International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-8 Issue-4, November 2019

Flexural and Izod Impact Properties of Sugarcane Powder Reinforced Epoxy Composite

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Abstract: Currently, the studies of the mechanical behaviour of natural fibre composites have become influential among researchers due to its environmentally friendly, useful by-product and cheap. Due to this it becomes a potential material to be included in the composite materials as a reinforcement. The aim of this study is to investigate the mechanical properties of sugarcane powder reinforced epoxy composites under flexural and Izod impact tests. The sugarcane powder was processed using the crushing machine and planetary mono mill machine and it was added into the epoxy matrix with four different compositions (5 vol%, 10 vol%, 15 vol%, and 20 vol%). The morphological surfaces of the composite after the mechanical tests were observed using a Scanning Electron Microscope (SEM). It was found that the impact strength of the composites decreased with the increase of powder compositions with a range of between 5.7 kJ/m^2 to 2.7 kJ/m^2. The flexure modulus, on the contrary, showed an increment trend with the increase in powder loading with a modulus ranged in between 757 MPa to 1208 MPa. The potential of this natural fiber have significant contribution on the properties of natural fibres polymer composites. Natural waste consumption of sugarcane fiber could decrease the usage of synthetic polymers and provide the environmental friendly material for further application.

Keywords: sugarcane powder, epoxy, natural fiber composite, impact properties, flexure properties.

I. INTRODUCTION

Generally, natural fibers such as kenaf, coir, sisal, and bamboo are recyclable, low weight, cheap, and possessed biodegradable property [1,2]. Due to these advantages, research on the natural fibers as a potential for reinforcement in composite materials has gained attention to investigate its possible outcomes to contribute to human society as a sustainability development. Earlier, natural fibers were discovered and developed into useful needs, such as clothing and papers. However, due to the increase of wastage of natural fibers such as sugarcane after the juice has been extracted, awareness among researchers have increased to reduce the waste of natural fibers especially to the environment. As a solution, natural waste of sugarcane eventually introduced to be among the potential reinforcement of natural fiber composites [3].

Sugarcane has the most significant amount of worldwide production than other natural fibers, due to their various benefits it can be to society[4]. Natural fiber reinforced polymer composites have been studied intensively as alternative to synthetic fibers (glass fiber). The disadvantages of polymer composites material reinforced by synthetic fibers associated some environmental and health problems. The natural fibers over synthetic fiber offer unique properties of low density, biodegradability, healthy environmentally, easy of separation, easy availability, enhanced energy recovery, non-corrosive nature, low cost, good thermal and acoustic insulation properties [4]. There are multiple types of natural fibers have been studied to be used as reinforcement in polymer composites such as Hemp, kenaf, ramie, sugar palm, oil palm, pineapple leaf, banana pseudo-stem, sugarcane, rice husk, wood, and bamboo are some examples of natural fibers [4][6][7]. Commonly natural fibers are extracted from the stems, leaves, and seeds of the plants [8]. However, the natural fibers have lacking of their behavior to swell due to the excellent absorption of water, and possess limited to their maximum temperature to process them due to its weak fire resistance [8]. Natural fibers are classified into several groups (Fig. 1) which are bast, seed, leaf, stalk, grass, etc.

This study investigated mechanical properties of sugarcane fiber reinforce epoxy composite via Izod impact, flexural properties and morphological surface after failure. Some early studies have been conducted as attempt to explore the capability of natural fiber such as sugar palm. Sastra et al. [6] studied the performance of sugar palm fiber reinforced epoxy composites and showing the good mechanical properties. Next, the evaluation of mechanical properties of sugarcane fiber reinforced natural composites have been reported by Gokul [8]. They studied on the three different types of composites were considered where sugarcane were added to polyester matrix, next addition of metal mesh or coconut shell where the sugarcane fiber was chemically treated using HCL or NaOH. They claimed that the composites reinforced with the NaOH treated sugarcane fiber and the metal mesh show superior tensile and impact properties whereas the composites reinforced with the NaOH treated sugarcane fiber show the best flexural properties [8].

Manuscript published on November 30, 2019.
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Retrieval Number: D5184118419/2019©BEIESP
DOI:10.35940/ijrteD5184.118419
Journal Website: www.ijrte.org

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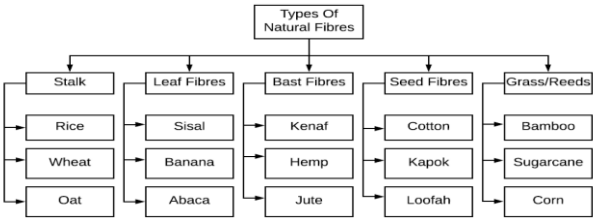

Fig 1. Types of Natural Fibers

Sugarcane or *Saccharum officinarum* can be classified into two parts, namely pith, the visceral fiber which contains softer and shorter fibers than rind, the outermost surface which is hard and long. These parts of sugarcane can clearly be seen as the residue after the sugarcane is crushed to extract the sugar[10]. The sugarcane consists of cellulose, hemicellulose, lignin, ash, and wax [11]. Table I shows that sugarcane is the highest source of natural fiber in the world production[12].

Table I. The World Wide Fiber Sources

Fiber Source	World Production (103 ton)
Bamboo	30,000
Jute	2,300
Kenaf	970
Flax	830
Sisal	378
Hemp	214
Coir	100
Ramie	100
Abaca	70
Sugarcane	75,000
Grass	700

A. Epoxy

Epoxy is an example of thermosetting which at least have one or more epoxide groups in the molecule. The characteristics of the cured epoxy resin include low fracture toughness and impact resistance, cannot be reshaped after curing, reduced resistance to initiate crack, and the propagation of crack is diminished. There are many advantages of thermosetting over thermoplastics which includes least possible shrinkage in the curing process, cheaper, better mechanical and fatigue strength, superior resistance to moisture, chemical, impact and corrosion, good insulation towards electricity and contains no Volatile Organic Compounds (VOCs)[13]. Epoxy resins have a theoretical density value of 1.2 g/cm^3[14].

B. Fibre Reinforced Polymer

This study covers the behavior of sugarcane powder reinforced epoxy under mechanical testings. The Fibre Reinforced Polymer (FRP) is widely used in many industrial sectors which well recognized, such as in automotive, constructions, and packaging industry. It consists of either thermosetting or thermoplastic polymers which in the form of matrix embedded in the fibers.

Although the features of FRP are not exhibited excellent mechanical properties investigations on it must not concede because there are much more new findings that yet to discover. Generally, the nature of FRP includes flexible to gain impact and heat resistance, high flexural and shear strength and rigid to increase their elastic modulus[15]. These composites between polymers and natural fibers have the advantages of low weight, density, and good for sustainability.

II. METHODOLOGY

This chapter will emphasize on the mechanical and morphological methodology of sugarcane powder reinforced epoxy resin composites. All experiments, fabrication process and testing were conducted in the Material Science/Material Composite Laboratory and Mechanical Strength Laboratory of UiTM Shah Alam. Fig 2 shows the overall flow of this study to achieve the objectives.

A. Flow of Study

The following flow chart is the steps and overall process in completing this research.

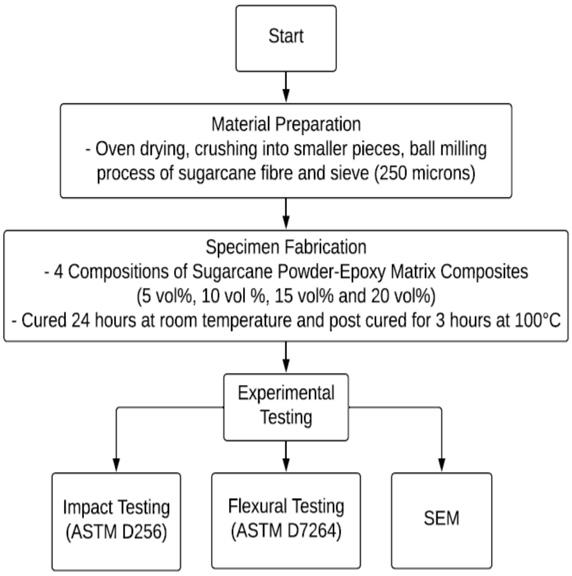

Fig 2. The Flow of Study

B. Material Preparation

Sugarcanes collected in the local market where the juice of the sugarcane was already extracted from the fibers were used as the reinforcement in this study. The fibers were cleaned with tap water to remove all dust and residues. Next, the entanglements of the sugarcane were loosened to ensure uniform drying process, and this process was managed manually (by hand). The sugarcane then being dried in the oven for 24 hours at 100 ℃.

Fig 3. The Dried Sugarcane

The thoroughly dried sugarcane (Fig. 3) was left for at least 30 minutes at room temperature before proceeded into the crusher machine to produce fine sugarcane powder. The crushing process of sugarcane was using ball mill process using the planetary ball mill machine with the speed of 300 rev/min for 90 minutes. Then the powder was sieved to a 250 microns (60 mesh) in a vibratory sieve shaker at an amplitude of 1.0 for 30 minutes.

Clear epoxy resin was purchased from a local industrial seller (ADI PAINT of KNADS Resources) which consists of epoxy resin and its hardener that has a mix ratio of 1:1. It is fully cured in 24 hours after the mixing process between the two solutions.

C. Fabrication

Density test was conducted to determine the composition by volume for the composite fabrication process. This test used buoyancy method; Archimedes Principle, which involved the weights of the epoxy. Three samples of pure epoxy resin were fabricated with random rectangular dimensions. The following is the equation (1) to calculate the values of density. As for the sugarcane powder, its density value was determined using the gas pycnometer. It required 1g to 2g of sugarcane powder to fill in the chamber to run the machine. The density test using gas pycnometer was operated in room temperature.

$$\rho = \frac{W_a}{W_a - W_b} \times (\rho_o - d) + d \qquad (1)$$

Where; ρ = Density of sample
W_a = Weight in air
W_b = Weight in liquid
ρ_o = Density of liquid
d = Density of air

The epoxy resin and sugarcane powder were mixed based on their compositions of 5 vol%, 10 vol%, 15 vol%, and 20 vol%. The mixed materials were poured into mold according to the standard specimen sizes of ASTM D7264 and ASTM D256. Then the specimen was cured at room temperature for 24 hours. After 24 hours, the specimens were taken out of the mold and post-cured in the hot press machine for another 3 hours at 100°C, then let them cool to room temperature.

D. Izod Impact Test

The Izod impact test conducted is according to the standard of ASTM D256. Izod impact test is a test that provides knowledge about plastic resistant under a pendulum swing. It requires a notch which will help produces a stress concentration that increases the probability of brittleness rather than ductility, then fracture. The Izod impact test was carried out using the Izod/Charpy impact tester machine in the UiTM Shah Alam Mechanical Engineering laboratory. This standard test has a constant rectangular cross-section that one end is grip by the machine. The standard specimen measurement is 63.5 mm (length) x 12.7 mm (width) x 3 mm (thickness) with unit energy of $kJ.m^2$

E. Flexural Test

The flexural test or a three-point bending test that is conducted is according to the standard of ASTM D7264 it is a purpose to measure the force needed to flexure a straight beam with three-point loading. The flexural test as in Fig 4 will be carried out using the INSTRON 3382 in the UiTM Shah Alam Mechanical Engineering laboratory with a capacity of 100kN. Commonly this test applies loading at the center while both sides of specimen are clamped at a specific rate. It is stated that natural fiber reinforced polymers have a high bending stiffness undergoes the flexural test. This standard test has the standard specimen measurement of 154 mm (length) x 13 mm (width) x 4 mm (thickness).

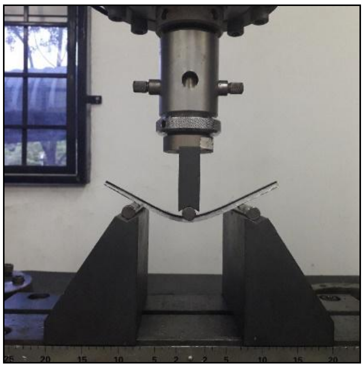

Fig 4. Specimen Set Up of Flexural Test

F. Scanning Electron Microscope (SEM)

The purpose of the SEM in this study is to investigate the fracture surface of Izod impact and flexural tests and provide a further understanding of the effect of the fiber content of sugarcane powder in the epoxy composite. The observation will be held in material science laboratory of Faculty of Mechanical Engineering, UiTM Shah Alam.

III. RESULT AND DISCUSSION

A. Density Values

The average density value of epoxy is 1.12754 g/cm^3 and a standard deviation of $6.558624x10^{-4}$ g/cm^3, while the sugarcane powder has a density value of 1.4856 g/cm^3 and a standard deviation of 0.0025 g/cm^3.

B. Izod Impact

The impact test was conducted with at least five samples for all compositions of sugarcane powder-epoxy composites according to ASTM D256. All samples were prepared with a 2-mm notch deep in the middle edge. Fig 5 shows the impact strengths of the composites. The impact strengths are decreasing as the compositions of sugarcane powder were increased. The 5 vol% composite has the highest strength of 5.7 kJ/m^2 while the 20 vol% has the least impact strength compared to other composites about 2.7 kJ/m^2.

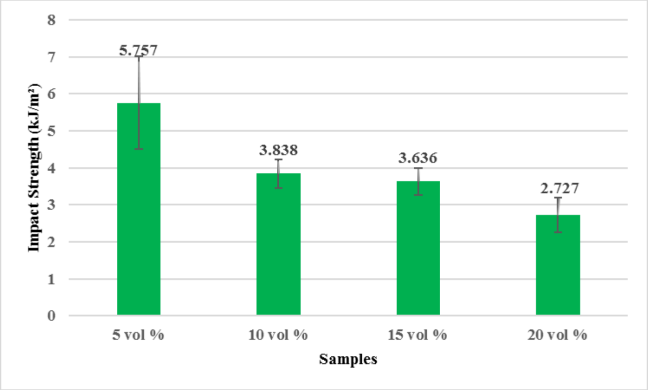

Fig 5. Izod Impact Strengths of Sugarcane Powder-Epoxy Composite

C. Flexure Test

The flexure test was conducted according to ASTM D7264 at a cross-head speed of 3 mm/min and support span of 90 mm. There were at least five specimens per composition tested to get the average values of flexural modulus and other flexural properties. The flexural modulus is directly proportional to the increasing of sugarcane powder loading. It is show that in Fig. 6, 5 vol% composite has the lowest flexure modulus about 757 MPa and highest of 20 vol% composition possess 1208 MPa.

It is interesting to note how the reinforced fiber reacts to the direction on the applied loading. The 20 vol% loading gives better resistance to bending and reduces the ductility of epoxy polymer. This is due to the good bond achieved between the composite mixture and fiber.

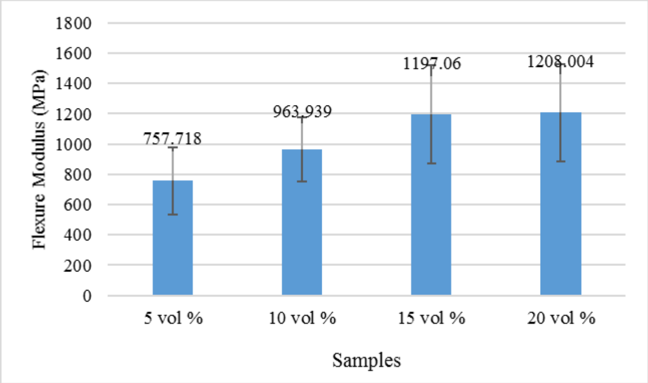

Fig 6. The Flexural Modulus of Sugarcane Powder/Epoxy Composite

Fig 7 represents the graph of the flexure stress of sugarcane powder/epoxy composite. The results show that the 15 vol% composite has the highest flexure stress, while the 5 vol% composite exhibited the lowest flexure stress among other compositions of the composite. The flexure stress values began to increase steadily as the volume percentages of sugarcane powder increased until it stopped increasing at 15 vol%.

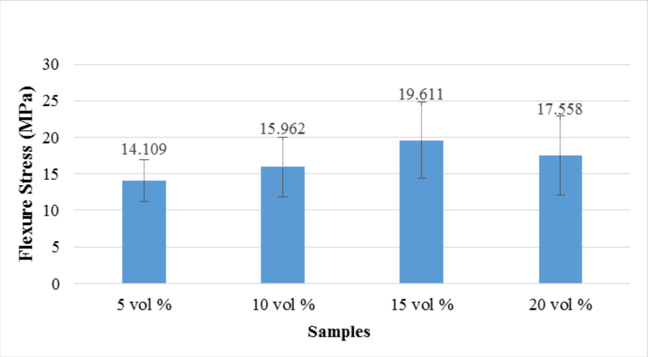

Fig 7. The Flexure Stress of Sugarcane Powder/Epoxy Composite

Next, the value of flexure stress at 20 vol% slightly decrease from its previous volume percentage. This might due to the maximum limit of 15 vol% has caused the saturated condition as resulted for 20 vol% specimen as it was unable to receive more load and finally fracture occurred. This results is comparable as reported by Subramonian [17] where claim the highest flexural strength of sugarcane/bagasse fiber composite content of Polypropylene (PP) with 10wt% of the filler was 57MPa, meanwhile the flexural strength then decreases with increasing filler where the lowest was 44.44MPa for PP with 40wt% filler.

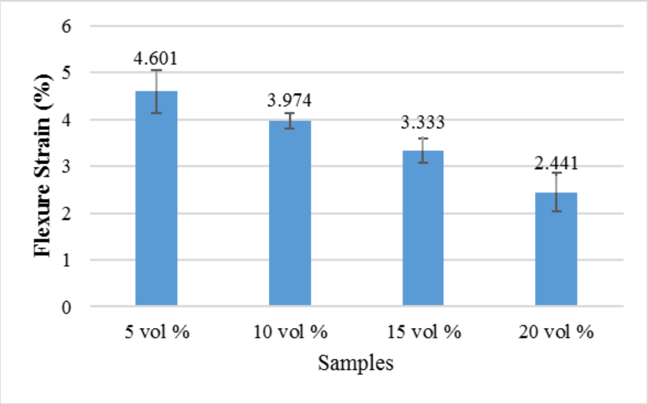

Fig 8. The Flexure Strain of Sugarcane Powder/Epoxy Composite

Fig 8 displays the graph of the flexure strain of sugarcane powder/epoxy composite. The volume percentage of 5 vol% specimen shows the highest flexure strain over the other powder compositions. The volume composition of 20 vol% has the lowest flexure strain. The pattern demonstrates a uniform decrease as the volume composition of sugarcane powder was increased.

Retrieval Number: D5184118419/2019©BEIESP
DOI:10.35940/ijrteD5184.118419
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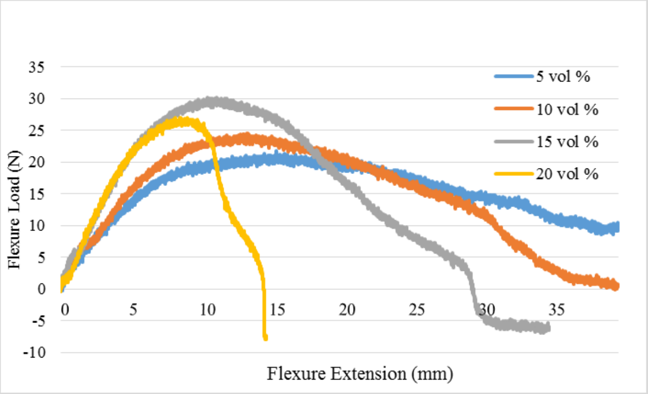


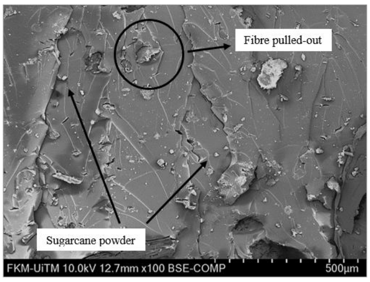
Fig 9. Typical Load-Extension of the Composites

The typical flexure load versus extension of the composites can be referred in Fig 9. From the graph obtained, it shows that the 5 vol% composite withstand the lowest flexure load. It also has the most significant extension of more 40 mm compared to other composites. As for the composite of 10 vol%, it has an almost similar curve that the 5 vol% composite possesses, and it has an approximate break at the extension of 40 mm, shorter than the 5 vol% composite. Next, the composite composition of 15 vol% exhibits the highest flexure load compared to other composites. This composite also began to fracture before the flexure extension of 30 mm. Then, the flexure load decreases back at the 20 vol% composite, and it has fractured fail before 15 mm. From this graph, the maximum limit of powder loading possess to 15vol% since the 20 vol% show the composite was fail below 15mm flexure extension.

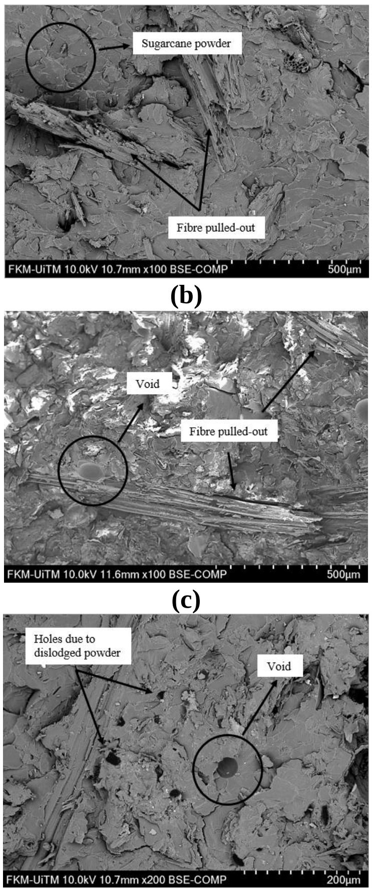
D. Scanning Electron Microscope (SEM)

The micrograph of morphological surfaces of SEM analysis of each composition of sugarcane powder in epoxy as in Fig 10.

It is show that the sugarcane fibres will adhere to the matrix that failure happened in fibre without pulling out fibre. The natural fibres absorb the majority of stresses and that stress is well transmitted to the fibres. The sugarcane powder entirely covered by the epoxy resin. A few voids could also be seen (Fig. 10 d) as more volume of powder were added as a result of air bubble which might produce during the stirring process earlier. Furthermore, higher sugarcane powder composition in the epoxy show the propagation of cracks in the material becomes more visible. However, it could also be noticed that the powder is well dispersed throughout the epoxy matrix.



(a)



(d)

Fig 10. (a) 5 vol% composites (b) 10 vol% composites (c) 15 vol% composites (d) 20 vol% composites

IV. CONCLUSION

In this work, the effect of powder loading of natural fibers toward flexural and Izod test was studied. The higher loading of 20vol% show decreasing trend of impact properties after more filler was added. The brittleness of the composites also increased as more sugarcane powder was added into the epoxy. This is supported where the maximum flexural load apply to 20vol% loading fail at lowest flexural extension below 15mm. The characteristics of the composites are dependent on the particle size and concentration of natural fiber reinforced in the polymer matrix.

The behaviour of natural powder (rice husk powder, sugarcane powder and pine needle particulate) and non-biodegradable powder (marble powder and silver powder) are nearly the same, which gaining the flexure modulus and diminishing the impact strength. The morphological of the fracture surfaces of the composite clarify that the sugarcane binds well with the epoxy and minimal voids could be seen.

ACKNOWLEDMENT

The authors would like to thank and express appreciation to Geran Insentif Penyeliaan (GIP) Universiti Teknologi MARA, Malaysia for the financial support in completing this research.

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