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ORIGINAL ARTICLE

Empirical models for estimating the mechanical and morphological properties of recycled low density polyethylene/snail shell bio-composites

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Abstract The empirical models for estimating the mechanical properties and morphological of recycled low density polyethylene/snail shell bio-composites was investigated. The snail shell of particle sizes 75, 125, 250 and 500 μm with a weight percentage of 0, 5, 10 and 15 (wt%) with recycled polyethylene (RLDPE) were prepared by compounding and compressive moulding technique. Samples were cut from the panel and subjected to mechanical testing such as tensile, flexural and impact energy. Scanning electron microscope was used to analyse the fracture surface of the samples. Linear regression equation and analysis of variance (ANOVA) were employed to investigate the influence of process parameters on the mechanical properties of the samples. Results obtained showed that: as the wt% snail shell particles increased from 5 to 15, there was a raise in the tensile strength by (2.69) and the flexural strength (1.53). Also the increase in the snail shell particle size from 75 to 500 μm decreased the tensile strength by −5.46, flexural strength −3.97 and impact energy by −1.97. The predicted results obtained were in good agreement with the experimental results. Hence, the work can be used for indoor and outdoor structural applications.

1. Introduction

Composites material have become important engineering materials all over the world because of the unique properties they offer when compared with polymer, metals or alloys. As a result most research and development are focusing on the development of composite materials. Polymer composites have received the attention of researchers because of low strength, hardness and wear of plastics or polymer for most engineering applications. Polymer composites are now being used in both indoor and outdoor structural applications in housing, construction, auto-industry, aerospace etc.

Natural fillers in the form of fibres of particulate have gained the attention of researchers in recent time as reinforcing materials in polymers, metals and ceramics. They are eco-friendly, low cost, low density materials; they are renewable

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in a large amount when compared with the artificial fillers. Some of the previous studies on the use of natural fillers on the production of polymer composites are: Patricio et al. (2007) studied egg shell (ES) as a new bio-filler for polypropylene composites, water absorption and mechanical properties of high – density polyethylene/egg shell composite were studied by Hussein et al. (2011), the tribological behaviour of recycled low density polyethylene (RLDPE) polymer composites with bagasse ash particles as a reinforcement using a pin-on-disc wear rig under dry sliding conditions was reported by Aigbodion et al. (2012a), Atuanya et al. (2011) investigated the suitability of using recycled low density polyethylene (RLDPE) in wood composite board manufacture, Aigbodion et al. (2012b) studied high density polyethylene (HDPE) composite reinforced with 20 wt% orange peels ash particles and the effect of palm kernel shell on the microstructure and mechanical properties of recycled polyethylene (RLDPE) was reported by Agunsoye et al. (2012).

There are lots of snail shell and waste water sachet (recycled low density polyethylene) waste materials, these wastes constitute nuisance to the environment not only in Africa but the world at large. The ability to convert these wastes into useful engineering materials e.g. composites sharpens the focus of this present research work. From the available literature no investigation has been conducted on the application of the snail shell particles in polymer composite materials. A relationship between the mechanical properties of the polymer composites and the process parameters (particle sizes and weight percentage snail shell) will give a better understanding of the mechanical properties. Based on the above-mentioned situation, the study described in this work intends to study the empirical model for estimating mechanical properties of RLDPE composites reinforced with snail shell particles.

2. Materials and method

2.1. Materials

Pure water sachet (RLDPE) used were collected around the refused dump at the Faculty of Engineering, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria. The RLDPE was washed, dried and pulverized to particles. The snail shell used in this work was brown snail shell obtained from Snail restaurants in Sabongidda-Ora, Edo-State Nigeria. The Snail shell was washed with water and ethanol, sun dried to remove the residual organic matter.

2.2. Equipment

The equipment used for this research were: metal mould, sieves, digital weighing balance, hack saw grinding machine, hydraulic press, compounding machine, Compressive machine and housefield tensometer, scanning electron microscope (SEM).

2.3. Method

40 kg of the dried Snail shell were oven dried at 105 °C for 5 h until all the moisture was completely removed (Hassan et al., 2012; Atuanya et al., 2014). The dried Snail shell was charged into a Denver cone crusher and was reduced to a size of 4–3 mm wider and then charged into a roll crusher to reduce the size of snail shells to between 2 and 1 mm. The products from the roll crusher were transferred into a ball milling machine and were left in the mill for 2 h; after which they were transferred into a set of sieves: 500 μm, 250 μm, 125 μm and 75 μm sizes and were sieved for 30 min using a sieve shaker machine. JOEL JSM 5900LV Scanning Electron Microscope equipped with an Oxford INCA™ Energy Dispersive Spectroscopy system was used to determine the Snail shell particle microstructure.

The Snail shell particles were dried in oven (UNB 100–500) for 24 h at 150 °C to a moisture content of 0.5–1% (based on dry weight) before composite production (75 μm, 125 μm, 250 μm, 500 μm) and (0, 5, 10, 15 wt%) were compounded with recycled polyethylene using a co-rotating twin-screw extruder. The temperature used was 160 °C with screw speed of 50 rpm (Agunsoye et al., 2012). Finally, the mixed samples come out in bulk form. The crushing machine was used to crush into particle form. The composite compounded was fabricated into size of 150 mm × 150 mm × 6 mm. The used temperature was 160 °C with a pressure of 25 Ton for 10 min. Each of the plate was cut into desired dimension for sample testing. Before the test, the samples were conditioned for 24 h at 23 °C and at 50% relative humidity (Suresha and Chandramohan, 2004; Singha and Thakur, 2008).

The tensile test was determined in accordance with ASTMD638-10 Standard Test Method for Tensile Properties of Plastics. This test method covers the determination of the tensile strength of unreinforced and reinforced RLDPE in the form of standard dumbbell-shaped test specimens. The samples were aligned properly to prevent bending moment occur during test. The cross-head speed was 5 mm/min and the gauge length was 40 mm. Three samples were tested for each composition and a mean of these samples was taken for Young modulus and tensile strength.

Flexural strength of the three-point loading system applied to a simply supported beam was used. The samples were aligned properly to prevent error measurement during test. The flexural strength was determined in accordance with ASTM D790-10 Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials. The test was conducted with a cross-head speed of 5 mm/min and a gauge length of 100 mm. Three samples were tested for each composition and a mean of these samples was taken.

The Izod test method was used to study the sample impact energy in accordance with ASTMD256-10 Standard Test Methods for determining the Izod Pendulum Impact Resistance of Plastics. The sample with dimension 55 × 10 × 4 mm was notched and placed vertically (Izod) in a vice with the notch positioned central to the top of the vice facing the swing patch of the pendulum. The pendulum having a known energy, strikes the sample and the swing height of the pendulum after breaking the sample is measured and subtracted from the calibrated swing height. The result is the absorbed energy which can break the sample.

A full factorial design of experiments of the type P^n (Miller and Freund, 2001) was used in the study of the mechanical properties where n corresponds to the number of factors and P represents the number of levels. Here i.e.: n corresponds to the number of factors (Particle size and wt% snail shell