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Investigation of Impact Behaviour of Sisal Fiber Reinforced Phenol Formaldehyde Composites

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Abstract

Short Sisal fiber reinforced Phenol Formaldehyde resin composites are prepared with varied fiber lengths (5 mm and 10 mm) and for varied weight fraction (20%, 25% and 30%) of the fibers. Here in this work, Sisal fiber is used as reinforcement. Since it is abundantly available in nature and majority of it is getting wasted without being used as reinforcement in engineering applications. Over the last thirty years composite materials, plastics and ceramics have been the dominant emerging materials. The 10 mm fiber length reinforced composite shown improved mechanical properties than 5 mm fiber length reinforced composite. Increase in impact strength is seen when the fiber content in the composite is increased from 20% to 25% and 25% to 30%. In relation to the fibre strength, the work of fracture is proportional to the fibre length and volume fraction for varying fibre size. The impact strength increases with the fibre volume fraction, according to the results, however proportionality is not shown. This implies that the impact strength of the composites is influenced by additional mechanisms. The main toughening mechanism in notched impact tests is crack propagation. The ability of fibres to absorb impact energy efficiently as a stress-transferring medium is characterised by an improvement in impact strength. The energy required for additional crack creation and propagation is increased by good interaction with the crack. Low fibre composition and relatively short fibre length may be the cause of the uncommon instance, preventing efficient energy dissipation. Weak interfacial bonding of natural fibers is mainly due to incompatibility of hydrophobic matrix and hydrophilic fiber. High moisture absorption causes dimensional changes of natural fibers as well.

Keywords: *Composite Materials; Phenol Formaldehyde; Short Sisal Fiber.*

1. Introduction

A composite is a structural material that consists of two or more combined constituents that are combined at a macroscopic level and are not soluble in each other. One constituent is called the reinforcing phase and the one in which it is embedded is called the matrix. The reinforcing phase material may be in the form of fibers, particles, or flakes. The matrix phase materials are generally continuous [1]. Natural fibers like banana, cotton, coir, sisal and jute have attracted the attentions of scientists and technologists for application in consumer goods, low-cost housing and other civil structures. It has been found that these natural fiber composites possess better electrical resistance, good thermal and acoustic insulating properties and higher resistance to fracture [2]. The use of natural fibers as reinforcements in polymer composites to replace synthetic fibers like glass is presently receiving increasing attention because of the advantages, including cost effectiveness, low density, high specific strength, as well as their availability as renewable resources. Owing to the poor wettability and absorbability towards polymers resulting from the hydrophilicity of plant fibers, however, the adhesion between the fibers and

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polymer matrices is generally insufficient. To improve the interfacial bonding, either surface modification of the fibers or plasticization of the fibers can be carried out. It is worth noting that chemical composition and cell structure of natural fibers are quite complicated. Each fiber is essentially a composite in which rigid cellulose micro fibrils are embedded in a soft lignin and hemicelluloses matrix. In addition, the micro fibrils are helically wound along the fiber axis to form ultimate hollow cells. Uncoiling of these spirally oriented fibrils consumes large amounts of energy and is one of the predominant failure modes. As a result, pretreatment of the fibers would result in chemical and structural changes not only on the fiber surface but also in the distinct cells, which in turn also influences the properties of the fibers and composites [3]. Natural fibers such as jute, flax, hemp, remi, sisal, coconut fiber (coir), and banana fiber (abaca) are abundantly available in nature. All these fibers are grown as agricultural plants in various parts of the world and are commonly used for making ropes, carpet backing, bags, and so on. The components of natural fibers are cellulose micro fibrils dispersed in an amorphous matrix of lignin and hemicelluloses. Depending on the type of the natural fiber, the cellulose content is in the range of 60–80 wt% and the lignin content is in the range of 5– 20 wt%. In addition, the moisture content in natural fibers can be up to 20 wt.%.

2. Method

The composite plates prepared initially are marked for required dimensions. They are cut to the markings using a wire saw for required dimensions. The edges of the specimens are rubbed against emery paper in order to bring them to the exact dimension. The specimens were prepared according to American Society for Testing of Materials (ASTM) standards. As a result, pretreatment of the fibers would result in chemical and structural changes not only on the fiber surface In the present work sisal fiber is used as reinforcement and phenol formaldehyde as matrix material. The sisal fibers are chopped into lengths of 5mm and 10mm and also the specimens were prepared for 5mm and 10mm separately. In the proposed work specimens were prepared as shown in Table 1 for three different compositions.

Table 1 Weight Fraction Composition of the Sisal Fiber Composites Used

Serial number	Weight Fraction Compositions of Sisal Fiber Composite
1	Short sisal fiber 30% + phenol formaldehyde 70%
2	Short sisal fiber 25% + phenol formaldehyde 75%
3	Short sisal fiber 20% + phenol formaldehyde 80%

The charpy impact test specimens were prepared according to ASTM D256 standard. The notch produces a stress concentration that increases the probability of a brittle, rather than a ductile fracture. The specimen used is a rectangular bar of 63.5mm×12.7mm×12.7 mm cross-section with a U-notch. A dimensional view of standard charpy impact test specimen is shown in Figure 1. Figure 2 shows the test samples. In this test, four samples are tested and the average of the four readings is taken as the Impact strength [4-7].

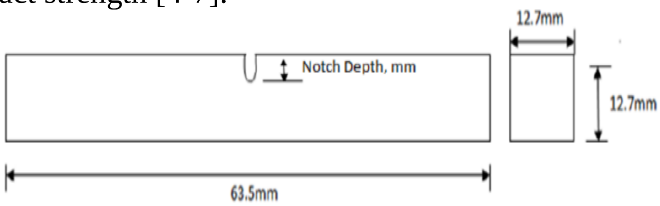

Figure 1 The Dimensional View of Specimen

Figure 2 Specimens Used for Testing

3. Experimentation

In this work impact test of Sisal Phenol Formaldehyde composites were conducted. Impact

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tests were conducted using an impact testing machine. A pictorial view of the impact testing machine is shown in figure 3. The machine consist of a massive base on which is mounted a vise for holding the specimen and to which is connected, through a rigid frame and bearings, a pendulum type hammer. The machine also has a pendulum holding and releasing mechanism and a digital indicator for displaying the test values. The pendulum shall consist of a single or multimember arm with a bearing on one end and a head, containing the striker, on the other. The arm must be sufficiently rigid to maintain the proper clearances and geometric relationships between the machine parts and the specimen and to minimize vibration energy losses that are always included in the measured impact resistance. Both simple and compound pendulum designs may comply with this test method. The Figure 4 shows the tested Impact specimens of the Sisal fiber-Phenol Formaldehyde composites

Figure 3 Impact Testing Machine

Figure 4 Impact Tested Specimens

4. Results and Discussion

Figure 5 shows the impact strength of the untreated and treated Sisal fiber reinforced Phenol Formaldehyde with different fiber length as a function of fiber weight percentage. It can be seen from the figure that as the fiber content increases, the impact strength increases for all type of composites. It can also be observed from the figure that the 30% weight of the fiber content showed more impact strength than the 20% and 25% weight of the fiber content. According to the results, impact strength increases at varying rates for all types of composites as the fibre content rises. An increase in the amount of fibre that might transfer the applied stress more efficiently because of an increase in the total fibre surface in contact with the matrix could result in an improvement in impact strength. The enhanced stress transmission at the fiber/matrix interface is the result of increased fibre wetting with the matrix. The work of fracture is therefore proportional to the fibre length and volume fraction for the same type of fibre, but for different fibre lengths and volume fractions, the fibre strength is varied. The impact strength increases with the fibre volume fraction, according to the results, however proportionality is not shown. This implies that the impact strength of the composites is influenced by additional mechanisms. The main toughening mechanism in notched impact tests is crack propagation. The ability of fibres to absorb impact energy efficiently as a stress-transferring medium is characterised by an improvement in impact strength. The energy required for additional crack creation and propagation is increased by good interaction with the crack. Low fibre composition and relatively short fibre length may be the cause of the uncommon instance, preventing efficient energy dissipation. Weak interfacial bonding of natural fibers is mainly due to incompatibility of hydrophobic matrix and hydrophilic fiber. High moisture absorption causes dimensional changes of natural fibers as well. Additionally, it has been noted that for some compositions, an increase in fibre length results in an increase in impact strength. Every fibre and composite type shows the same pattern. It might be because there are more shorter fibres at the same volume percent level. There are more fibre ends

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in proportion, which leads to greater areas of stress concentration. Less active fibres and a larger damage zone result from this. This reduces the impact strength of the composites by weakening their capacity to withstand impacts. It might be because there are fewer fibres in longer fibres, which improves fibre dispersion. As a result, there is less chance of fibre agglomeration in the matrix because there is less fibre stacked up. Consequently, every single fiber could interact with the matrix more effectively.

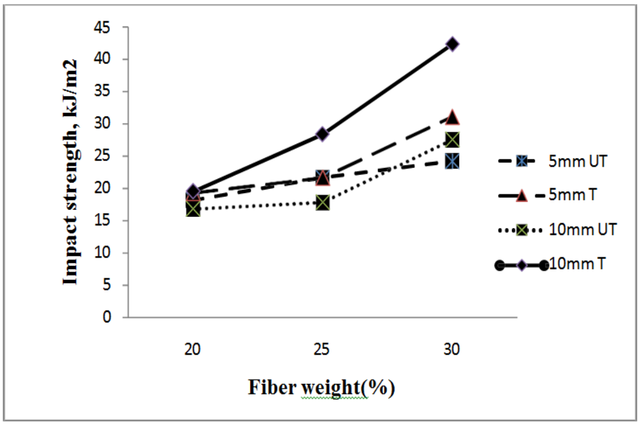

Figure 5 Impact Strength v/s Fiber Weight (%) of Sisal Reinforced Phenol Formaldehyde Composite

Table 2 Impact Strength Values of Untreated Sisal Fiber-Phenol Formaldehyde Composites at Three Different Weight Fractions and Two Different Fiber Lengths

Fiber weight (%)	Fiber length(mm)	Impact strength (kJ/m^2)
20	5	18.18
	10	16.78
25	5	21.63
	10	17.8
30	5	24.18
	10	27.52

It can be seen from the Table 2 that for untreated composites the impact strength improves with the increase in fiber content. At 20% of the untreated fiber content with 5mm fiber length the impact strength value found to be 18.18 kJ/m2, when the fiber content is increased to 25% the impact strength value increases to 21.63 kJ/m2 with an increase of 19% in the impact strength value and 12% increase in the impact strength value when the fiber content in the composite is increased from 25% to 30%. At 20% of the fiber loading for the composites made with 10mm fiber length the impact strength is 16.78 kJ/m2. When the fiber loading is increased from 20% to 25% the impact strength value was found to be 17.8 kJ/m2, with an increase of 6% in the impact strength value and increase of 55% impact strength value is found when the fiber loading is increased from 25% to 30%. Comparing across the fiber length for the same composites, at 20% and 25% of the fiber loading the composite made with 5 mm fiber length shown highest impact strength values compared to the 10mm fiber length. But at 30% of the fiber loading the composite with 10mm fiber length showed better impact strength values compared to 5mm fiber length.

Conclusion

In this work the short sisal fiber reinforced Phenol Formaldehyde composites were prepared for different fiber lengths, fiber weight percentage. Tensile properties are tested for Sisal- Phenol Formaldehyde composites. The composites showed an increasing trend in their impact strength values when the fiber content is increased from 20% to 30%. This confirms that the increase in fiber content increases the mechanical properties; this may be due to fibers acts as carriers of load and stress is transferred from matrix along the fibers leading to effective and uniform stress distribution which resulted in a composite having good mechanical properties. Comparing across the fiber lengths, the composite made with 10mm fiber length showed better results than the 5mm fiber length for most of the composite combinations. This confirms the increase in the fiber length increases the mechanical properties and this is because at the same volume fraction level there are a higher number of shorter fibers correspondingly, there are more fiber ends resulting in more stress concentration regions leading to more damage zone.

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