

Mechanical Properties of Wood Waste Reinforced Polymer Matrix Composites

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This research work set is an investigation into the mechanical properties of polymer matrix composites (PMC) produced by the use of wood waste. Low density polyethylene was reinforced with sawdust from African teak as a filler, and Sodium hydroxide as the binder. The composite were fabricated by a compression moulding technique; composites with amounts of wood waste ranging from 20, 30, 40, 50, and 60 wt. % were produced. Results indicated that 40% of wood waste was the optimum reinforcement. Increasing amount of reinforcement improves the strength and stiffness of the composites but decreases the impact strength. The results also suggests that the rate of water absorption of the composite was high in the first few hours and that the highest water absorption rate was observed with 60% reinforcement. Microstructural examination revealed that there were small discontinuities and a reasonably uniform distribution of wood particles in the polymer matrix.

Keywords: Wood waste, Polymer Matrix Composite, Mechanical Properties, African Teak

1. INTRODUCTION

Composite is a material formed with two or more components, combined as a macroscopic structural unit with one component as the continuous matrix, and the other as the fillers or reinforcements. Normally, the matrix is the material that holds the reinforcement together and has lower strength than that of the reinforcing material. In the plastic based composites, the polymer, thermoplastic or thermoset material act as a matrix and the particles of wood or any other natural particles act as the filler. The reinforcing particles form the main load-carrying component in the composites. It provides high strength and high stiffness as well as resistance to bending and breaking under the applied stress. Interfacial bonding between the fillers and the matrix provides the key mechanism of transfer of stress from the matrix to the fillers.

Investigations on polymer-based composite materials have opened new routes for polymer formulations and have allowed the production of new composites with optimal properties for specific applications [1, 2]. The production of polymer matrix composites reinforced with wood flour is an established technology [3-5]. And in order to achieve the required combination of properties, interfacial interactions are often modified in these composites. Interfacial adhesion can be achieved by the chemical modification of the wood, by surface coating or by the introduction of a coupling agent. The particle size of wood

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flour that is most often used for the reinforcement of plastics is large and the particles easily debond when the composite is subjected to stresses that could lead to the formation of large voids. A number of natural occurring fillers and fibers used in composite have been studied over the years. These include wood fillers [3-6], wheat straw, almond husk, ash rice husk [7, 8], pineapple leaf, [9] coconut fruit fibers, Wood based filler derived from oil palm wood flour [10] etc. These fillers introduce some advantages compared to traditional inorganic fillers, including their renewable nature, low density, non-abrasive properties, reasonable strength, and stiffness [11].

Using a natural filler to reinforce composite materials offers the following benefits compared to a mineral filler [12, 13], the natural filler is strong and rigid, light weight, environmental friendly, economical, renewable and offers an abundant resource. However, natural filler have the disadvantage of degradation by moisture, poor surface adhesion to hydrophobic polymers, non-uniform filler sizes, they are not suitable for high temperature applications [14] etc. The objective of this research work is therefore to investigate the mechanical, the water absorption and the microstructural properties of low density polyethylene wood waste reinforced composite material

2. MATERIAL AND METHODS

2.1 Preparation of Wood Reinforcement

Wood samples were collected from African teak from a woodmill in Bida, Nigeria. The samples were sun-dried for two days to remove excess moisture, soaked in hot water (100°C) for 1 hour, washed thoroughly, and air-dried for three days at room temperature. They were then reduced to irregularly formed particles 1 to 2 mm in size in a plastic mill equipped with two rotating knives. The sawdust particle size, the time of alkaline treatment, compression moulding parameters (time, pressure, and temperature), the concentration of the NaOH solution, and the HCl acid solution, were all held constant while only the wood sample content was varied. [15]

2.1.1 Chemical Treatment of Wood Reinforcement

25g of a sample (1-2mm wood waste) were introduced into a 150ml solution of 20% NaOH and stirred thoroughly with a mechanical stirrer for 30 minutes. The mixture was next filtered and the residue was dissolved into a 100ml of prepared diluted hydrochloric acid to remove excess NaOH. The mixtures were stirred, filtered and the residues were collected. The treated samples were thoroughly washed five times with distilled water [16]. The treated fibre samples were air-dried at room temperature for three days followed by drying in an oven dried at 105°C.

2.1.1.1 Compounding of Wood Polymer Composites

A 200 ton capacity compression moulding machine was used to compound the wood polymer composites. In the initial stages, the female part of the mould was fixed on the carrier seat of the machine. The LDPE (Low density polyethylene) was poured into the oven system where it was melted and maintained at 180°C. At this stage the polymer was ready and the mixing of the wood particles with the molten polymer took place inside the oven system at temperature 180°C and pressure of 40kg/cm² for 10 minutes. The procedure was repeated for the various amounts of wood reinforcement. Impact test was carried out in accordance to ASTM D256. Compression testing was carried out according to ASTM D695. Water absorption testing was carried out according to ASTM D570. Finally, a scanning electron microscope JEOL 6010LA was used for surface characterisation.

3. RESULTS AND DISCUSSION

3.1 Mechanical Properties

Fig. 1 indicates that as the wood waste filler particle content increases, the composite becomes more stiff and less ductile. It is evident that as the particle content is increased beyond 60% reinforcement, the particles may not interact with the polymer matrix and the interfacial adhesion that is responsible for the composite stiffness and strength would be much lower as the particles agglomerate.

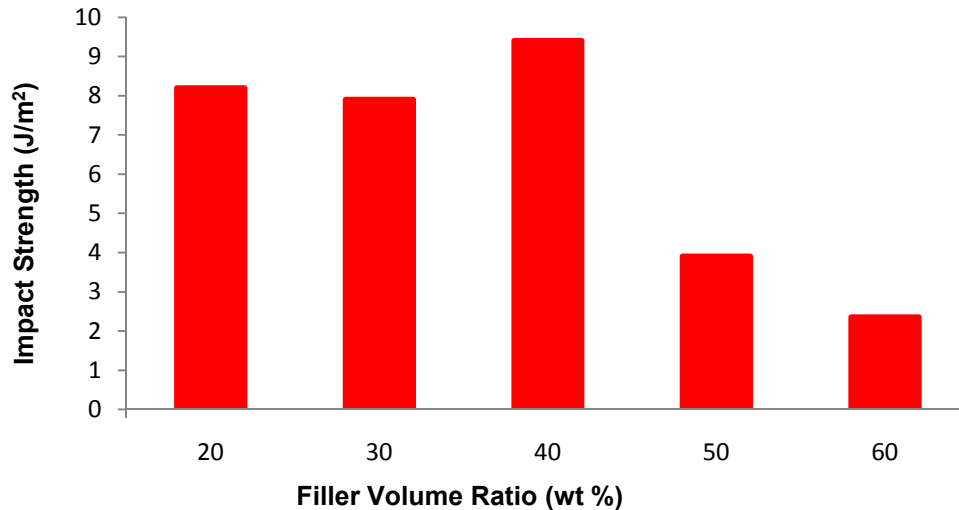


Fig 1: Effect of filler volume ratio on impact strength.

Fig. 2 shows how wood content affects the compressive strength of PMCs (polymer matrix composites). Increasing fiber reinforcement improves the strength and stiffness of the composite. The hardness strength also shows a slight increase as the filler volume ratio increases, and gradually decreases above 50 wt%. The water absorption test results are shown in Fig 3. It is clear from this figure that the composites absorb water at very fast rates in the initial stages, and a saturation level was reached in each curve. It was also observed that as the filler volume fraction increases, the water absorption rate of the composite increases.

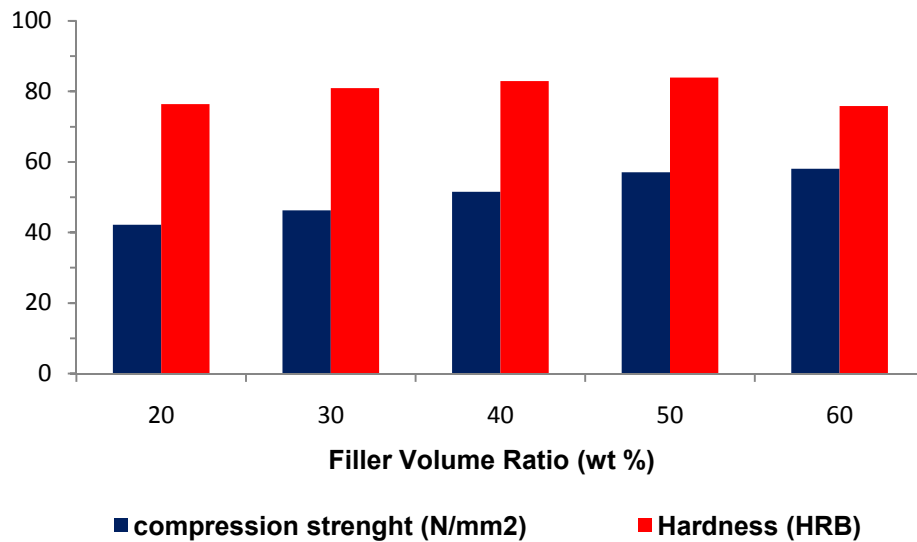


Fig 2: Effect of filler volume ratio on compression and hardness strength

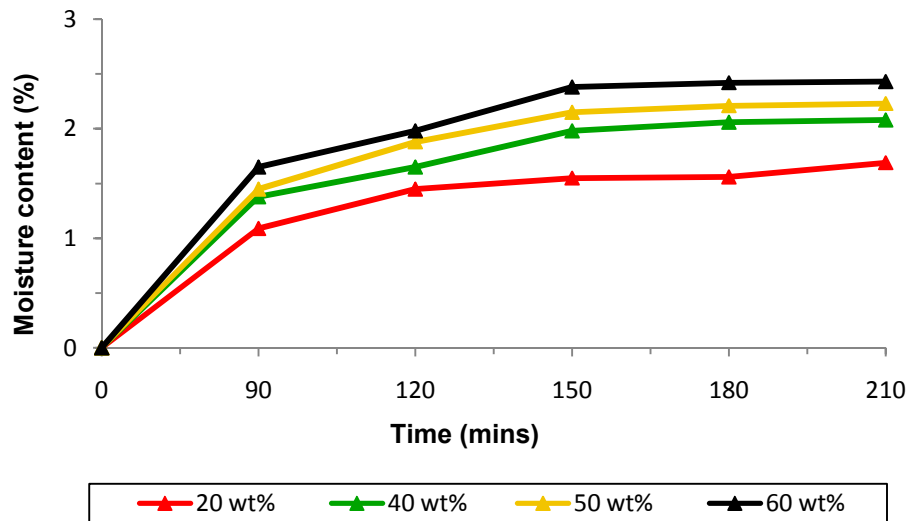
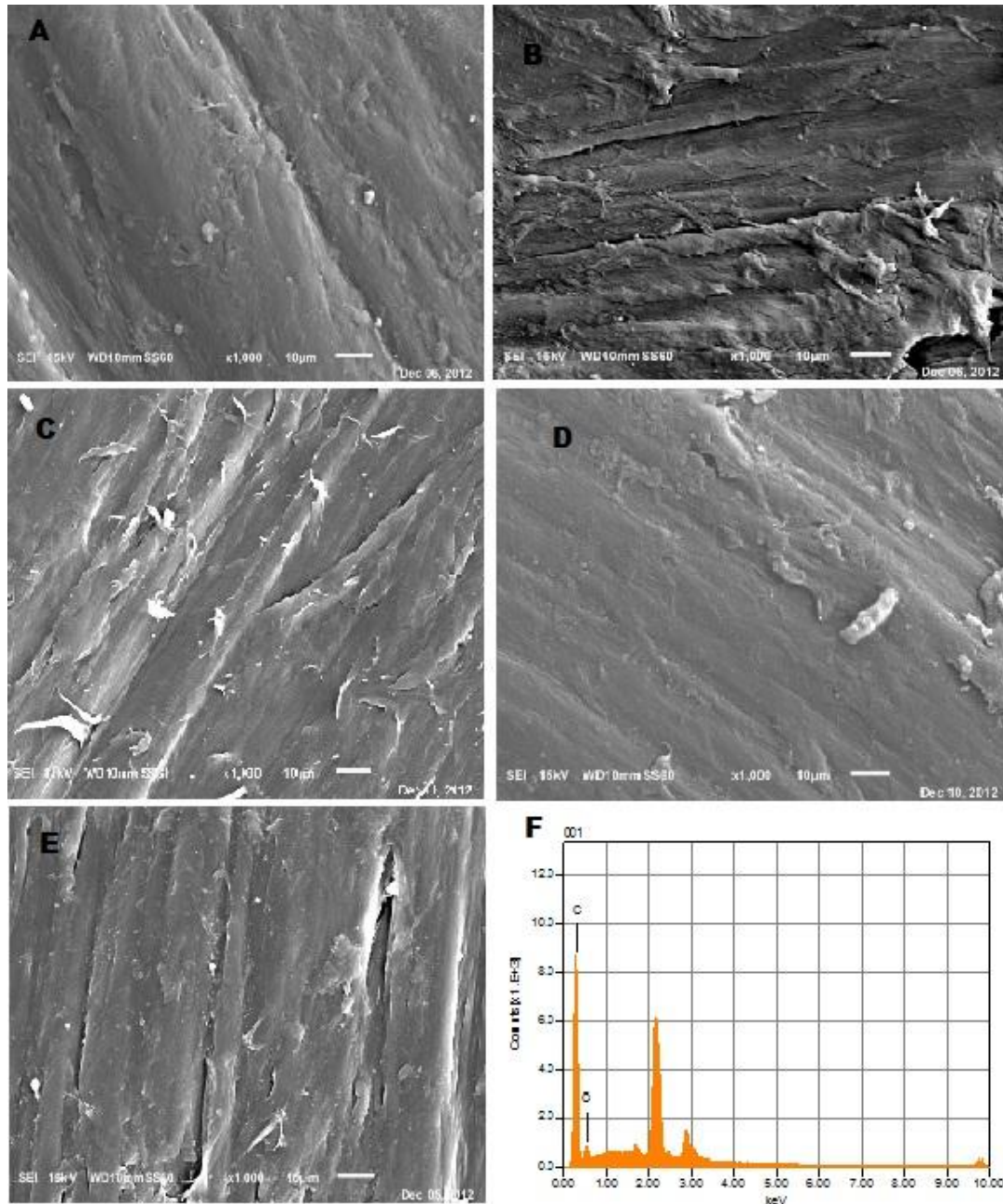


Fig 3: Water absorption behaviour of composites as a function of filler volume fraction and time of immersion

3.1.1 Microstructural characterisation

Fig 4 shows micrographs of the surfaces of composite sample using SEM with EDS, traverse section of prepared samples were viewed. Particles are well wetted by the polymer and the analysis clearly showed differences in microstructure of the composite produced by varying the wood particle content. The microstructure revealed that there were small discontinuities and a reasonably uniform distribution of wood particles in the LDPE

126 matrix. EDS analyses show that there are no chemical interfacial reactions between the wood
 127 particles and the LDPE. This was considered to be due to the processing temperature that
 128 was not high enough to cause any chemical reactions. The major elements revealed by the
 129 EDS are C (carbon) and O (oxygen). These elements are the major functional group in the
 130 wood particles.
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 134 **Fig 4: SEM micrographs of composites(A) 20%, (B) 30%, (C) 40%, (D) 50% (E) 60%, (F)**
 135 **EDS**
 136

4. CONCLUSION

This work relates to wood waste as a reinforcing filler in LDPE (Low density polyethylene). The wood particles that have high strength and high modulus coupled with good adhesion and uniform dispersion into the matrix material give the better mechanical properties compare to the unreinforced polymeric material. Microstructural studies have revealed that there is a good dispersion of the filler into the polymer matrix. Composite fabrication for a specific application requires the appropriate filler material and to include optimizing its content in the composite system.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration of all authors. Author MRO collected and performed all analyses, characterization, and wrote the first draft of the work. Author AOK managed the literature searches. Author MRO & AOK designed the study, managed the analyses of the work, Author IPE & UKO interpreted the results, corrected, and prepared the final manuscript. All authors read and approved the final manuscript.

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