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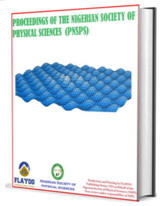

Compatibilizer impact on the mechanical properties of doum fiber reinforced polyester composite

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ABSTRACT

Natural fibers such as doum, jute, and hemp are emerging as alternatives to glass fibers for reinforcing polymer composites. However, the hydrophilic nature of natural fibers often leads to poor adhesion with hydrophobic polymer matrices. This results in inferior mechanical properties of the composites. This study aimed to investigate the effect of incorporating maleic anhydride (MA) as a compatibilizer on the hardness and tensile property of doum fiber-reinforced unsaturated polyester (UP) composites. MA as a compatibilizer has been used in a few studies and the good efficiency of MA was shown by the good interaction of maleic anhydride non-polar chain with the polymer matrix. Dom fibers were manually extracted and treated with a 5% NaOH solution. The UP resin was reinforced with 0.3-2.7 wt% untreated doum fibers and 0.3-2.7 wt% MA was added as the compatibilizer. The components were mixed thoroughly and cured by hand layup technique. Hardness was evaluated using a Vickers hardness tester. tensile tests were performed on an electronic universal testing machine to determine the tensile strength, elastic modulus, and elongation at break. Three (3) samples were tested for each composition and the results were averaged. Incorporating MA led to a significant increase of about 225 and 106% in hardness and tensile strength respectively compared to the control. Accordingly, the addition of MA improved the interfacial adhesion between the hydrophilic doum fibers and hydrophobic UP resin matrix, hence, improved the hardness and tensile property of the composites.

Keywords: Doum fibers, Compatibilizer, Maleic anhydride, Unsaturated polyester.

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1. INTRODUCTION

In recent years, there has been an increasing interest in sustainable and eco-friendly materials to replace traditional synthetic composites. Polyester has good strength, ductility, stiffness and hardness and so is one of the popular choices as base for a filled composite. Some of its applications include food trays for oven use, roasting bags, audio/video tapes as well as mechanical components [1]. Compatibilizers are substances or materials which contain reactive functional groups that overcome incompatibility between filler and matrix in a composite [2]. A few compatibilizers such as polyethylene-co-acrylic acid (EAA), polyethylene-co-glycidyl methacrylate (PEgMA) and maleic anhydride (MA) have been studied for the development of composites [3]. Additionally, the utilization of agricultural waste as a potential source

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for composite reinforcement materials has garnered attention due to its environmental benefits and the opportunity to create value-added products. Natural fiber-reinforced polymer composites have emerged as a potential environmentally friendly and cost-effective alternative to synthetic fiber-reinforced composites [4]. Therefore, in the past decade, several major industries, such as the automotive, construction, and packaging sectors, have shown considerable interest in the progress of new natural fiber-reinforced composite materials [5]. Research communal mostly accepts plant fibers due to the short span of its growing period, renewability, and full availability [6].

Vegetation and animals are the sources of natural fibers. Natural fiber is also extracted from Biomass and finite resource energy, such as oil palm, sisal, flax, and jute.

Doum fruits are cultivated worldwide for their nutritional value and economic significance. After the leaves of the tree fall or the tree dies, a considerable amount of waste, specifically the leaf fiber, is generated. Unfortunately, most of this agricultural residue is discarded, leading to environmental concerns such as pollution and landfill accumulation. As a sustainable approach, researchers have been exploring the potential of using doum fibers as a raw material in composite manufacturing, particularly in conjunction with thermoplastic.

2. EXPERIMENTAL METHODS

2.1. EXTRACTION OF FIBER

The doum fiber was extracted at the National Research Institute for Chemical Technology (NARICT). The doum fibers were extracted manually using the scraping method. A shaft knife was scratched against the doum leaves to remove the woody tissues from the fibers. The fibers were washed very well and dried. Subsequently, the dried fibers were combed to make them far apart.

2.2. FIBER SURFACE TREATMENT

To overcome difficulties in the dispersion of the fibers and increment of the water uptake by the fibers; surface modification on the doum fibers was carried out. Surface modification is highly likely to improve the interfacial adhesion of the filler and the matrix despite their different polarities [7]. Sodium hydroxide (NaOH) is the most commonly used chemical for cleaning cellulose fibers' surfaces. In Ref. [8], the authors reported the effectiveness of 5% NaOH solution in the treatment of Roystonea-regia fibers. Thus, a 5% NaOH solution is chosen for the present research. Two alkaline treatment solutions were prepared into separate bowls, with 5% (m/vol.) sodium hydroxide in distilled water. doum fibers (chopped to an advantage level of 1cm) then were soaked in an alkaline solution of 1900ml at a proposition of 10:1 i.e solution (550ml): fibers 55g), (for 4 hours at room temperature. Subsequently, the fibers were washed with distilled water (until the pH of the remaining wash solutions was 7.0), and then the fibers were exposed to dryness for three days.

2.3. PREPARATION OF UNSATURATED POLYESTER RESIN MATRIX AND DOUM FIBER-REINFORCED COMPOSITE

The fibers and the resins were weighed in grams using a weighing balance, a known amount of unsaturated polyester resin was poured into a plastic bowl, the chopped fiber was added to the resin and mixed to obtain a homogenous mixture, and the compatibilizer was directly added to increase the rate of bonding between the thermoset and the reinforcement, 2grams of peroxide and 2grams of curing agent were added to speed up the reaction and also to cure the samples quickly before the samples were poured in the glass mold, aluminum foil was placed in the glass mold and paraffin oil was added to aid in releasing the composite. After the composite had successfully cured, the samples were taken for cutting. The percentage composite of polyester resin and the doum fiber is given in Table 1.

Table 1. Composition of the sample in wt%.

	% Composition	
CONTROL	Unsaturated Polyester	100
	Maliec anhydride	0
	Doum fiber	0
SAMPLE 1	Unsaturated Polyester	97
	Maliec anhydride	0.1
	Doum fiber	2.9
SAMPLE 2	Unsaturated Polyester	97
	Maliec anhydride	0.2
	Doum fiber	2.8
SAMPLE 3	Unsaturated Polyester	97
	Maliec anhydride	0.3
	Doum fiber	2.7
SAMPLE 4	Unsaturated Polyester	97
	Maliec anhydride	0.4
	Doum fiber	2.6
SAMPLE 5	Unsaturated Polyester	97
	Maliec anhydride	0.5
	Doum fiber	2.5

2.4. MECHANICAL TESTS

The study of the reinforced composite's mechanical properties, such as hardness and tensile performance, was conducted according to ASTM standards.

2.5. HARDNESS VALUE DETERMINATION

Indentec universal testing machine was used to determine the hardness value of the six (6) samples. The samples were prepared according to the provisions in the ASTM E18-79 standard. The sample for the hardness test was prepared. it was polished to achieve a flat surface finish. Hardness tests were performed by taking an average of three (3) readings for each sample.

2.6. TENSILE PROPERTIES DETERMINATION

The reinforced specimen's tensile properties were determined using an electronic universal testing machine, with serial number 190536. The experiment was carried out in the materials testing laboratory of the metallurgical and Materials Engineering Department of Ahmadu Bello University (ABU), Zaria. The samples were molded to (ASTM D 638) standard. The tensile strength was automatically obtained directly from the machine screen. Each experiment was conducted three times and recorded.

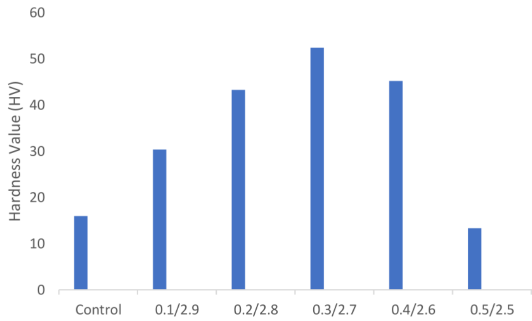

Figure 1. The hardness behaviour of doum-reinforced polyester composites with fiber/compatibilizer additions.

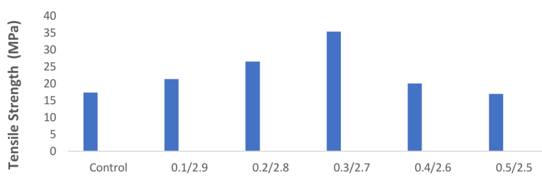

Figure 2. The tensile strength of doum-reinforced polyester composites with fiber/compatibilizer additions.

3. RESULTS AND DISCUSSIONS

3.1. HARDNESS

Figure 1 shows the effect of fiber loading and maleic compatibilizer addition on the hardness value of the doum-reinforced composite. The test result shows that the [0.1/2.7] exhibited the lowest hardness values of 13.30 HV. It can also be seen that the hardness values of the reinforced composites increase about 225% with an increase in fiber loading with the highest value at (0.3/2.7) at 52.43Hv. Whereas, the hardness property increases with decreasing addition of the coupling agent (compatibilizer). The increase in hardness value observed as the coupling agent decreased could be a result of qualitative interfacial adhesion between the doum filler and the polymer matrix. Notwithstanding, the decline could be due to phases separation at higher fiber addition. Likewise, in Ref. [9], the authors observed that the increasing of the maleated polyethylene (compatibilizer) content resulted in better interfacial adhesion between the fiber and the polymer matrix.

3.2. TENSILE PROPERTIES

Figure 2 shows the effect of fiber loading and maleic compatibilizer addition on the tensile strength of the doum-reinforced composite. The test result shows that the control (unreinforced polyester) exhibits a lower tensile strength of 17.39MPa. It can also be seen that the tensile strength of the reinforced composites increases with an increase in fiber loading; for 0.1/2.9,0.2/2.8 and 0.3/2.7. A considerable increase of roughly 106% at 0.3/2.7 fiber loading. However, a significant decrease for 0.4/2.6 and 0.5/2.5 is noted. Similarly, in Ref. [10], the authors revealed that addition of compatibilizer or plasticizer improved the interfacial adhesion between the matrix and the filler, hence, improved the tensile properties of a composite. Nevertheless, the decline could be link to phases separation at higher fiber content.

4. CONCLUSION

In this study, the hardness and tensile properties of doum fiber-reinforced polyester composites were evaluated and the result and discussion were presented. The following conclusions can be drawn from the study:

i. Incorporating Maleic Anhydride (MA) significantly increases the hardness (52.43 Hv) and tensile strength (35.38 MPa) compared to the control, indicating increased fiber-matrix adhesion.
ii. The hardness and tensile strength all increase progressively with Maleic Anhydride (MA) content up to an optimal level of (0.3wt%).
iii. Higher Maleic Anhydride (MA) levels in the composite caused deterioration in the mechanical performance.
iv. Analysis such as fracture toughness analysis and microstructural examination is recommended for future work in order to assess the impact of the Maleic Anhydride (MA) on the composites.

DATA AVAILABILITY

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