreases from its maximum peak of 39.00 gradually to 26.67 which is its minimum value. This decrease could be due to moisture adsorbed on the fiber and poor dispersion of fiber in matrix. Thesame trend were found similar to the previous finding s of [16] and [17]. Table 3 also indicate a decrease in the tensile strain of the composite this is most like due to the decrease in extension/elongation. Similarly on the same Table 3 an increase in the modulus of elasticity is observed this due to the decrease in tensile strain. Lopez-Crespo [18] find similar trend in their investigation of tensile properties of composites. The trend in Tensile strength, Strain and modulus of the PVC-Wood fibre composite provide in table 3 above can be represented as a chart in following figures;

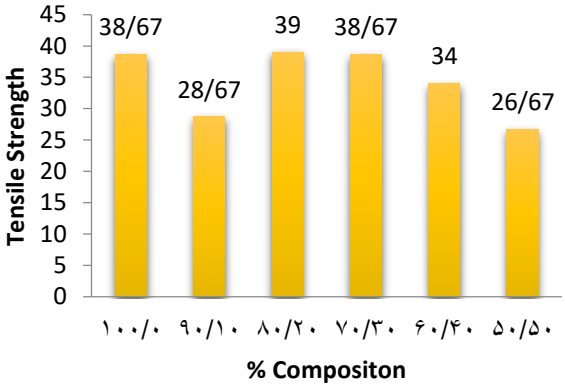

Figure 3: Variation of Tensile strength with % composition

2.1. FTIR Result

FTIR spectroscopy has been proved to be a useful technique for characterization of intermolecular interactions between groups in self-polymer or different polymer molecules in blend systems. These intermolecular interactions, mainly hydrogen bonding and dipole–dipole interaction, lead to either shifts in frequency or changes in absorbance of specific functional groups [19].

The wave number 883.67cm^{-1} is a C-H bending vibration of RC=CR alkynes. 705.02cm^{-1} and 769.63cm^{-1} are the C-H out of plane vibrations of trans RCH=CHR alkenes. 1157.33cm^{-1} is typical of C-H wag of alkyl halides. The C-H rock vibration is associated with 1356cm^{-1}. The wave numbers 2946.36 represent RCHOC-H functional group of aldehydes. The bands 3418.94 cm^{-1} and 3418.94 cm^{-1} are consequence of the presence of O-H groups. 1731cm^{-1} denote C=O stretch of carbonyls. These functional groups are present in materials like carbohydrates, starch and some other natural gums [20].

The FTIR of treated PVC-WF composite revealed frequencies and peaks due to interaction between the solvents and composite matrix. The results obtained indicate the presence of several functional groups arising from the formation of new bonds and shifts in frequencies when compared to those deduced from the pure PVC.

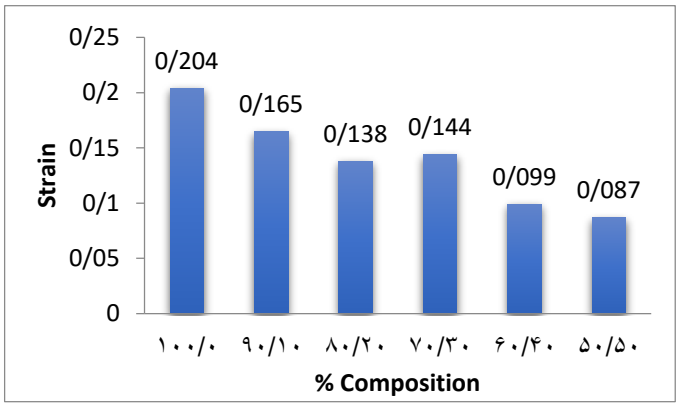

Figure 4 .Variation of Tensile strain with % composition

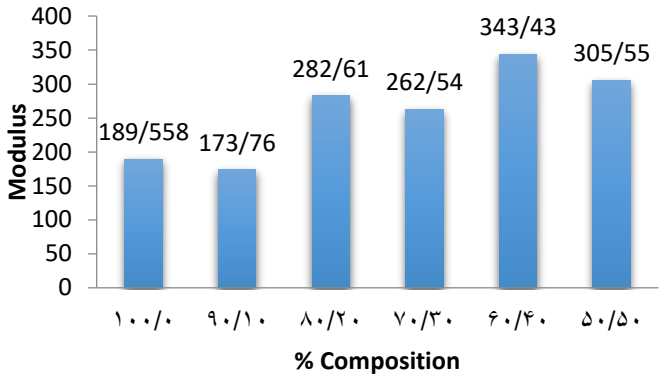

Figure 5: Variation of modulus of elasticity with % composi

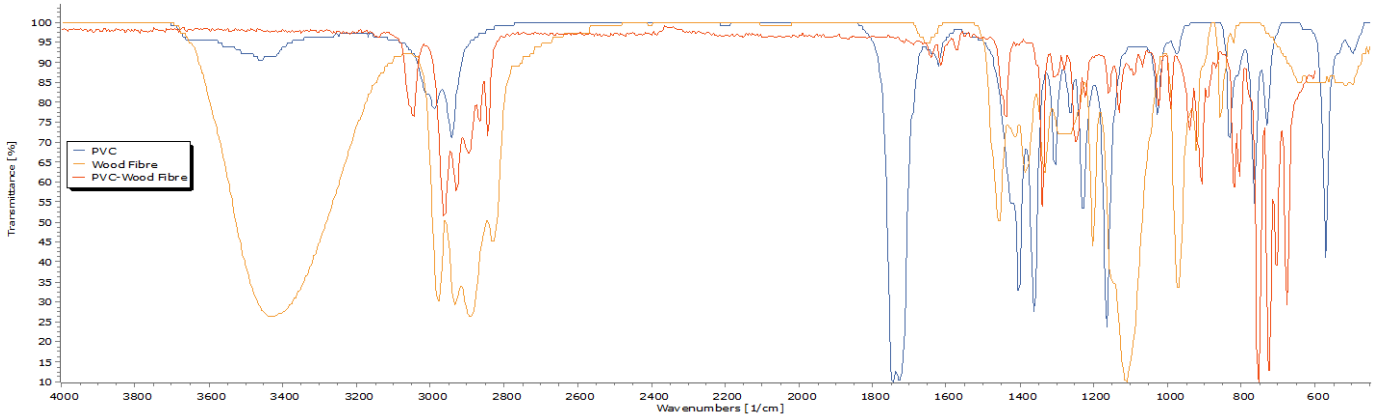

Figure 6. FTIR spectrum of PVC, Wood Fibire and PVC-wood fibre composite respectively

Table 4: Summary of FTIR Spectra of PVC showing functional group assignments of the various peaks

S/N	Peak	Intensity	Area	Functional Grp Assignment.
1	581.81	19.609	203.183	C-Cl stretch
2	1630.87	22.785	76.959	CH=CHR
3	1734.06	18.403	127.373	C=C stretch
4	2929	17.321	368.2	$-CH_2-$

Table 5: Summary of FTIR Spectra of WF showing functional group assignments of the various peaks

S/N	Peak (AHY)	Intensity	Area	Functional group assignment
1	443.64	17.616	159.805	-
2	883.43	58.568	35.796	C-H out of plane
3	1356.46	49.271	105.73	C-H Rock
4	1653.05	53.139	38.032	C=C stretch
5	2946.36	49.17	230.19	C-H stretch
6	3412.19	28.15	145.892	O-H stretch

Table 6: Summary of FTIR Spectra of PVC-WF showing functional group assignments of the various peaks

S/N	Peak	Intensity	Area	Functional group
1	423.39	22.857	61.219	
2	469.68	23.072	33.717	
3	591.2	22.65	205.45	C-Cl stretch
4	1052.2	16.149	244.98	C-O stretch
6	1624.12	23.124	86.188	Ar-CH=CHR
6	1731.17	22.379	116.592	C=O stretch
7	2929	20.611	442.3	-CH2- stretch
8	3418.94	95.909	576.92	O-H stretch

2.2. Surface morphology study

Scanning electron microscopy (SEM) is utilized to record the images of a surface of materials/specimens at a desired position to obtain topographic/morphological picture with better resolution and depth of focus compared to an ordinary optical microscope. In application to materials science of polymers and rubbers, SEM study commonly aims at visualization of phase morphology, surface and cross-sectional topography,

surface molecular order and elucidation of failure mechanism. Figure 7 to 9 shows the scanning electron micrographs of Wood-fibre (WF), PVC and PVC-WF composite at 1.00 KX magnification. The Figures generally revealed that the particles in the gum has irregular shapes and dimensions which appear porous. At 1.00 KX magnification, the micrograph clearly revealed the existence of some cavities which could enhance its adsorption capacity. Among the studied samples, wood-fibre was found to exhibit highest water swelling capacity, highest solubility in water suggesting that the gum is a hydrogel [21].

The scanning electron micrograph of *PVC* at 1.00 1.00 KX magnification revealed that the polymer consists of aggregates of regular shapes and dimensions. Existence of molecular slaps or cavity cannot be seen in the micrographs. The scanning electron micrographs of the composite at 1.00, KX magnification shown in figure 9 revealed a smooth surface with irregularly spaced pores. The system has an irregular network but could likely provide favoured adsorption sites. The micrographs revealed the existence of particle aggregations with some internal bridges within the system.

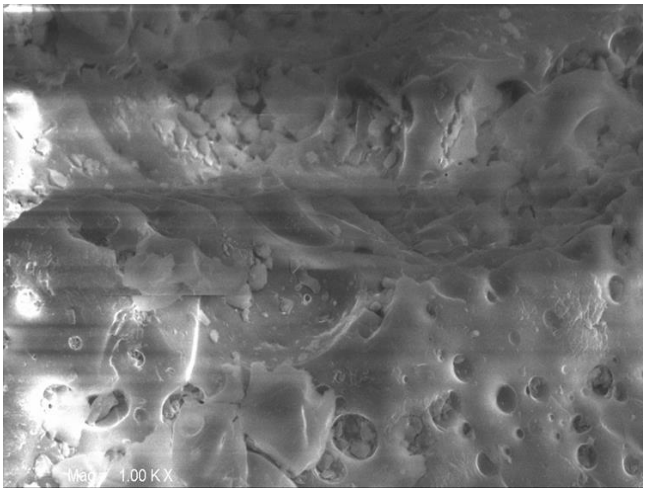

Figure 7: scanning electron micrograph of wood-fibre at 1.00 1.00 KX magnification

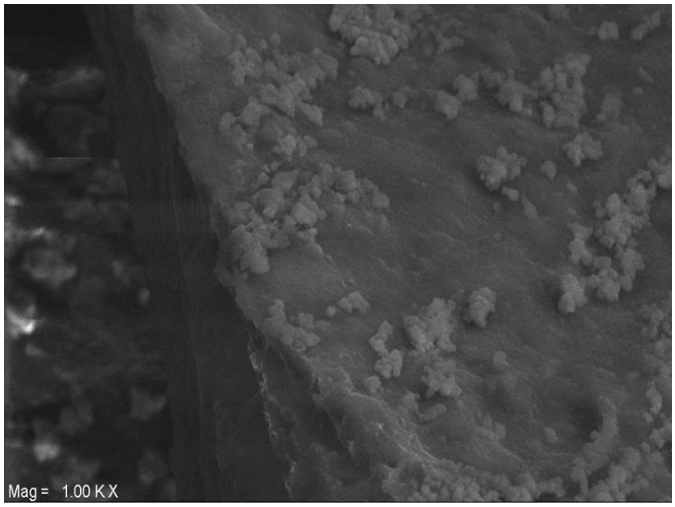

Figure 8: scanning electron micrograph of PVC at 1.00 1.00 KX magnification

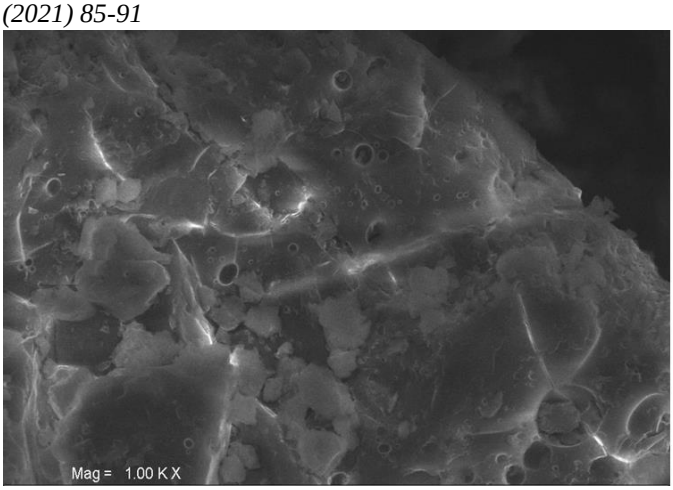

Figure 9: scanning electron micrograph of PVC-WF at 1.00 1.00 KX magnification

3. Experimental

3.1. Materials

The materials that were used for the study are listed on Table 7.

Table 7: Materials used and their sources

S/n	Material	Source
1.	Recycled Polyvinyl Chloride (RPVC)	Samaru, Community
2.	Hardwood Fibre (Mahogany)	Sabon Gari SawMill

3.2. Equipment

The equipment that were used for the production in this research, the function, the manufacturer's name and the model no are as shown in Table 8.

Table 8: List of equipments used, functions and their manufacturers name

S/n	Function	Equipment	Manufacturer's name	Model no
1.	Weighing operation	Weighing balance	Mettle instruments Ltd	AE 200
2.	Hardness testing	Hardness tester (Durometer)	Muverdurometer	5019
3.	Pressing	Hydraulic hot press	Carver inc. hydraulic press	3851-0
4.	Impact strength testing	Impact tester	Resilimpactor testing machine	412-07-15269C
5.	Compounding (Mixing)	Two roll mill Machine	Allen-Bradley	802T-WS1P
6.	Tensile strength testing	Hounsfield Monsanto Tensometer	Hounsfield Monsanto Ltd	386083-W9

3.3. Materials Collection

Waste Polyvinyl Chloride pipes were collected from duping sites within Samaru metropolis while Hardwood fibre was collected from Sawmill in Sabon Gari Market, Zaria, Kaduna State.

3.4. Materials Preparation

The waste Polyvinyl Chloride pipes collected were washed and dried to remove dirt. The clean waste pipes were crushed on a plastic crusher into pellet form at the department of Polymer Technology, Nilest, Zaria.

The Hardwood fibre was milled into 1mm fibre length on a laboratory milling machine at the Quality control laboratory, Nilest, Zaria. It was then treated using 5%w/v NaOH solution at 50ºC for 1 hour.

3.5. Formulations of Leather Buff waste-LDPE Heel-lift Composites

The formulation was based on varying the filler (Hardwood fibre) from 10- 50g at 10g interval as shown in the table 3.

Table 9: Formulations for the PVC-HF composite

% Composition PVC:HF	Hardwood Fibre(g)	RPVC (g)
Control (100:0)	0	100
A (90:10)	10	90
B (80:20)	20	80
C (70:30)	30	70
D (60:40)	40	60
E (50:50)	50	50

3.6. Mixing of Hardwood Fibre-Recycled PVC Composites

According to the formulation as shown in the formulation table 3, the composites samples were produced by a mixing process involving the introduction of the Recycled Polyvinyl Chloride (RPVC) while the rolls of the two rolls mill machine were in counter clockwise motion and soften for a period of 5 minutes at a temperature of 160°C, upon achieving a band formation of the RPVC on the front roll, wood fibre (filler) was manually added to the bank as the rolls rotate at a rate of 500 rpm. The composite was sheet out and labeled accordingly. The samples was designated A, B, C, D, and E accordingly as shown in table 3.

3.7. Formation of the Composite Samples

The composite obtained from the mixing process was placed into a metal mould of dimensions 120mm x100mm x 3mm and was placed on the hydraulic hot press for shaping at temperature of 150ºC and pressure of 3bar for 5mins. It was cooled and labelled.

4. Characterization of Produced Composite Samples

4.1. Hardness Test

The hardness test was carried out using the Durometer Hardness tester with model no. 5019 on shore A scale. The sample was placed on the mounting stage and the dial gauge adjusted to zero (0), the hand lever was used to raise the stage such that the sample come in contact with the dial point and exact pressure/force on the sample and the reading was taking. This was repeated three (3) times at different positions on the sample. Average hardness value was determined using the formula in equation 3.3.

$$\text{Average Hardness} = \frac{\text{1st + 2nd + 3rd readings}}{3} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (1)$$

4.2. Impact Test

The impact strength test of the composite samples was determined using Charpy Impact testing machine with model no 412-07-15269C. The procedure used was in accordance with that recommended by ASTM D-256. Samples were sectioned to 100mm **x** 10mm **x** 3mm dimensions after which 2 samples each were prepared, mounted on the machine, and a swinging pendulum released, under gravity, to hit the sample(s). The energy at impact was read directly from a dial indicator of the machine and the average impact energy was calculated using equation 2. The average impact energy was used to compute the impact strength of the samples using equation 3. The results obtained are given in Fig.3 and Table 3.

$$\text{Average Impact Energy} = \frac{\text{1st + 2nd}}{2} \text{ (J)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$\text{Impact Strength} = \frac{\text{Average Impact Energy}}{\text{Sample Thickness}} \text{ (J/mm)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots..\ldots\ldots\ldots\ldots\ldots\ldots.. (3)$$

4.3. Tensile Strength Test

The tensile test was carried out using the Hounsfield Monsanto Tensometer (model 9875) according to ASTM D-638. A dumbbell shaped samples were subjected to a tensile force and tensile properties such as tensile strength, Strain, modulus for each sample were calculated using the equations 4

$$\text{Tensile Strength} = \frac{F}{bd} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where,

F = Maximum tensile load

b = Sample thickness

d = Sample width

$$\text{Strain} = \frac{\Delta L}{L} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where,

ΔL = Change in Length

L = Gauge Length

$$\text{Modulus} = \frac{Stess}{Stain} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

……...(6)

4.4. FTIR Analysis

FTIR is commonly used for qualitative identification of various functionalities. The FTIR spectrum of the powdered gum was recorded with a Perkin Elmer RXI spectrophotometer (Connecticut,USA). The dry powder was mixed with KBr and pressed into pellets. The spectrum was obtained by scanning between 4000 and 500/cm.

5. Conclusion

Natural fiber reinforced polymer composite has beneficial properties such as low density and less expensive when compared to synthetic composite products. This would provide an advantage for utilization in commercial and industrial applications. This study has shown that all mechanical properties of the Polyvinylchloride (PVC) and wood dust where affected by the addition of fillers which decreased with increasing filler content. The FTIR result also confirms the formation of new bonds in the composite, while the SEM analysis which describes the surface morphology of PVC-WF composite shows the material ability to absorb water and be applied in other adsorption research. There was no significant change to the overall mechanical properties of the composite, which could be an advantage in terms of cost saving.

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