Effect of Bagasse Fibre Reinforcement on the Mechanical Properties of Polyester Composites

Isiaka Oluwole Oladele

Department of Metallurgical and Materials Engineering, Federal University of Technology, Akure, Ondo State. Nigeria
E-mail: wolesuccess2000@yahoo.com

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Abstract: The use of natural fibres for the reinforcement of polymers intended for different applications has been on the increase in recent years due to its advantages. In this study, bagasse/sugarcane (Saccharum officinarum) fibre was used to reinforce unsaturated polyester material in order to assess the viability of the composite materials developed for engineering applications. Sugarcane fibres gotten from the farm plantation were purified by washing thoroughly with water followed by sun drying and pulverizing. The particles were then sieved into 75 µm and added to the polyester in predetermined proportions of 5, 10, 15 and 20 weight percent (wt%) for the production of the composites. Mechanical tests (tensile and hardness) were carried out on the samples from where it was observed that the reinforcement was able to enhance the mechanical properties of the developed composites with a verge point value of 10 wt% reinforcement.

Keywords: Bagasse fibre; particulate; reinforcement; unsaturated polyester; mechanical properties

1. Introduction

A fibre-reinforced polymer (FRP) is a composite material consisting of a polymer matrix imbedded with high-strength fibres, such as glass, aramid and carbon (Groover, 2004). Generally, polymer can be classified into two classes, thermoplastics and thermosettings. Thermoplastic materials currently dominate, as matrices for bio-fibres; the most commonly used thermoplastics for this purpose are polypropylene (PP), polyethylene, and poly vinyl chloride (PVC); while phenolic, epoxy and polyester resins are the most commonly used thermosetting matrices (Malkapuram, et al., 2008). In the recent decades, natural fibres as an alternative reinforcement in polymer composites have attracted the attention of many researchers and scientists due to their advantages over conventional glass and carbon fibres.

Polyester is classified in the group of general purpose thermoset which are characterised by having average mechanical properties, lower resistance to temperature, higher coefficients of expansion and low cost/commodity-like production and sales. The overall cost can be reduced either by finding a less expensive processing method or by blending the polymer with low cost filler materials. In order to improve the mechanical, physical and other properties, or to tailor a composite for a specific use or to facilitate processing and reducing the cost, natural fibres have been used as reinforcing or filler materials. The advantages of plant fibers are low cost, low density, acceptable specific strength, good thermal insulation properties, reduced tool wear, reduced respiratory irritation, renewable resource and recycling possible without affecting the environment (Husseinsyah and Mostapha, 2011). Fibres of this type, for instance, hemp and flax, are successfully used as packaging material, interior panels in vehicles, and building components, among others.

Moreover, natural fibres like banana, sisal, hemp and flax, jute, coconut, sponges, bamboo, wood dusts and oil palm (Idicula et al., 2005; Jacob et al., 2004; Hautala et al., 2004; Chand and Dwivedi, 2006; Brahmakumar, et al., 2005; Oladele and Adewuyi, 2008) have attracted scientists and technologists for applications in consumer goods, low-cost housing and other civil structures. A number of investigations have also been conducted on several types of natural fibres to study the effect of these fibres on the mechanical properties of polyester matrix composite materials. EL-Tayeb (2008) studied the effect of untreated short bagasse fibre reinforcement on the abrasive wear performance of polyester and the result revealed that wear of SCRP composite was sensitive to variations of load, fibre length and fibre orientation and less sensitive to sliding velocity.

Husseinsyah and Mostapha, (2011) investigated into the effect of filler content on properties of coconut shell filled polyester composites, and the results revealed that increase in coconut shell content led to the increase on tensile strength, Young’s modulus and the water absorption. Oladele, (2013) investigated the effect of bone ash and bone particulate reinforced polyester composites for biomedical applications and established that the tensile and flexural properties were enhanced. Fibre-filled commodity thermoplastics were first introduced into the market with the intention of producing a range of new materials for lightly stressed engineering applications (Brahmakumar, et al., 2005).

Recently, natural fibres have proved to be effective...
reinforcement as simple fillers in thermoplastic and thermoset matrix composites for automotive sectors (EL-Tayeb, 2008). This work was carried out to investigate the effect of bagasse/sugarcane fibre particle addition on the mechanical properties of unsaturated polyester material. Bagasse fibres are usually regarded as agricultural waste after the extraction of the sugar content. However, they are now being utilised for engineering application in this work so as to turn waste to wealth.

2. Materials and Methods

The main materials that were used for this work are as follows; unsaturated polyester resin procured from Pascal Chemical store in Akure, Ondo State, Nigeria.

The starting material for a thermo set polyester matrix is an unsaturated polyester resin that contains a number of C = C double bonds. Unsaturated polyesters refer to that family of polyesters in which the backbone consists of alkyl thermosetting resins characterised by vinyl instauration as a result of these structure, they are highly reactive. Bagasse/sugarcane (Saccharum officinarum) Fibre with its constituent as shown in Table 1, Ethyl Ketone Peroxide (MEKP) was used as the catalyst, Cobalt 2% in solution was used as the accelerator, polyvinyl acetate was used as the mould releasing agent and ethanol as a cleaning/washing agent.

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Amount (%)</th>
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<tbody>
<tr>
<td>Moisture</td>
<td>49.0</td>
</tr>
<tr>
<td>Fibre</td>
<td>48.7</td>
</tr>
<tr>
<td>Soluble Solids</td>
<td>2.3</td>
</tr>
<tr>
<td>Cellulose</td>
<td>41.8</td>
</tr>
<tr>
<td>Hemicelluloses</td>
<td>28.0</td>
</tr>
<tr>
<td>Lignin</td>
<td>21.8</td>
</tr>
</tbody>
</table>

2.1 Material Preparation

Sugarcane plant that was grown for one and half years was used in this work. The bagasse fibre after the extraction of the sugar content was procured from the farm plantation. The fibres were washed with water so as to remove both excess sugar and dirty particle that might have stick to the fibres and sundried for 4 weeks before pulverizing using Denver laboratory ball mill. The particles from the process were sieved with sieve shaker 16155 Model into 75µm sieve size.

2.2 Mould Production

Tensile mould of gauge length 25 mm of a dumb-bell shape was used for the production of tensile samples.

2.3 Production of Composites

To develop the composites, 1g each of catalyst and accelerator was added to 100g of the unsaturated polyester resin. The bagasse in the particulate form was varied in a predetermined proportion of 5, 10, 15 and 20 weight percent (wt%), respectively. The mixture was stirred for about 5-7 minutes until there is proper wetting and soaking of the particles by the polyester resin. The homogenous slurry is poured into the mould and allowed to cure at room temperature before it is removed. The curing rate for each sample was taking and recorded before they are stripped from the mould. The stripped samples were allowed to cure further at room temperature in the laboratory for 28 days before the mechanical tests were carried out.

2.4 Mechanical Testing of Cast Samples

Following the moulding of the composites, samples were prepared for tensile and hardness tests. These tests were carried out as follows:

1) Determination of the tensile properties of the materials

In the present study, tensile tests were performed on INSTRON 1195 at a fixed Crosshead speed of 10 mm min⁻¹. Samples were prepared according to ASTM D412 (ASTM D412 1983), and tensile strength of the standard and conditioned samples were calculated.

2) Determination of the hardness property of the materials

The samples were indented using micro hardness tester following ASTM procedure No.D2240. The reading is noted from the calibrated scale. Five readings were taking for each sample and the average value was used.

3. Results and Discussion

Figure 1 shows the result of the ultimate tensile strength (UTS) property for the various samples produced. It was observed from the results that the UTS increases as the fibre weight content increases up to a threshold point of 10 wt% before experiencing depreciation. This is essentially likely to happen because as the fibre content increases, the tendency for the fibre/matrix bonding strength to decrease is high. As shown, 5-10 wt% reinforcement gave better results than 15-20 wt% because at low fibre content, the bagasse fibres are wetted properly by the polyester and there is little or no fibre touching one another.

![Figure 1. Variation of the Ultimate Tensile Strength against Fibre Weight Content](image-url)
However, at higher fibre content, the reverse was the case, the fibres are touching one another thereby reducing proper fibre wetting and bonding between the bagasse fibre and the polyester matrix. This actually leads to the reduction of the strength of the composites at this higher fibre content. The results show that the unsaturated polyester matrix had a value of 10.01 N/mm² while sample with 10 wt% had 23.68 N/mm².

The result of the effect of fibre content on the tensile modulus was shown in Figure 2 where similar trend to that of the UTS was observed. However, there is slight different in the trend as the modulus for the 15 wt% bagasse reinforced sample has higher value than the 5 wt% reinforced sample. The tensile modulus for 10 wt% reinforced sample emerges as the best with a value of 913.73 N/mm² compared to unreinforced polyester matrix with a value of 318.30 N/mm².

Figure 3 shows the tensile strain result. It was observed that the unreinforced polyester material has the highest tensile strain property of 3.72 % followed by 5 wt% fibre content reinforced sample with a value of 1.39 %. It was observed that the tensile strain property reduces as the fibre content increases from 5-20 wt%. The sugarcane fibres have provide reinforcement effect in polyester matrix because the stiffer the material, the greater the strength and modulus as revealed in Figures 1 and 2, and hence the lower the tensile strain.

4. Conclusion

The result shows that 5-10 wt% reinforced samples gave the best hardness property where the 10 wt% reinforced sample marginally exceed 5 wt% reinforced sample with values of 75.51 MPa and 72.57 MPa respectively compared to the unreinforced polyester matrix with a value of 30.40 MPa. Enhancement of mechanical properties was possible due to adequate wetting and bonding between the sugarcane fibre and the polyester. This was in agreement with the work of El-Tayeb, (2008). It was noticed that microscopic observation evidenced that sugarcane fibre (SCF) has the ability to have a fairly good bonding with polyester matrix. This in turn made the separation of fibre from the composite more difficult, and also contributed to improvement of wear resistance for chopped bagasse/polyester composite.

Figure 5 shows the variation of curing time with the samples. From the results, it was observed that curing rate increases as the fibre content increases. Curing rate is a parameter that can determine and influence the rate of production. The result shows the addition of bagasse fibre brings about rapid curing, and hence save time and resources compared to the unreinforced polyester. While it takes 1 hour for 15-20 wt% fibre content sample to cure, it takes 24 hours for the unreinforced sample. Sample with 10 wt% fibre content displayed best mechanical properties. It takes 2 hours to cure which is also commendable.

The use of bagasse/sugarcane fibre particles as reinforcement in unsaturated polyester matrix brings about
improvement in the mechanical properties. Hence, by investigating the effect of bagasse fibre addition on the mechanical properties of unsaturated polyester material, it was interesting to note that the reinforcement yielded several promising results. These are:

1) There is enhancement in the mechanical properties of the reinforced polyester composites up to threshold point of 10 wt% bagasse fibre loading.

2) Bagasse particulate fibre in the range of 5-10 wt% gave the optimum results which show that low fibre weight content is good for better enhancement of properties.

3) Curing rate increases as the bagasse fibre content increases which implies that, curing rate for polyester material is improved by the addition of bagasse fibre thereby leading to increased production rate.

References:


Author’s Biographical Notes:
Isiaka Oluwole Oladele obtained Masters and PhD in the area of natural fibre reinforced polymer composites from the Department of Metallurgical and Materials Engineering, Federal University of Technology, Akure, Ondo State, Nigeria. Dr. Oladele has supervised many undergraduates and postgraduates research and has published in both local and international journals and conference proceedings in this area.