Effect of the Fibers Amount and Their Length on the Thickness and Strength of Green Composites Sugarcane-Polypropylene

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ABSTRACT

Sugarcane fiber has been studied as a potential reinforced fibers to develop green composites of sugarcane fibers-polypropylene (PP). In this study, sugarcane fibers were alkali treated with 10% v/v NaOH solution for 2 hours. Sugarcane fibers added to polypropylene matrix was 3 cm, 5 cm and as their original length. They were added in the various weight percentage ratios between sugarcane fibers to PP of 20/80, 25/75, and 30/70. Tensile test in accordance with ASTM D638-03 type 1 was conducted for all specimens. The fracture surface of tensile test specimen was then observed by using Scanning Electron Microscope (SEM) to study the interface bonding between sugarcane fibers and polypropylene, mixture homogeneity and breaking mechanism. Results from the tensile tests show that performing alkali treatment for 2 hours increases the tensile strength of the composites up to 20,76 MPa with the original length sugarcane fibers treated with 10% NaOH for 2 hours in the 30/70 weight ratio percentage composite. The SEM observation shows the removal of the lignin and hemicellulose by the NaOH solution after 2 hours of soaking which improves the mechanical bonding between sugarcane fiber and PP. Therefore it increased the tensile strength.

Keywords:
Composite, sugarcane fiber, polypropylene, alkali treatment

1. Introduction

Composites have been developed quickly and used massively by people for varieties of fields. The uniqueness of the properties makes it possible to fulfill people's need of material which is tough, strong, and flexible enough for certain purposes.[1] Those materials such as carbon fiber has been widely used for automotive and aviation industries. However, the manufacture of synthetic composites is blamed to be one of the factors of increasing air pollution due to its hydrocarbon powered processes.[2]

Natural fibers such as flax, kenaf, hemp, jute, coconut, sisal, and sugarcane have been used traditionally as daily goods such as clothes and baskets. Further technology discovers different approach for natural fibers. Those fibers are now used as reinforcement fibers for biocomposites.

Increasing number of environmental awareness makes biocomposites usage grows rapidly. [3] The global natural fiber composites market has reached US$ 298,3 million in 2010. By 2016 the market is predicted to reach US$ 531,3 million. Indonesia , the 11th largest producer of sugarcane along with Asia has been one of the emerging market for biocomposite material.

Sugarcane fibers are extracted sugarcane, leaving only the solid part and moisture. It weighs 30-32% of total cane weight. The fiber itself is similar to the other natural fiber and consists of 46,4% cellulose, 23,9% hemicellulose, 23,6% lignin, 2,4% juice, and 3,7% ash.[4]

However, sugarcane fibers as a reinforcement have to be bond with matrix. In this approach, the bonding between matrix and fiber becomes a factor of mechanical properties. Low interfacial adhesion between fibers and matrix, and moisture has been a limitation of getting desired mechanical properties.[5] To overcome these problems, surface modifications are applied to the sugarcane fibers. Alkali treatment was used to remove the lignin and hemicellulose on the surface and therefore improving the surface bonding between cellulose of fibers and matrix. NaOH, a strong alkaline substance is commonly used in the alkaline treatment of natural fiber.[6]

Mishra (2011) reported an increase on the tensile of alkaline-treated sugarcane fiber-epoxy composites up to 72,85 MPa. It is 21,92% increase compared to the tensile strength of untreated sugarcane fibers-epoxy composite (59,75 MPa). In this research, the duration of alkali treatment, the weight of sugarcane fibers added, and the length of fibers itself is varied to achieve the desired mechanical properties.[4]

Polypropylene, an abundant material is used for matrix in this research. The weight % ratios applied to the sugarcane fibers/PP mixture were 20/80, 25/75 and 30/70. The alkali treatment applied to the fibers was 2 hours and the fibers' lengths used varied, i.e. 3 cm, 5 cm, and as their original length. In this approach, thickness and tensile strength of various specification of sugarcane fiber-polypropylene composite can be studied.

2. Experimental Method

2.1. Materials Preparation

As first stage of specimen preparation. Sugarcane bagasse were neutralized using 70% ethanol for 1 hour with ratio of alkali volume to weight of fibers was 2,5 liter ethanol: 1 kg of sugarcane bagasse. The aim of neutralization was to prevent bagasse to ferment furthermore. Neutralized sugarcane bagasse then dried at open air for 6 hours and oven dried at 200°C for 30 seconds holding time. Dried bagasse were soaked in 10% v/v NaOH solution for 2 hours at 70°C temperature. The ratio between bagasse and NaOH solution was 15 ml of NaOH solution: 1 gram of sugarcane bagasse. Then it was rinsed with distilled water until pH level of 7 as indicated by pH meter. Air drying of 6 hours and oven drying with 30 seconds holding time was done before it was cut to the 3 cm, 5 cm and as their original length.

2.2. Manufacture of Composite

Table 1 shows the amount of sugarcane fibers-polypropylene prepared to make composite. 60 gram total weight mixture per composite sample then mixed in a machine using centrifugal blower. The final composite then formed into sheet by hotpressing it using pressure of 175°C and 9,8 KPa for 3 minutes. Table 2 shows identification code for various composite specifications.

2.3. Tensile Test

Final composites then cut into dimensions according to ASTM D638M-03 type 1 and tested using Instron 600 DX with extension rate of 5 mm/minute.

2.4. Microstructural Analysis

Using FEI type Inspect S50 Scanning Electron Microscope (SEM), the fractured surface of the sample was analyzed to understand relationship between tensile strength and the microstructure. Sugarcane fiber was also analyzed to compare the surface 2 hours alkaline treated fiber and non-treated fiber.

Table 1 Weight % ratio and volume fraction of sugarcane fiber/polypropylene.

Weight % Ratio of Fiber/PP (%)	Weight of Fiber (gram)	Weight of PP (gram)	Volume Fraction (%)
20/80	12	48	12,69
25/75	15	45	16,23
30/70	18	42	19,95

Table 2 Identification Code of Specimens

Code	NaOH Soaking Time	Sugarcane Fiber Length	Weight % Ratio of Fiber/PP
AIX	2 jam	3 cm	20/80
AIY			25/75
AIZ			30/70
AJX		5 cm	20/80
AJY			25/75
AJZ			30/70
AKX		Original length	20/80
AKY			25/75
AKZ			30/70

3. Result and Discussion

3.1. Thickness

Width and thickness of the composite specimens were measured before tensile test was performed. This measurements would help to understand the effect of different length of sugarcane fibers and weight % ratio of sugarcane fibers/PP on the thickness. The sample thicknesses range from 1,89 to 3,22 mm. The thickness increases as the weight % of sugarcane fiber increases. It is found that composites with 3 cm and 5 cm sugarcane fibers, samples in these groups have composites with the weight % ratio of fibers/PP 30/70 as their highest in tensile strength. However, specimen using original length (mean=15,54 cm), samples with 20% sugarcane fibers is the thickest. It is possible that this abnormally high thickness was caused by the fibers that resisted the hotpressing machine pressure. Weight % ratio of fibers/PP effects the thickness in a way that the rigid construction of fibers resists the hotpress pressure.

Aside from weight % ratio of sugarcane fibers/PP, length of the fibers themselves is also a main factor. The approach from the different point of view, samples with original length is the thickest in 20/80 and 25/75 group. However, in 30/70 group, samples with original length fibers top the tensile strength with slight difference. This difference in thickness occurs as a result of rigid construction made by different amount of sugarcane fibers. Composites with more length and amount of fibers get higher thickness.

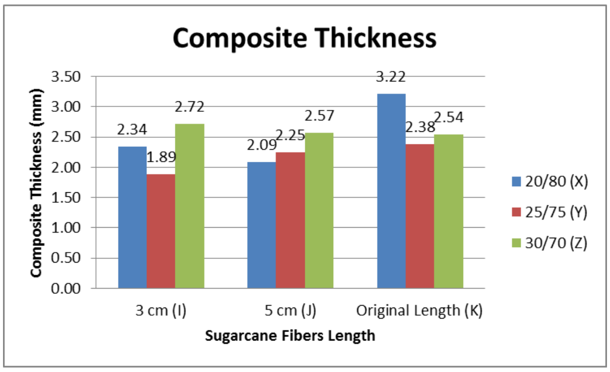

Fig. 1 Thickness of composites from various length and amount

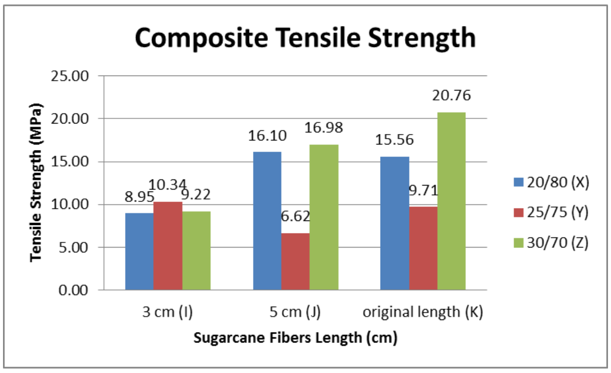

Fig. 2 Tensile strength of composites from various length and amount

3.2. Tensile Properties

Sugarcane fibers give tensile strength for the composite. During hotpressing, molten PP filled the spaces between fibers and therefore stiffness was provided. Fig. 2 shows tensile strength up to 20,76 Mpa in 30% original length fibers composite, in the same way 5 cm fibers group highest tensile strength achieved by 30/70 sugarcane fibers/PP % weight ratio composites (16,98MPa). In 3 cm fibers composite group however, the highest tensile strength achieved by 25/75 fibers/PP weight % ratio (10,34 MPa).

The tensile strength of 3 cm group composites range from 9,22 to 10,34 MPa. Whereas 5 cm fiber composite varies from 6,62 to 16,98 MPa and in original length fibers composites it start from 9,71 to 20,76 MPa.

In Fig. 2, most of the data show highest tensile strength for 30% fibers composites except for 3 cm group (the 2nd highest). Then as the amount lessens, the strength decreases in 20% fibers weight ratio. However in 25% fibers weight ratio, tensile strength decreases even more. This data exclude composites with 3 cm fibers composite which shows 25% fibers composite as the highest in tensile strength. Fibers transfer load from one part of the composite to other parts and it means higher amount of fibers, the higher the tensile strength. However, the bonding between PP and fibers is one of the main factor, a composite must have enough PP to wet fibers.

Lengthwise, composites consist of longer fiber tend to have higher tensile strength because of the transfer load factor. Fig 2 shows dominance of the samples have higher tensile strength in their original length (mean=15,54 cm). The results in fig 2 show samples have their peak tensile strength in their original length (2nd in 20% and 25% sugarcane group but very close to the 1st).

3.3. Microstructural Study of Sugarcane Fiber Surface

SEM images of non-treated and 2 hours treated sugarcane are shown in Fig. 3. The images show the effect of alkali treatment on modified fibers surface. Fig. 3 a) shows untreated sugarcane fiber revealeing no fibrillation due to the existence of lignin and hemicellulose; while Fig. 3 b) shows sharp contouring surfaces of fibers after 2 hour treatment. Alkali treatment was reported to remove lignin from the cellulose therefore breaking the natural bond between cellulose fibers.[6]

a) b)
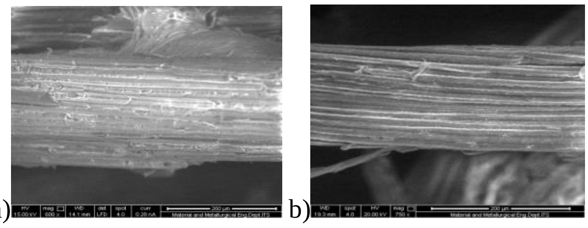
Fig. 3a) untreated sugarcane fiber surface, b) 2 hours treated sugarcane surface

3.4. Study on Fracture Surface of Composite

SEM test was done after the tensile test to understand the fracture mechanism, distribution of fibers, as well as bonding between fibers and matrix. Fig 4 shows fracture surface of composite AJZ which consisted of 30/70 surgarcane fibers/PP with sugarcane fibers of 5 cm length. Its tensile strength was measured as 16,98 MPa. It can be seen in Fig. 4 a) that the fibers were not homogenously distributed across the surface. Most of the fibers were located in the middle section of the sample cross section with transversal direction to the direction of tensile strength. It could cause splitting of the fibers when tensile stress was applied (Fig 4 b and c). It can be seen clearly that the main factor of the fracture was fiber splits.

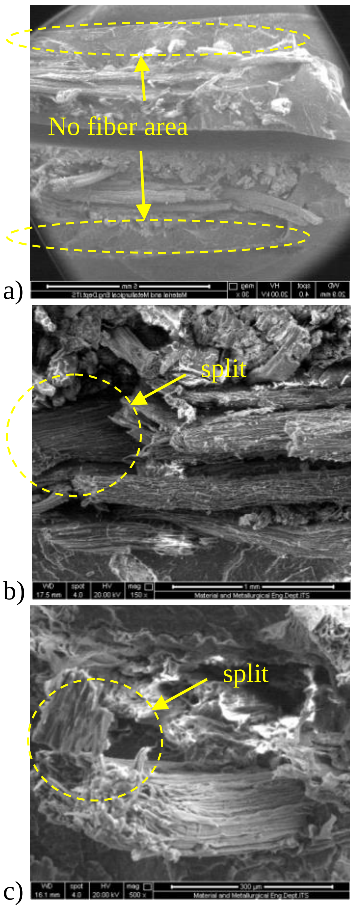

Fig. 5 SEM images of fracture surface composite AJZ (5 cm fibers and weight % ratio fibers/PP 30/70)

4. Conclusion

SEM observation shows changes on the surface of alkaline treated sugarcane fiber. Less lignin and hemicellulose is present resuting in defibrillation. The longer and higher amount of fibers produced thicker samples. Aside from abnormally thick AKX sample, samples with weight % ratio fibers/PP of 30/70 are always the thickest when compared among others (2,72; 2,57 and 2,54 MPa in AIZ, AJZ and AKZ samples).

Composites with the original length fibers and weight % ratio of 30/70 fibers/PP produced highest tensile strength. The tendency shows that the longer the fibers, the higher tensile strength is achieved. Sample AKZ, which contains fibers as their original length and weight % ratio fibers/PP of 30/70 tops the tensile strength.

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