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Preparation and Characterization of Wood Dust Natural Fiber Re-Enforced Polymer Composite

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ABSTRACT: Composites based on natural fiber reinforcement have generated wide research and engineering interest in the last few decades. This is mostly due to their high specific strength, low cost, low density, light weight and biodegradability and has earned a special category of green composite. In this study, wood dust reinforced composite were processed with 2wt%, 4wt%, 6wt%, 8wt%,10wt%, 12 wt.% and 14wt%. The tensile, impact, stress and strain tests were performed at different wt% to study the mechanical behavior of the composite. The result of the study showed that the mechanical properties decrease considerable up to 16.7 wt% wood dust contents. However, above 16.7 wt% there was no significant change to the overall mechanical properties of the composite, therefore yielding an advantage of cost saving.

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The increase in environmental consciousness and the fast growth of the manufacturing industries suggest the need for more economical and biodegradable materials which have better properties such as good mechanical properties, excellent chemical resistance, reduce maintenance and lower cost May-Pat *et al*., (2013). As a result composite materials are one of the materials which possess such properties. Recently, the use of composites have replaced many other conventional materials, this is actualized by the advantage polymer offers over conventional materials such as metals Puglia *et al*., (2005). This advantage includes ease of availability, lightweight, ease of processing, biodegradability, improved finish of molded part composite, and cost reduction Shalwan *et al*., (2013). Natural fiber reinforcement polymer matrix composites are cheaper, tougher and environmental friendly. The fibers are usually glass, carbon, bamboo and wood dust possess good reinforcement capability when properly combined with polymer. The composite here is a combination of the matrix which is Polyvinylchloride (PVC) and reinforcement as wood dust. The use of the matrix is to hold the fiber together for a more efficient transfer of load between them Adekomaya *et al*., (2016). Wood plastic composite materials are such materials which are used mainly in the building industries Ticoalu *et al*., (2010). 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 (Cappucci, 2009).

In 2013, Uddin 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. Moreover, recycling has proven to be the best way to resolve the plastic waste problem. Other recycling methods have been used to manage the situation such as the burning of the plastic which releases toxic substance such as dioxins, mercury and furan which results in environmental pollution Srivabut *et al*., (2018); Ashori *et al*., (2009). Moreover, the applications of Natural Fiber Polymer Composites are growing rapidly in numerous engineering fields. The different kinds of natural fibers such as jute, hemp, oil palm, and bamboo reinforced polymer composite have received a great importance in different automotive applications, structural components, packing, and construction. 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 Shalwan *et al*., (2013). Based on reviewed literature, it is necessary to further investigate alternative mode of

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recycling plastic wastes. Importantly, the possibility of utilizing waste Polyvinylchloride (PVC) and waste wood dust as recyclable materials that can be used for the production of furniture such as chair, table, post-boxes, grain storage silos, and biogas containers.In this study, the tensile, and impact property of composites were investigated. The study examined the development of new class of composite materials that aids the defects of conventional material since the thermal properties of polymers are inadequate for other structural purpose.

MATERIALS AND METHOD

Materials: The materials used for this study includes; Wood dust, Polyvinylchloride (PVC), Silicone gel, Tetrahydrofuran (THF), Sieve, Beaker, Stirring rod, Weighing balance, Universal tensile machine, Impact testing machine.

Method: A solution of 70ml of tetrahydrofuran (THF) was poured into a beaker, and 20gram of waste Polyvinylchloride (PVC) plastic was measured using a weighing balance. Then, the measured waste (PVC) was added into the beaker containing 70ml of tetrahydrofuran (THF). Then stirred for about 10 minutes, until waste Polyvinylchloride (PVC) was completely dissolved. Then a sample of 2, 4, 6, 8, 10, 12, and 14wt% of waste wood dust was measured separately using a weighing balance. The wood dust measured was then added to the mixture of tetrahydrofuran (THF) and Polyvinylchloride (PVC) and stirred continuously until there was a homogeneous mixture. Here, the dissolved waste Polyvinylchloride (PVC) and the wood dust serves as filler. Thereafter, these mixtures were poured into a metallic mold, and then allowed to solidify for about 10 hours. The tensile strength and impact strength mold were lubricated with silica gel (releasing agent) prior to casting of the polymeric mixture. A total of 7 samples (composite) were prepared and tested for both tensile and impact test. This was performed for each sample of wood dust. The wood dust polymer composite was developed and their mechanical properties (tensile and impact strength) were evaluated. The schematic view of production procedure is shown in Figure 1.

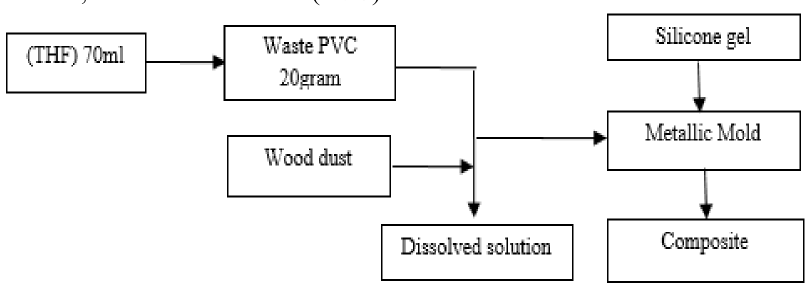

Fig 1: Schematic view of production procedure

RESULTS AND DISSCUSSION

Tensile properties of composite: The tensile strength of fiber reinforced composite is shown in Figure 2. As shown in Figure 2, at 9.1wt%, the tensile strength of the composite was 144MPa. Further increase in wood dust from 9.1 wt% to 23.1wt% led to decrease in tensile strength of composite from 144MPa to 64MPa. A slight increase in the tensile strength was found with further increase in wood dust to 33.3wt%. Thereafter the tensile strength decreased steadily to about 16MPa. Similar trend in the tensile properties of the composites sawdust was reported in previous report (Dorothy, 2015). The tensile strength of the composite formulated from the "wawa", mahogany and their mixture and plastic water sachet. Their graphs shows a similar pattern, that is the tensile strength decreased as the 0% loading of the sawdust increased. It was reported that for the composite, the tensile strength decreased from 34.45MPato 30.22MPa when the loading was increased from 10wt% to 50 wt%. Furthermore, the same trend and all other formulations were found to similar to previous findings of Crespo *et al*., (2009); Kim *et al*., (2005); and Georgopoulos *et al*., (2005). A particle size of 150 mm. was tested, and it was reported that there was a difference in the tensile strength of plasticized Polyvinylchloride (PVC) without filler and the plasticized polyvinylchloride (PVC) filler with wood dust particles. An increase in content of the filler led to decrease in the tensile strength. This decrease could be mostly due to the stress concentration effect around the filler particle, which is produced by the weak interaction phenomena of the plasticized polyvinylchloride (PVC). The decrease in tensile strength could be due to several reasons. Some of the reasons could be due to moisture adsorbed on the fiber, and poor dispersion of fiber in the matrix. Others could be due to an increase of interfacial defects or de-bonding between the polymer and the fiber or the use of untreated fibers. The de-bonding was found to be more than 41.2wt% sawdust composite.

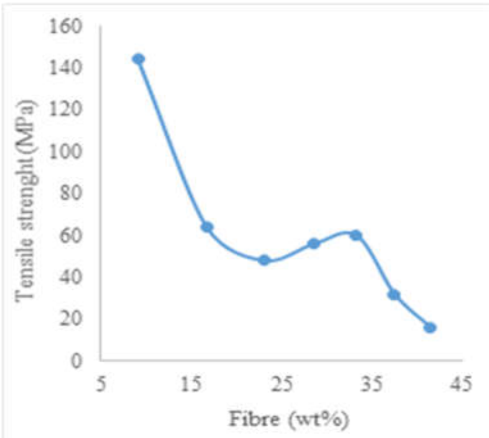

Fig 2: Tensile strength of composite at different weight percent

Impact properties of composites: The impact strength of fiber reinforced composite is shown in Figure 3. As illustrated in Figure 3, there was gradual decrease in the impact strength with an increase in percentage weight of wood dust. A maximum of 360.7MPa was obtained at 9.1wt%, and the minimum 321.4MPa at 41.2wt% wood dust.

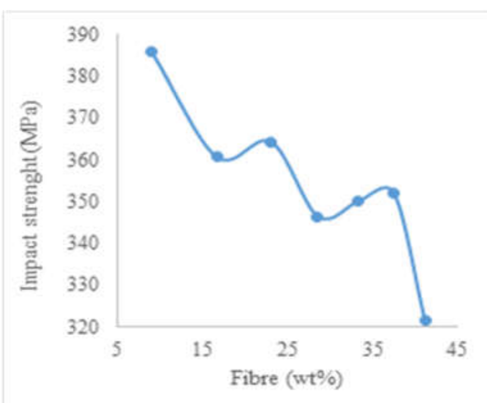

Fig 3: Impact test for composite at different weight percent

The decrease in impact strength could be probably due to the dilution effect. As the wood fiber content increase, the ductile portion (PVC matrix) automatically reduced, thus decreasing the composite toughness. Bledzki *et al*., (2004), reported similar findings on creep and impact properties of wood fiber, polypropylene composites influence of temperature and moisture content. This suggests decrease in impact strength of natural fiber/polymer composite was usually derived from de-bonding and friction effect, especially for the composite when no fiber treatment was applied.

Stress/strain of the composites: The stress–strain curve of a material can be used to determine several properties. Stress is the measure of force applied over an area, and is the normalized displacement. The maximum stress a material can withstand is the ultimate tensile strength, the linear behavior of a material over a given range and the slope of that function is called Modulus of Elasticity (MOE) or Young's modulus Rahul *et al.*, (2014).The stress and strain values for the various formulations were computed from the force or load applied on the samples and the extent of elongation. The values recorded were used for curves. The stress-strain curve for the various formulations is shown in Figure 4. As shown in Figure 4, at 0.042 wt%, the stress to strain value of the composite was 0.004 MPa. Further increase in wood dust from 0.042 % to 0.036 % led to a decrease in the tensile modulus from 0.004 MPa to 0.002 MPa. The stress (0.002 MPa) remains unchanged with increase in strain from 0.036 wt% to 0.024 wt%. However, it decreased from0.002MPato 0.01MPa and thereafter remains constant when strain increased from 0.018wt% to 0.024wt%.

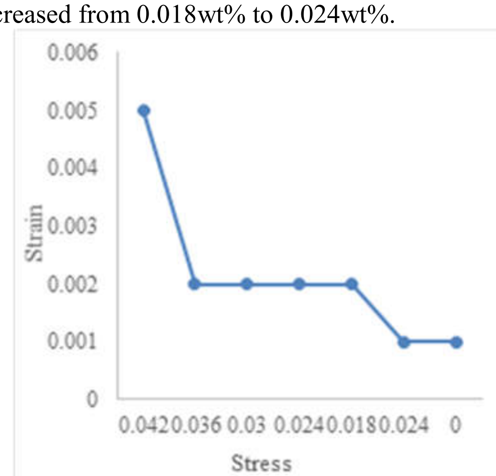

Fig 4: Stress to strain of composites at different weight percent

Tensile modulus of composites: The Tensile modulus of fiber reinforced composite is shown in Figure 5. As illustrated in Figure 5, at 9.1wt%, the tensile strength of the composite was 0.10MPa. Further increase in wood dust from 9.1% to 16.7% led to a decrease in the tensile modulus from 0.10MPa to 0.06MPa.Similar decrease on the tensile modulus was found when the wood dust increased by 23 wt%. At 28.6wt% and 33.3wt% there was an increase in the tensile modules from 0.08MPa and 0.11MPa respectively. After 37.5wt%, continual decrease was found for the tensile modulus to be 0.04MPa. At 41.2wt% there was decrease in tensile modulus of the composite to 0 MPa.

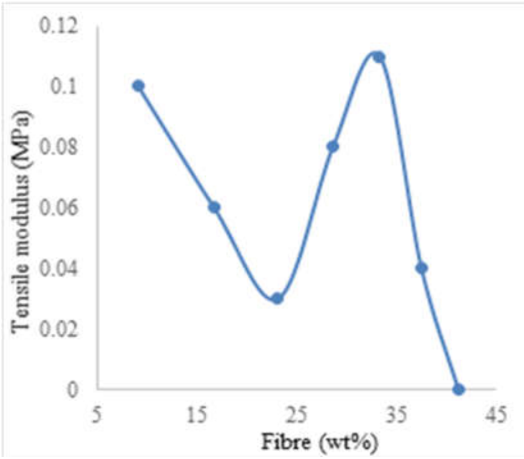

Fig 5: Tensile modulus of composite at different weight percent

The decrease in tensile modulus was attributed to two possible reasons, one being poor dispersion of the sawdust particle throughout the polyvinylchloride (PVC) matrix and the other the moisture adsorbed in the sawdust. It was found that the sawdust fiber tended to cling together due to strong inter-fiber hydrogen bonding and resisted dispersion of the individual fiber as fiber content was increase from 9.1 wt% to 33.3 wt %. Based on the investigation of Crespo *et al.*, (2009), where the tensile tests were carried out using different filler content samples. Their results showed increase in percentage weight of the filler. Likewise, maximum load, tensile modulus, tensile stress and strain value increased and with a maximum at 10wt% filler content. However, these properties decreases and become minimum at 15% wt. expect for the tensile modulus value which attains its minimum value at 0 wt%. In summary, Figure 2, Figure 3, Figure 4 and Figure5 shows the tensile strengths, impact strengths, tensile modulus and stress to strain values, respectively, of polyvinylchloride and wood dust composites containing different wood dust amounts. Generally, it was found that increasing the sawdust content resulted in a very similar trend of decrease in all mechanical properties. Similar trends were reported by Beigloo *et al*., (2017); Djidjelli *et al*., (2008). The decrease in the tensile properties of the composites, due to addition of wood dust, can be considered in two different zones. First, it was between 0.0wt% and 16.7wt% and secondly between 16.7wt% and 41.2wt%. The addition of wood dust had a more pronounced effect on tensile properties at concentration below 16.7 wt%. Beyond these concentrations, the tensile properties were affected to a lower extent by the wood dust content Chatree *et al* (2018). This could be of economic benefit to industries as one could add greater amounts of sawdust (between 16.7 and 41.2 wt %) to replace the polymer without significant changes in mechanical properties, therefore leading to cost savings. Although the change in the tensile modulus and tensile strength were similar, the explanations offered here for each property change differs. One it is expected to obtain greater tensile modulus as the wood dust fiber usually retains most of its lignin, it was, however, not the case here. The tensile modulus was found to reduce with wood dust amount. The decrease in tensile modulus could be attributed to two possible reasons. In addition, the decrease in tensile strength could be due to other reasons, such as moisture pick-up in the fiber, poor dispersion of the fiber in the matrix, an increase of interfacial defects or de-bonding between polymer and fiber due to use of untreated fibers. The de-bonding was observed to be more in the 41.2wt% wood dust composite. A fiber content greater than 16.7 wt% seemed to have a small effect on the change of tensile strength of the composite. Similar behavior was found for the impact strength of the composite. The decrease in impact strength was probably due to dilution effect. That was because an increase in wood fiber content led automatic reduction in ductile portion (PVC matrix). This leads to the decrease in composite toughness. This finding was found to be in agreement with the study of Bledzki *et al*., (2004), who suggested that decrease in impact strength of natural fiber/polymer composite was usually derived from de-bonding and friction effect.

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) / wood dust where affected by the addition of fillers which decreased with increasing filler content. 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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