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The Effect of Walnut Shell Powder on the Properties of Polypropylene Filled Composite

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Abstract

The effect of particle size and filler content on the mechanical and end-use properties of walnut shell powder filled polypropylene have been investigated at filler contents of 0 to 20 wt % and particle sizes of 0.100, 0.200, and 0.300mm. The polypropylene composites were melt-blended and homogenized in an injection moulding machine. Experimental results showed that for all the particle size of walnut shell powdered filler considered the tensile strength, elongation at break, and flexural strength of the polypropylene composites decreased with increase in walnut shell filler contents. However, the hardness and specific gravity of the composites were found to increase with increase in filler loadings and particle sizes. The water absorption properties of the composites as a function of filler content increased with increase in walnut shell filler content and also decreased with reduction in the particle sizes. The incorporation of walnut shell powder into the polypropylene was inefficient in reducing the flame propagation rate of polypropylene.
Keywords: Polypropylene, Composite, Mechanical and End-Use Properties, Walnut shell

Introduction

Fillers are the next materials in terms of volume that is required in the plastic industry apart from the base polymers. The most commonly used fillers in plastic industries are mineral fillers and natural fillers. Presently, natural fillers are being used as alternative to conventional mineral fillers in compounding of plastics so as to enhance the properties of the plastics and reduce the over dependent on the petroleum-based resources due to high rate of depletion of the natural resources [1]. In addition, to the overcome the other limitations associated with the use of mineral fillers (especially glass fiber, talc, asbestos, silica, mica, etc) in plastic industry which include; high cost, non biodegradable, loss of energy during processing, abrading of processing equipment, and increase in the density of composite systems, non renewable and abundant resource and its hazardous effect

to environment [2]. However, the disadvantages of the natural fillers are summarized as follow; degradation by moisture, poor surface adhesion to hydrophobic polymers, non-uniform filler sizes, not suitable for high temperature application, susceptibility to fungal and insect attack, etc [3].

Polypropylene is a commodity thermoplastic that offers a combination of outstanding physical, chemical, mechanical, thermal and electrical properties not found in any other

thermoplastic. It has a lower impact strength compared to low or high density polyethylene, but superior working temperature and tensile strength.

Polypropylene provides excellent resistance to organic solvents, degreasing agents and electrolytic attack. It has lower impact strength, but its working temperatures and tensile strength are superior to low or high density polyethylene. It is light in weight, resistant to staining, and has a low moisture absorption rate. It is a tough, heat-resistant, semi-rigid material, ideal for the transfer of hot liquids or gases, and is recommended for vacuum systems and where higher heats and pressures are encountered. It has excellent resistance to acids and alkaline, but poor resistance to aromatic, aliphatic and chlorinated solvents. Due to these outstanding properties, it is used in a wide variety of applications in the modern technology including packaging and labeling, textiles (e.g., ropes, thermal underwear and carpets), stationery, plastic parts and reusable containers of various types, laboratory equipment, loudspeakers, automotive components, and polymer banknotes [4]. This is as a result of excellent properties of the polypropylene. Many researchers have reported in the scientific literature the use different filler materials for making polypropylene composites. For instance, Jute [5], Kenaf [6], wood flour [7], rice husk [8], flax [9], graphite flakes [10], aluminium and magnesium hydroxide [11], calcium carbonate [12], mineral filler [13]. Walnut shell powder is a hard fibrous product made from crushed walnut shell. It is hard, chemically inert, non toxic and biodegradable. The use of walnut shell powder in filling polypropylene had not been reported in the scientific literature to our knowledge. Walnut shell is a domestic waste. This study focused on the effect of walnut shell powder content and particle size on the properties of polypropylene to exploit the potential of agro-based waste fiber in Nigeria as an alternative particulate material for the development of a new composite.

Materials and Methods

Materials

The polypropylene used in this study was obtained from Ceeplast Industry, Aba Abia State, Nigeria. It has a melt flow index of 2.5 - 3.5 g/min, and density, 0.926 g/cm^3. The walnut shell from which walnut shell powder was produced was collected locally from Onitsha metropolis, Anambra state, Nigeria. The walnut shell was properly treated to remove impurities before it was crushed and sieved to three particle sizes of 0.100, 0.200, and 0.300mm.

Preparation of Polypropylene/Walnut Shell Powder Composites

The polypropylene/walnut shell powder composites were prepared by proper and thorough mixing 200g of polypropylene with appropriate filler quantities (0, 5, 10, 15 and 20 wt%). Then, each of the composite constituent was melt-blended and homogenized together in an injection moulding machine. The resulting composite samples were produced and obtained as sheets.

Properties Testing

The tensile test measurements were determined using standard procedure (ASTM D 638) from which Tensile Strength, Elongation at Break, and Flexural Strength (ASTM D 790), Hardness, Shore D

(ASTM D 2240), Specific gravity (ASTM D 792), and Water Absorption, 24hrs (ISO 180) of the prepared polypropylene composites were determined using standard methods. A modification of ASTM D 4804 was used to determine the flame propagation rate behaviour of the polypropylene composites.

Results and Discussions

Tensile Strength

Figure 1 illustrates the effect of walnut shell powdered filler content on the tensile strength of the polypropylene composite. From the figure, it is observed however that for all the particle sizes of the filler investigated the tensile strength of the polypropylene composite decreased with increase in filler content. This shows the inability of the filler to support the transfer of the stress from matrix to filler particles during deformation. The behaviour could be attributed to poor interfacial adhesion between the filler and matrix, and agglomeration of the filler particles. This is because as the filler content increased, there is increase in the interfacial area which abridged interfacial bonding between filler particle (hydrophilic) and matrix polymer (hydrophobic) and thus decreased the tensile strength.

Elongation at Break

The effect of walnut shell powdered filler on the elongation property of filled polypropylene is as shown in Figure 2. It is seen from the figure that the elongation at break of the polypropylene composites decreased with increase in filler content at any given filler particle size considered. This could as a result of the poor interfacial bonding which cause partial separation of interfacial spaces between filler and polymer matrix, obstruct stress propagation when tensile stress is loaded, induce increased brittleness and decrease elongation at break. Hence, the elongation at break is a measure of the ductility of the material.

Flexural Strength

Data on the impact of walnut shell powdered filler content on the flexural strength of polypropylene composite is shown in From Figure 3. It is observed from the figure that flexural strength of the polypropylene composites decreased with increase in filler content and increased with decrease in filler particle sizes at any given filler particle size considered.

Hardness

Figure 4 shows the effect of walnut shell powdered filler content and particle size on the hardness of polypropylene composite. The figure shows that the hardness of all the polypropylene composite at a given filler particle size increased with increase in the amount of filler incorporated into the polymer matrix. The observation is an indication that walnut shell powdered filler enhanced the impact strength and abrasion or resistance to indentation of the composites. This is because the composite becomes stiffer and harder with increase in filler content which results to increase in composite hardness.

Specific Gravity

Figure 5 illustrates graphically the effect of walnut shell powdered filler on the specific gravity of polypropylene composite. The figure shows that there is a general increase in the specific gravity of the polypropylene composites with increase in filler content at any walnut shell powdered filler particle size considered. In addition, it is observed that

composites with smaller particle sized filler have higher specific gravity than composites with higher particle sized filler. This could be attributed to the better uniform dispersion and more packing of the smaller sized filler with the polymer matrix of the composite. Generally, the slight increase in specific gravity of the polypropylene composite is attributed to light weight of the walnut shell. The result is an indication that incorporation of walnut shell powder filler into the polypropylene matrix increased the density of the polypropylene composite since density has a relationship with specific gravity.

Water Absorption (cold water -24hrs)

The effect of walnut shell powdered filler content on the water absorption behaviour of polypropylene composites at different content of walnut shell powder is shown in Figure 6. All the polypropylene composites investigated show a similar pattern of water absorption uptake as observed from Figure 6. That is, for all given particle sizes of the walnut shell powdered filler examined the water absorption uptake increased with increase in the filler content. In addition, it is observed that as the particle size of the walnut shell powdered filler increased the water absorption uptake of the polymer composite increased. Walnut shell is a natural fibre and this behaviour is attributed to strong hydrophilic nature of the walnut shell with many hydroxyl groups in the fibre structure. The hydrophilic nature of walnut shell causes the water absorption of the lignocellulosic materials and results to the formation of hydrogen bonds between filler and water molecules on the cell wall of the filler. Similar observation has been reported by Husseinsyah and Mostapha (2011) in filling polyester system using coconut shell [14]

Flame Propagation Rate

The flame propagation rate behaviour of polypropylene filled walnut shell powder is illustrated graphically as shown in Figure 7. The figure shows that the burning rate behaviour of polypropylene composite increased with increase in filler content for all particle sizes investigated. It is observed that walnut shell powder is inefficient as filler in decreasing the rate of burning of polypropylene composite and good percentage of the contents of walnut shell fibre support combustion and so create environment that increase the flame spread of the composite. This behaviour could be as a result of the poor dispersion walnut shell powered filler within the polymer matrix and the inability of walnut shell powdered filler decrease the energy needed to initiate burning in the composite system.

Conclusion

The preparation of polymer composite using walnut shell powder and polypropylene matrix has been utilized successfully. It is observed that polypropylene/walnut shell powder composite general showed characteristic changes in properties. The density, water absorption and flame propagation rate showed gradual increment while tensile properties did not show remarkable improvement. Hence, it can be concluded that the polymer composite prepared with polypropylene and walnut shell powder is useful for low weight applications since density is slightly improved. In addition, the polymer composite should not be suitable for application where water absorption uptake is

critical factor. Furthermore, it is evident that decrease in tensile strength shows that adhesion between walnut shell powder and polypropylene matrix is of low order or poor. It is suggested that with the aid of a coupling agent the tensile strength of the composite can be enhanced.

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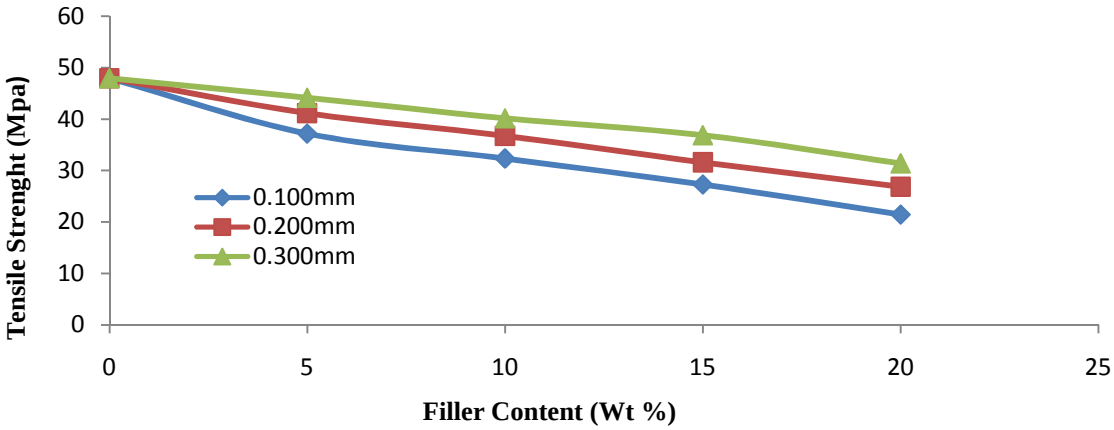

Figure 1: Plot of Tensile Strenght (MPa) Versus Filler Content (Wt %)

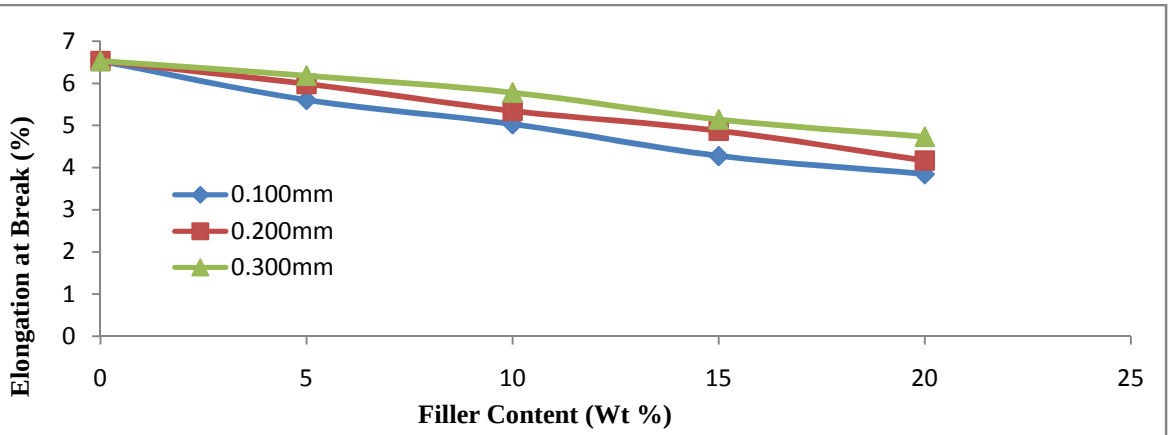

Fig 2: Plot of Elongation at Break (%) versus Filler Content (Wt %)

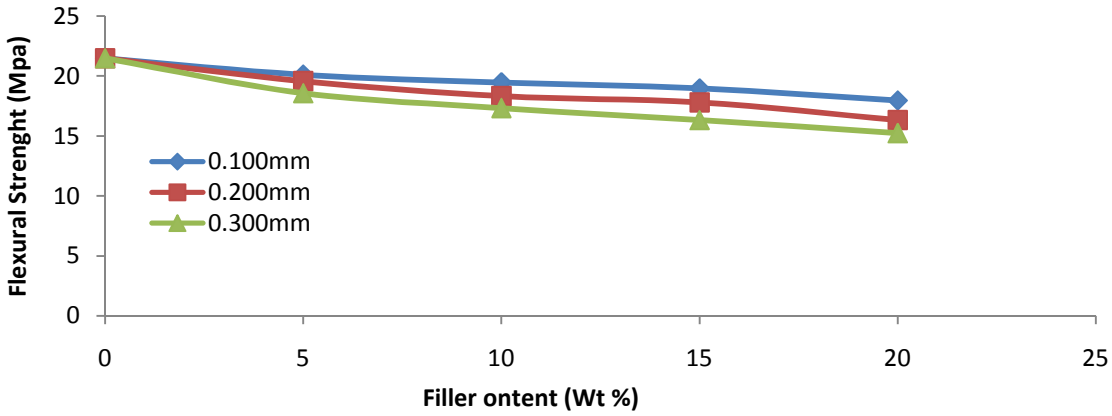

Fig 3: Plot of Flexural Strength (MPa) Versus Filler Content (Wt %)

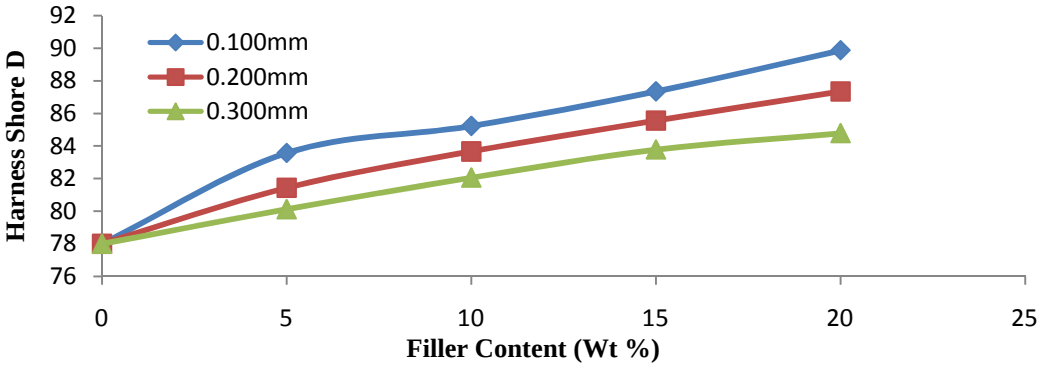

Fig 4: Plot of Hardness, Shore D versus Filler Content (Wt %)

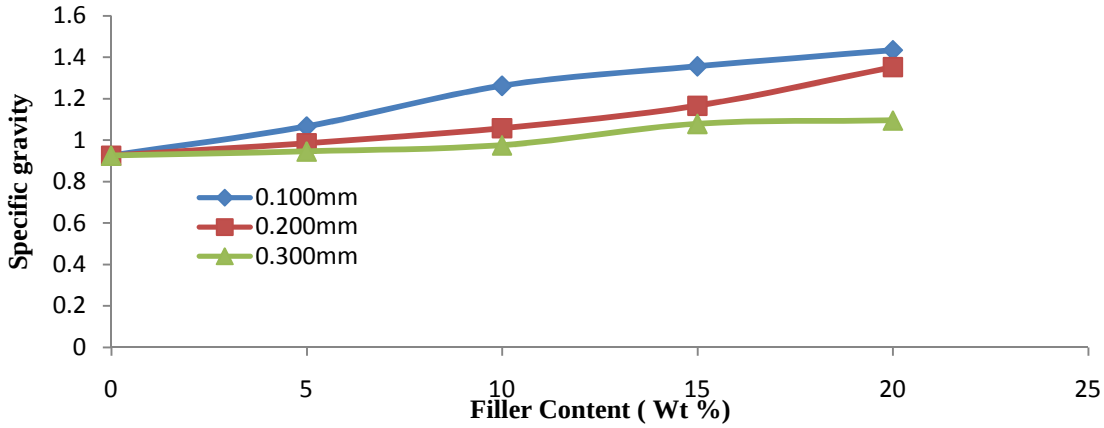

Figure 5: Plot of Specfic gravity Versus Filler Content (Wt %)

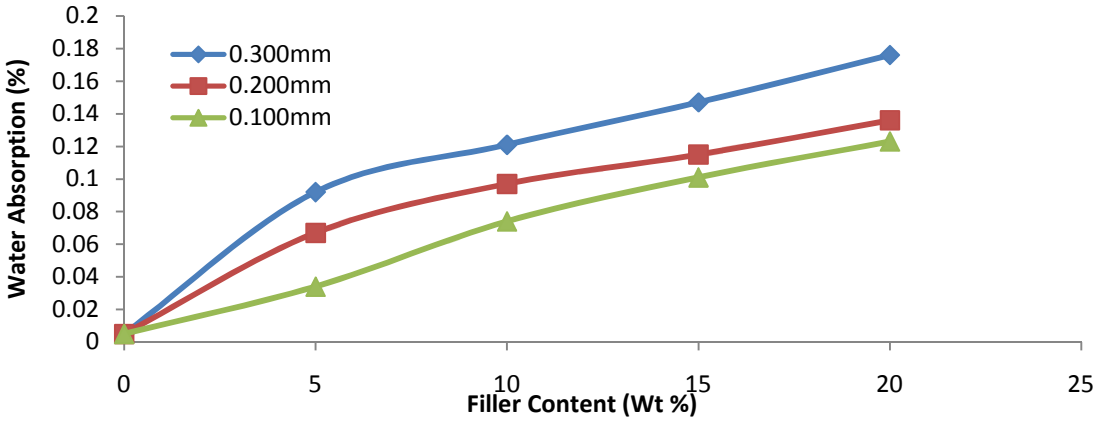

Figure 6: Plot of Water Absorption Versus Filler Content (Wt %)

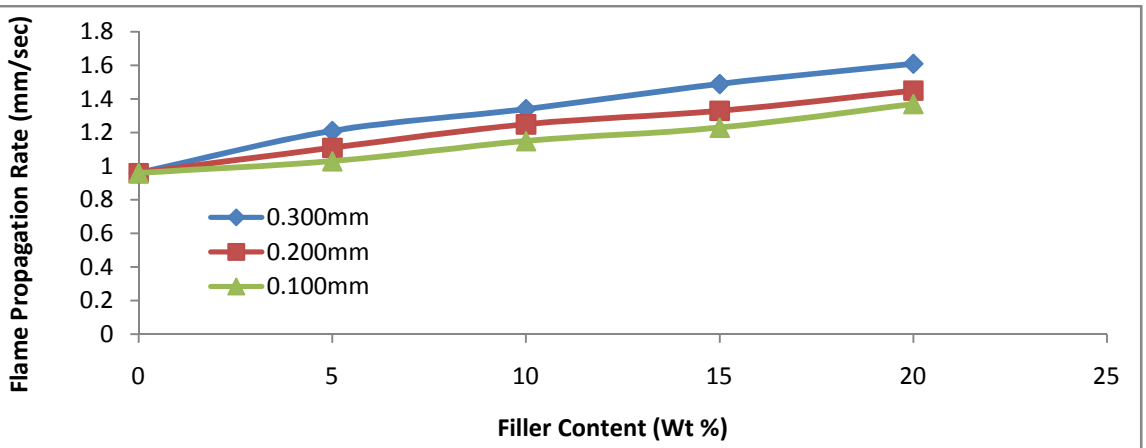

Fig 7: Plot of Flame Propagation Rate (mm/sec) Filler Content (Wt %)

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