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EFFECTS OF SUGARCANE BAGASSE FIBERS ON THE MECHANICAL BEHAVIOUR OF HIGH DENSITY POLYETHYLENE

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Abstract

The effect of sugarcane bagasse fibers (10, 20, 30, 40%) on the mechanical behaviour of high density polyethylene (HDPE) was investigated. The sugarcane bagasse fibers were alkali-treated in 5% of sodium hydroxide solution, before compounded with HDPE matrix via hot pressing technique. The bagasse/HDPE composites were appraised to determine the tensile strength, flexural modulus, hardness and percentage elongation. The results showed a decreased in the tensile strength and elasticity with the addition of bagasse fiber in HDPE. The morphology of the composites showed clustering of the fibers in the polymer matrix and to some degree, weak adhesion between bagasse fibers and HDPE matrix was evident. The study revealed that 20% and 30% of bagasse/HDPE exhibited improved hardness (106 HRR) and flexural modulus (2.6 GPa) when compared to fiber-free HDPE matrix.

Keywords: Polymer composite, Sugarcane bagasse fiber, Tensile properties.

1. Introduction

The use of natural fibers as reinforcements in polymer composites have been extensively used in numerous industries such as electronics, aerospace, automotive, marine, packaging and construction, owing to their low cost, eco-friendly, low density, high specific strength and biodegradability [1-3]. High density polyethylene (HDPE) is a thermoplastics polymer matrix that has high rigidity, strength and improved creep behaviour [4]. Typical natural fibers such as kenaf, jute, sisal and sugarcane bagasse are generally used as reinforcements to produce natural fibers/polymer composites [1]. In particular, sugarcane bagasse is a widely available agricultural residue, where the fibrous residue of cane stalks is retrieved after juice extraction from the sugarcane [5]. Sugarcane bagasse contains about 50% of cellulose, 25% of hemicellulose and 20% of lignin [2]. Owing to its constitution, bagasse fiber reinforced composites often resulted in better mechanical properties [1].

One of the limitations of natural reinforcements are their sensitivity to heat during processing, low thermal stability and low compatibility with matrix. Alkali treatment was subsequently introduced, where the fibers were alkali-treated in 0.03-40 wt% sodium hydroxide (NaOH) solution [3, 6]. Besides, this method was found to increase the strength and stiffness of the overall fibers/matrix composites. Typically, alkali treatment removes amorphous components and waxes from the fibers' surface which modified the surface roughness, thus improved the compatibility between the fiber and matrix [6-8]. Specifically, one of the studies reported that the tensile strength of bagasse fiber was greatly enhanced with alkali treatment of 5-8 wt.% NaOH. Besides, a slight improvement in the stiffness was also evidenced when 2-4 wt.% NaOH was treated on the bagasse fiber [6]. This observation is consistent with a finding where the tensile strength of bagasse fiber was increased from 96.2 to 156.9 MPa after alkali-treated with 1% NaOH [1].

Cao et al. [7] demonstrated that alkali-treated bagasse/polyester composites had successfully improved tensile strength, flexural strength and flexural modulus by about 10-15%, if compared with the untreated composites. Besides, these mechanical properties were found to improve with the addition of bagasse fiber content (20, 35, 50, 65 wt%) [7]. The increase of tensile strength and modulus was also evidenced with the additions of 10-20 vol% of alkali-treated fiber content in polyester matrix [9]. However, a reduction in tensile strength was identified despite an increase in tensile modulus when 10, 20 and 30 wt% of bagasse fiber were added in recycled HDPE [10]. In another research, the tensile strength was found to be remained at about 8-9 MPa, regardless of bagasse fibers content (10, 20, 30, 40, 50 wt%) reinforced in recycled low density polyethylene (LDPE) [11]. Based on the literature, 5% of NaOH was selected in the present work as the alkali treatment content for sugarcane bagasse fibers. The present work investigates the influence of sugarcane bagasse fibers in amounts varying from 10, 20, 30 to 40% on the mechanical behaviour of HDPE.

2. Methods and Materials

The as-received HDPE was in the pellet form and the sugarcane bagasse fibers were collected from a local source, scraped and cut into smaller sizes. The bagasse fibers were soaked in 5% NaOH solution and stirred for half an hour. The fibers were then rinsed with distilled water to remove the NaOH solution and dried in an oven

at 108 °C for 24 h. This was followed by grinding using a rotor mill and sieve shaker to produce fiber powders. Varying amounts of fibers (10, 20, 30 and 40%) were mixed with the HDPE by an internal/extruder mixer (HAAKE PolyLab Rheodrive 16 OS) at 200 °C. Finally, the resulting solid mixtures were crushed (TW-SC-400F) and stored in sealed coffee bag envelopes.

The bagasse/HDPE composites were prepared by hot-pressing technique, with prescribed composition of the matrix and filler materials that placed into the mould. A steel mould was designed with two stainless steel plates that positioned on the top and the bottom of the mould, to ensure no direct contact between the melted blend and the mould. The mould was preheated at 205 °C and kept for 12 min. at the upper section of the plate. The mould was then transferred to the lower section of the hydraulic hot moulding, where the temperature was increased to 220 °C and hot pressed at 5 MPa for 15 min. The compacted composite sample was removed from the mould once cooled to ambient temperature.

Tensile test was carried out for all the composite samples (250 × 25 × 2.5 mm) using a universal tensile testing machine (Shimadzu AG-1), according to ASTM D3039 specification. A load cell capacity of 100 kN was applied to each sample and subjected to a fixed strain rate, until failure, at a cross speed of 2 mm/min. Tensile modulus and tensile strength were then calculated. The changes in gauge length for each sample were measured using a vernier calliper, before and after the failure. Flexural test was also performed on all the composite samples (80 × 12.5 × 3 mm), with a load range of 500 N and a crosshead speed 1 mm/min. The hardness of the composite samples was then determined by a Rockwell hardness machine (Mitutoyo Wizhard), with a load of 15 kg according to ASTM D785 standard. The morphology of the fibre-matrix composites was examined using a scanning electron microscope (SEM, JEOL JSM5310).

3. Results and Discussion

The effect of bagasse fibers additions on the tensile strength and tensile modulus of HDPE composites are shown in Fig. 1. It was noticed that these tensile properties decrease with the increase in bagasse fiber content in HDPE. The tensile strength of HDPE was substantially reduced from 21.8 MPa (fiber-free HDPE) to 13 MPa for 10% bagasse/HDPE composite. Similarly, the tensile modulus experienced a sharp decrease of about 48%, from 522.3 MPa (fiber-free HDPE) to 271 MPa (10% bagasse/HDPE composite). As fibers played a major role in determining the overall strength and stiffness of composite materials, the abrupt decrease in tensile properties could be due to inferior physical characteristics of the as-received sugarcane bagasse [12]. The high-pressure sugarcane juice extraction process was deemed to degrade the physical characteristic of the bagasse fibers, if compared to other types of natural fibers [13]. Besides, it was also envisaged that the incorporation of bagasse created void in the matrix and led to the deterioration of tensile strength, where a research reported that bagasse/polyester composites often possessed high porosity (~7.6%) [13]. Furthermore, the low tensile properties could be caused by the weak interaction between the bagasse fibers and HDPE matrix [14].

In terms of elasticity, Fig. 2 shows a significant reduction in the percentage elongation with increasing fiber content. The percentage elongation was less than 2.5% for all the bagasse/HDPE composites as compared to 32% measured for the fiber-free HDPE, thus indicating the low elasticity of bagasse/HDPE composites.

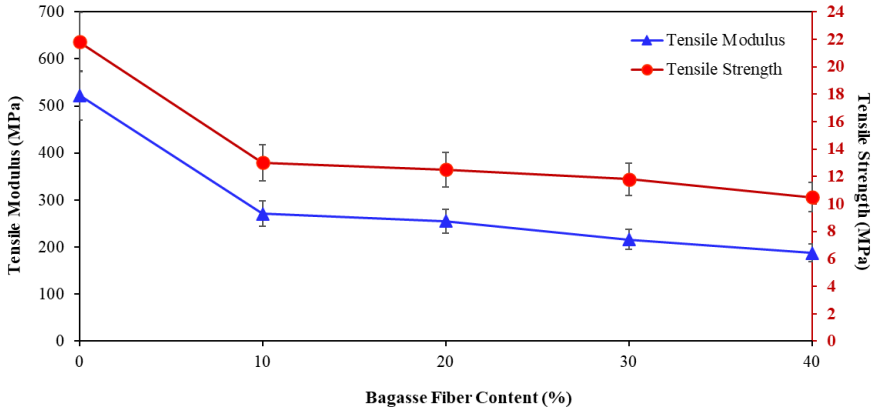

Fig. 1. Effect of sugarcane bagasse fibers on the tensile properties of HDPE.

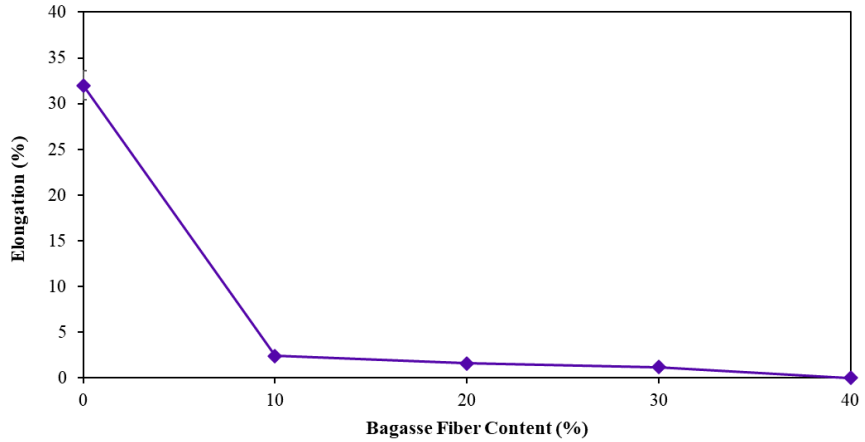

Fig. 2. Variation in percentage elongation of the composites as a function of fiber content.

A similar observation was reported by El-Fattah et al. [10] where an abrupt decreased in the composite elongation was evident with the addition of 10, 20 and 30 wt% bagasse fibers in HDPE. The variation in Rockwell hardness of HDPE matrix and bagasse/HDPE composites is shown in Fig. 3, which fluctuated between 101.5 and 106.5 HRR. The 20% bagasse/HDPE composites recorded the highest hardness of 106.5 HRR, followed by 106 HRR for 30% bagasse/HDPE composites. Figure 4 shows the effect of bagasse fibers on the flexural modulus of HDPE. The addition of bagasse was beneficial in enhancing the flexural modulus of HDPE. The flexural modulus of HDPE has been improved from 1.52 to 2.07 GPa when 10% bagasse was added in the HDPE matrix. The flexural modulus maintained at about 2.6 GPa for 20 and 30% bagasse/HDPE composites, before surged up to about 4 GPa for 40% bagasse/HDPE composite. This behaviour concurs with the finding of Mulinari et al. [2] who reported that higher flexural modulus and inferior tensile properties were obtained for 10 wt% bagasse/HDPE composites as compared to fiber-free HDPE. The present results revealed that 20 and 30% alkali-treated bagasse fibers generally improve the hardness and stiffness of HDPE matrix despite their lower tensile properties.

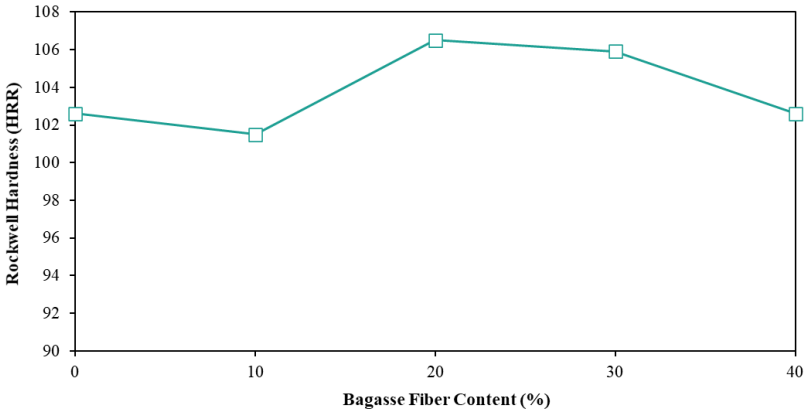

Fig. 3. Variation of Rockwell hardness of HDPE with different bagasse fiber content.

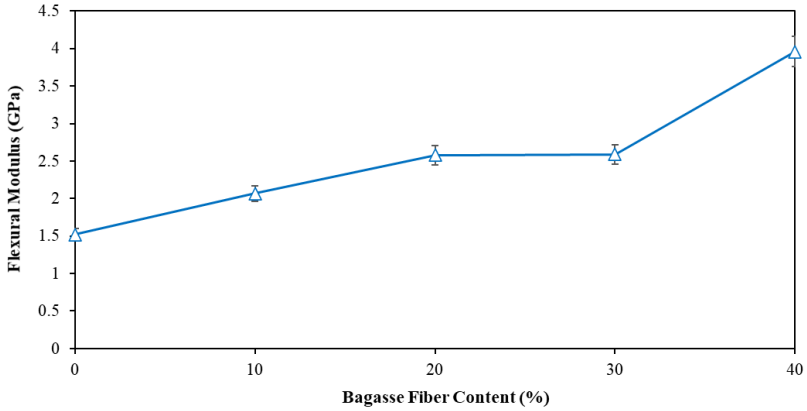

Fig. 4. Variation in the flexural modulus of the composites as a function of fiber content.

The cross-section morphology of the fiber-free HDPE matrix and bagasse/HDPE composites are shown in Figs. 5 and 6, respectively. The fiber-free HDPE possessed a smooth surface after hot pressing and exhibited no visible cracks (Fig. 5). On the other hand, agglomeration of fibers as well as the presences of week adhesion between the fibers and the HDPE matrix were observed for all composites as shown in Fig. 6. The agglomerations of bagasse fibers is believed to be responsible for the lower tensile properties of the composites.

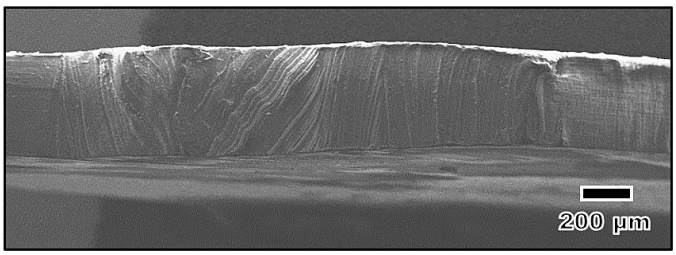

Fig. 5. Cross-sectional view of the fiber-free HDPE sample.

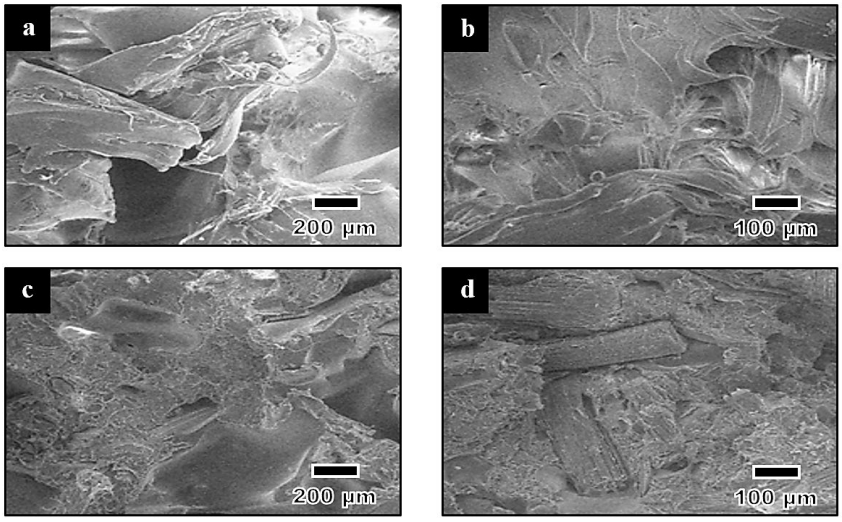

Fig. 6. SEM micrographs showing the cross-section of: (a) 10% (b) 20% (c) 30% and (d) 40% bagasse/HDPE composites.

4. Conclusions

The effect of different amount of treated sugarcane bagasse fibers on the mechanical behaviour of HDPE was evaluated and compared with the fiber-free HDPE. It was found that the incorporation of 10 to 40% bagasse fibers demonstrated a mix effect on the mechanical properties of the composites. It was found that the incorporation of bagasse fibers led to inferior tensile properties, low elasticity and weak adhesion between the fibers and the HDPE matrix. Nevertheless, the addition of 20% and 30% bagasse/HDPE composites was found to improve the flexural modulus and Rockwell hardness when compared to the fiber-free HDPE.

Abbreviations

HDPE	High Density Polyethylene
HRR	Rockwell Hardness
NaOH	Sodium Hydroxide
SEM	Scanning Electron Microscope

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