Experimental Investigation on Mechanical Properties of Bagasse Reinforced PE Composite for Automotive Component

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Abstract

The use of natural fibers as a polymer composite additive is one of the alternative in the production of automotive components. It adds value to the wasted natural ingredients while reducing the depleted use of petroleum-based materials and also reducing the impact of pollution on the environment. In this research, specimen of composite is constructed from polymer (polyethylene, PE) as the main ingredient and cane bagasse fiber as additives in three ratio of composition 60%:40%, 50%:50 and 40%:60%. The tests performed to determine the mechanical properties of the composite specimen are charpy impact and flamebility test. The study from the charpy impact test shows composite A, 60% PE:40% sugar cane bagasse fiber has provided a good ductility, strength and toughness. Meanwhile the results of flamebility test also shows a composite C 40% PE:60% sugar cane bagasse fiber has the best burn resistance properties. The significant combination of PE and cane bagasse fiber composite to produce the automotive component is 50%:50%, cause it provide good value to meet the mechanical properties of impact and flamebility. As a recommendation for improvement, smaller ratios are used for sugarcane fibers as a co-mixed PE to see more accurately the effectiveness and other mechanical tests such as hardness and water absorption tests.

Key Words: Polymer Composite, Polyethylene, Cane Bagasse

Introduction

The world's needed to be environmentally friendly and against the instability and availability of non-petroleum products based on thermoplastic materials is extremely difficult. The need to make manufacturing products more convenient and cost-effective to consumers requires more effort into the processing and production of natural fiber composites which enable lower production cost to the company and provide greater mechanical properties for polymeric materials (Aji et. al., 2009).

The automotive industry relies heavily on petroleum-based products for the generation and manufacture of vehicle components. To reduce the dependence on fuel and petroleum-based products there is a growing need for further research to produce eco-friendly products and sustainable materials to replace existing materials. The need for biocomposite materials has been received by the automotive industry due to the increase in timber prices, the presence of new sources of fiber, environmental concerns, technological advances, competitiveness, research and development in the developed countries. With this development, this commodity can be commercialized and expanded on the use and market for eco-friendly products (Harun et al., 2009).

The use of polymeric materials from petroleum based has a negative effect over a long period of time to the environment. It is difficult to dispose and pollute the environment. Reducing petroleum resources require the world to use alternative materials as a polymer-based product. Wasted of sugar cane bagasse is also an issue as it is thrown away without any use. The production of automotive components from plastic composites and natural materials is still lacking in Malaysia. A study on the production of automotive components from plastic composites and natural fiber should be carried out. Revenue plastic composite with natural fiber are expected to reduce the problem.

Natural fibers have many advantages than their exceptional synthetic fibers. Now, various types of natural fibers has been studied for use in composites including flax, jute straw, wood, hemp, grass, rice husk, barley, oats, wheat, rye, sugarcane, bamboo, kenaf, hemp, palm oil, hemp, mulberry, papyrus leaves, banana fiber and pineapple fiber. Application of natural fibers in plastic products as composite filler material can reduce the use of synthetic polymers and also reduces environmental pollution. A natural fiber that is capable of self-biodegradable can help the decomposition process of disposal of synthetic polymer-based products in a shorter time (Taj et al., 2007).

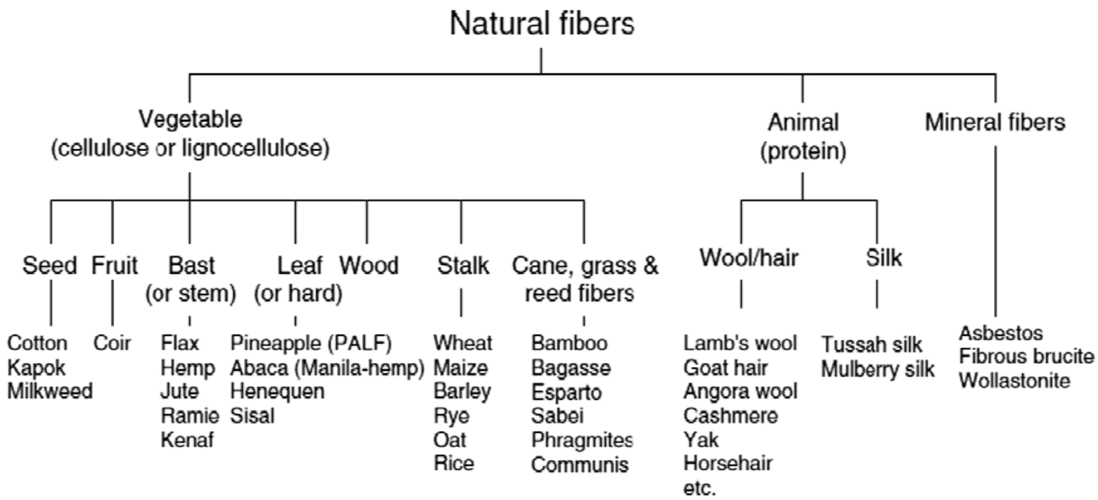

Figure 1. Classification of natural fiber (Akil et al., 2011).

Sugar cane based on its chemical composition contains a high lignocellulose. This lignocellulose can be used as an alternative substitute for wood in the manufacture of composite boards. The sugar cane fiber length between 1.7 to 2 mm with a diameter of about 20 micro, this cane crust meets the criteria to be processed into composite boards. The sugar cane contains 48-52% water, 3.3% sugar and 47.7% fiber. Scientifically it has a chemical composition of 3.28% ash, 22.09% lignin, cellulose 37.65%, 27.97 pentosan and SiO_2 3.01% (Husin, 2007). The sugar cane bagasse has many advantages over organic fillers because it can be biodegradable, low cost and recyclable. The sugarcane bagasse is usually thrown away after the water is squeezed as shown in Figure 2.

Figure 2. Sugar cane bagasse

These natural fiber materials have been used by European carmakers and this trend has reached North America and the Natural Fiber Composite Industry has recorded 40-50% growth in 2000 (Rouison et al., 2004). In an effort to be environmentally friendly, automotive engineers have now developed Eco cars. It is expected to be a sustainable vehicle for the future, running on biopetrol. It uses a natural fiber composite panel where the resin has been incorporated into matrix material (Kenning, 2003).

The green or sustainable design philosophy has increased the use of natural and bio-based plastic similar to PET or ABS properties. The idea of incorporating plastic and natural materials or synthetic materials is not so new, as is the idea of an engineering composite material in the manufacture of cars. For example according to Gay et al. (2003), commercial cars such as BX Citron 1983, have been constructed with glass and polymer composite materials, a combination of polyamide and polyester. Additional design solutions appear on the one-to-one circuit, teams like Ferrari, where weight gain has become the issue of carbon fiber, epoxy resin and Nomex bee nest is used to reduce weight and lower production costs (Gay et al., 2003).

In the last decade, natural fiber composites with thermoplastic mats and thermosets have been employed by European car manufacturers and suppliers for door panels, back panel chairs, dashboard panels, and other automotive interior parts (Holbery & Houston, 2006). Most of the fibers used in the automotive industry are flax, hemp, kenaf, jute and sisal. The composite of natural fiber reinforced polypropylene (NF / PP) can be prepared as a layer and then formed to the desired shape and thickness. This lightweight and environmentally friendly composite is very popular in internal applications (Apisak, 2007).

The main purpose of exploring natural fiber in automotive, is the demand for light parts and good recycling. With natural fiber composites, weight reduction of cars up to 35%, where this can be translated into lower fuel consumption and hence lower environmental impact. In addition, natural fiber composites also offer good mechanical performance, good formability, high sound absorption and cost savings due to lower material costs (Apisak, 2007). Figure 3 shows the use of natural fibers as an alternative material for the interior components of Mercedes Benz and Daimler Chrysler.

Figure 3. Internal components made of natural fibers composite for Mercedes E-Class cars

The objective of this paper is to study the mechanical properties of composite bagasse reinforced polyethylene through an impact test and a flammability test. Then determine the significant combination of PE and cane bagasse to produce automotive component.

Materials And Methods

Materials

In this study, sugarcane bagasse is dried first to prevent moisture occurring which may affect composite strength. Dried cane bagasse are blended into a powder and then mixed with polyethylene pellets to produce a composite. The composite are composed of polyethylene polymer and sugar cane bagasse categorized in three different mix compositions as are listed in Table 1.

a. Cane bagasse fiber b. Polyethylene pellet

Figure 4. Material of composite

Table 1. Condition of polyethylene and cane bagasse

Composite	Composition	
	Polyethylene (PE)	**Cane bagasse**
A	60 %	40 %
B	50 %	50 %
C	40 %	60 %

Specimen's preparations

The next phase is to mix the composite combination and produce a composite board using extrusion machine at SIRIM Shah Alam. The last phase is prepared a specimen of the composite board as shown in Figure 5 to study the mechanical properties of this composite through testing to determine the mechanical properties of the composite carried out by the impact test and flamebility test.

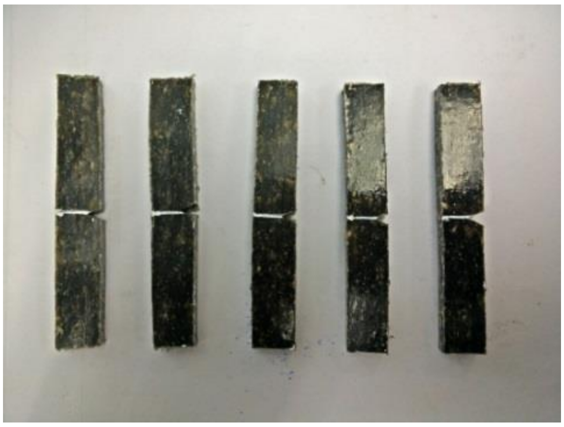

Figure 5. Sample of composite specimen

Impact Test

The impact test carried out by type of charpy with V notch on the specimen of 10mm x 4mm x 100mm according to ASTM D6110. Firstly the specimens put in the straps or in the 'clamp' horizontally. The pendulum with 15 J of energy are released at a speed of 5m/s from the back of the notch made at 160^0 angles as in Figure 6. Three samples for each composite composition carried out an upward test.

Figure 6. Impact test apparatus

Flamebility Test

Horizontal flamebility test was runned to study a flamebility of composite. The specimens used were cut three samples for each set composite mixture according to the standard size of ASTM D635. The specimens are placed on retort holders. Then the time is recorded when the fire is lit at the start of the specimen. Time to take until the fire goes out and the length of the burned specimen is measured. Figure 7 shows a horizontal flamebility test was run in the burning chamber.

Figure 7: Horizontal flamebility test

Results And Discussions

Charpy Impact Test

In this impact test, the curve is a stressful or initial crack. The results of this test are influenced by the shape and sharpness of the curve. Sharp curves are used, because less energy are required to break the specimen. On the charpy impact test, the fracture behaviour produced on the specimen may give some details regarding the following properties: Fragile polymers - the fracture surface is smooth, sparkling and cracking can break. Ductile Polymer - does not show the appearance of a particular fracture but its cross-sectional area decreases and seems to be torn. Figure 7 shows fracture appearance of 3 specimens after impact test and the data of the test result was tabulated in Table 2. Meanwhile Figure 8 show bar chart of data distribution.

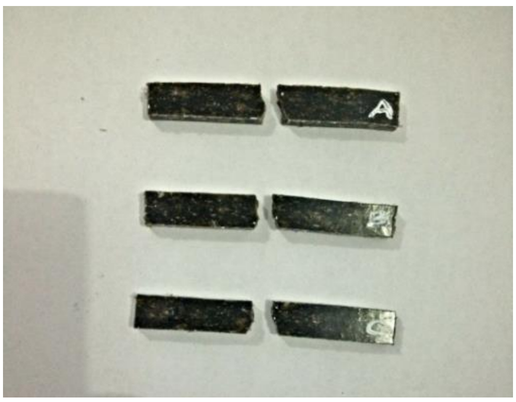

Figure 7: Charpy impact test on specimen

Table 2: Charpy impact test data

Composite	Energy Absorption (Joule)				Impact strength (J/mm²)	Type of fracture
	1	2	3	Average		
A	4.5	4.6	4.9	4.5	0.1167	Brittle
B	3.0	2.8	3.1	3.0	0.0742	Brittle
C	2.5	2.7	2.6	2.6	0.0650	Brittle

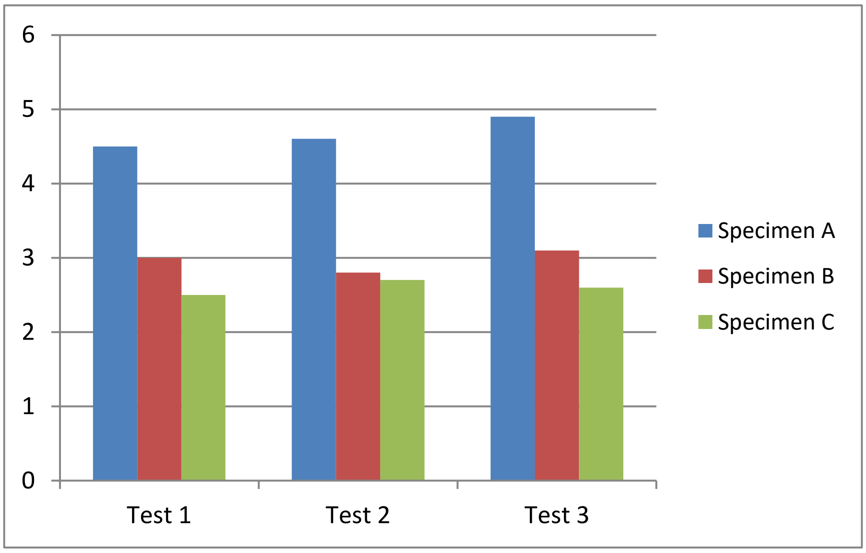

Figure 8: Bar chart energy absorption of charpy impact test result by specimen

From the results of the test it clear shown that composite specimens A give the highest energy absorption reading level with average 4.5 Joule followed by composite B and C. Composite A can absorb a lot of energy applied to it because it have a high ductility properties compared to composite B and C. The higher the impact energy absorbed by the composite, the higher the ductility and the strength of the composite. Composite with a lot of polymer materials composition will give a higher ductility due to the ductile properties of polymer. But based on the fracture state that occurs on the specimen after the test, all of specimens showed a brittle fracture characteristic. That mean the all specimen have low ductility. Maybe cause by not right combination ratio or process to produce a polymer composite.

Horizontal Flamebility Test

Table 3 below shows a summary of findings from experiments conducted for composite specimens A, B and C. The observation was done to see the specimen burned beyond the size of 1 inch and 5 inch or not based on the ASTM D635 standard procedure. The time of the specimen burned before it was removed was also recorded. Overall, all specimens burned down to 5 inches (127mm).

Table 3: Horizontal flamebility test data

Composite		**A**				**B**				**C**		
Specimen	**A1**	**A2**	**A3**	**Average**	**B1**	**B2**	**B3**	**Average**	**C1**	**C2**	**C3**	**Average**
Burn 1” (Y/N)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Burn 5” (Y/N)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Burned Time (s)	7:41	7:30	7:35	7:35	9:39	9:43	9:52	9:44	9:38	10:39	11:55	10.44

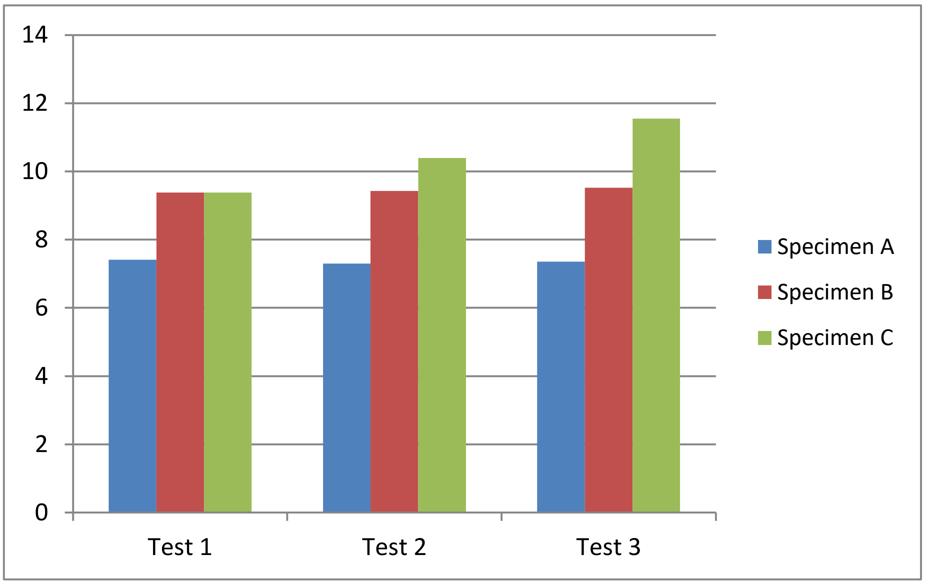

Figure 9: Bar chart burning time of horizontal flamebility test result

Based on the bar chart in Figure 9 shows the results burning times for composite specimen C takes the longest time to burn with 10:44 seconds This is closely followed by specimen B where the time taken to burn is 9: 44 seconds and the most flammable specimens are specimen A 7.35 seconds. High plastic material composition such as specimen A causes the composite to be flammable due to the presence of a large amount of petroleum-based substances. Whereas, high of cane bagasse fiber content as well as specimen C can help slow down the composite burning process.

Conclusion

For the conclusion the results of this study has fulfilled the objective can be summarized as follows:

i. The study from the charpy impact test shows composite A 60% PE : 40% sugar cane bagasse fiber has provided a good ductility, strength and toughness compared to composite B and C.

ii. The results of flamebility test shows a composite C 40% PE : 60% sugar cane bagasse fiber giving a high burning time reading. This means that if the time taken for burn is high, the burning process is slow so that it has low flamebility properties compared to composite A and B.

iii. The significant combination of PE and cane bagasse fiber composite to produce the automotive component is 50% PE and 50% cane bagasse fiber. This combination it the best compared with others by consideration of impact and flammability test result. It still has a good ductility, toughness and also it's hard to burn. So this combination of composite is suitable to produce a automotive component. This situation helps towards the use of wider polymer composite with sugar cane bagasse in the automotive industry for produce a component of automotive such as interior door panel or dashboard panel.

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