Journal of Material Science and Mechanical Engineering (JMSME)
p-ISSN: 2393-9095; e-ISSN: 2393-9109; Volume 2, Issue 13; October-December, 2015 pp. 1-5

http://www.krishisanskriti.org/Publication.html

Influence of Fiber Percentage on Mechanical Properties of Hybrid Composite Materials

A. Devaraju

Department of Mechanical Engineering, Adhi College of Engineering and Technology, No.6 Munu adhi Nagar, Sakarapuram, Near Walajabad, Kanchipuram-631 605, Tamilnadu, India
E-mail: adevaa2011@gmail.com

Abstract—*Composite is a material in which two or more constituent materials are combined and produce single material. The composite material provides the required physical and/or chemical properties. Moreover, composite materials are stronger, lighter, and less expensive than traditional materials. Therefore, the use of composite in engineering field is increasing day by day. Composite consists of mainly two phases i.e. Fiber and Matrix. The fibers may be polymers, ceramics, metals, Jute, Coir, Silk, Banana, Bamboo fibers and animal feathers. Matrix is durable glue that provides a high level of bonding between fibers. In the present work, epoxy is used as matrix and Banana and Sisal fibers were used as fibers for preparing the composites. During preparation of specimens, the fiber was taken as a continuous one. The fiber as treated with NaOH and* H_2O *solutions. The specimens were prepared by varying the weight percentage of fiber (5% to 35%). The mechanical properties of composites such as tensile strength, impact strength and hardness have been evaluated. The effects of stress, strain and displacement variations under various volume fraction of fiber have also been analyzed.*

Keywords: Natural fibers, Mechanical properties, volume fraction, hardness.

1. INTRODUCTION

In recent days, one of the highest attractive research line is development of natural fiber reinforced composite. Composites have been developed to meet several industrial demands such as (i) need for easier processing, (ii) light weight etc. One of the famous natural fiber based composites is, the combination of banana and Sisal fiber based hybrid composite. However, the limited published research work is available on mechanical behavior on banana and sisal fiber composites as follows.

Chandramohan et al [1] reported that natural fibers are obtained from natural resources. Natural fibers have many advantages such as low density, high biodegradability, reasonable specific strength properties, good sound abatement capability, low cost, and existence of vast resources. Furthermore, at the end of their life cycle, these fibres can be incinerated for energy recovery. Because it has good calorific value [1]. Ranjan et al [2] have worked in the reinforcement flax, hemp and jute for developing thermoplastic and thermoset composites. These composite materials have been successful in semi-structural as well as structural applications [2]. Some of the bio-based composites are used in car door trim, seat-back trim, dashboard supports, rear shelves and also exterior parts, such as transmission covers [3]. Banana fibers are obtained from the dried stalk of banana trees. Shashi Shankar [4] reported that banana fiber possesses good specific strength comparable to those of conventional materials, like glass fibers. Furthermore, this material has a lower density than glass fibers [5]. However, banana fibers possesses some challenges such as high moisture uptake, low thermal stability and low bonding with polymers [6].

Therefore, it is concluded that with appropriate surface treatments are required to improve the mechanical properties such as tensile strength, impact strength and hardness. An alkali treatment is the effective method to (i) remove the impurities from the fiber, (ii) decrease moisture absorption, (iii) enable mechanical bonding, and (iv) improve the matrix-reinforcement interaction [7]. Sisal fiber urea formal dehyde composites show good flexural strength and utilized in future fiber board applications [8]. Jarukumjorn et al[9] investigated about tensile and fracture toughness properties of woven sisal textile based on epoxy and vinyl-ester and reported that mechanical properties considerably affected by water absorption cycles.

Jun et al [10] reported that sisal fiber has high tensile strength and short renewable times. It is obtained from the leaves of the sisal plant (Agave sisalana). Brazil and India are the main producers of sisal fiber. Many studies have been done on the development of new composite materials using sisal fiber [11]. Recent literatures reveal that sisal fibers have the potential to be used for the production of cellulose nano particles such as nano whiskers [12]. Significant improvements in the mechanical and thermal properties were observed by incorporating sisal nano whiskers into these polymer matrices. Moreover, the reinforcing capability of sisal nano particles can be improved by chemical modification. Due to this, mechanical and thermal properties can be improved [12].

Hence, in the current research work, a new class of natural fiber based composite was developed and its mechanical properties such as tensile strength, Rockwell hardness, and impact strength were evaluated.

2. MATERIALS AND METHODS

2.1. Natural Fibers

Most recently, natural fibers have attracted the attention of scientists and technologists. Because these fibers provide so many advantages such as low-cost, low density, high specific properties etc., than conventional reinforced materials. Apart from these advantages, natural fibers are biodegradable and non abrasive. In current study, Sisal fiber and Banana fiber have been selected.

2.1.1. Sisal fiber

Sisal leaves was obtained from Agave Sisal farm, and was cut into length of 500mm sliced longitudinally and were chopped and cleaned using a benzene-ethanol mixture in a 2:1 liquid ratio by volume [11]. Sisal fiber were soaked in (NaOH) solution at desired concentration and stirred for 90 minutes. Pre-treatment of sisal with (NaOH) can partially remove the lignin and hemicelluloses which results in weight loss of Sisal fiber. After that, this alkali treated products were filtered and washed with distilled water (with pH value 6) and then dried under vacuum at 60°C to remove free water. Then it was cut to required dimensions and stored in an air tight container. The photographic image of raw Sisal fibre used for the present study is presented in Fig. 1.

2.1.2. Banana fiber

The banana stem was obtained from farm, and was cut into length of 400mm sliced longitudinally into six pieces and then these were submerged in water for 15 days, after which the stems were removed from the water and were loosened by swishing back and forth in a pool of tap water.

Fig. 1: The photographic image of raw Sisal fiber

Fig. 2: The photographic image of the raw banana fiber

They were subsequently sun dried for eight hour and further loosened by manual combing [4]. The extracted fibers were then treated with 5% sodium hydroxide (NaOH) Solution for four hours, under total immersion condition which eleminate oxidation of the fiber, after which it was washed in overflowing tap water until neutral pH is attained. Then it was cut to the required dimensions and stored in an air tight container. The photographic image of the raw banana fibre is presented in Fig. 2.

2.1.3. Resin & Epoxy

The espol 12.00 was selected for this fabrication since it is a quick curing unsaturated polyester resin based on Orthophthalic raw material for laminating purpose. Moreover, it is suitable for both hand lay-up and gun spray up.

2.2. Mould Preparation and Fabrication of Fibers

Mould is fabricated with a mallet sheet of 50*50 cm size and rubber block piece is pasted on the dimension 300mm x 300mm on four sides.

Fig. 3: Mould fabrication with a mallet sheet of 50*50 cm size

Fig. 4: The fiber arrangement on the mould

Then the fibers were weighed. According to fiber weight, the resin and hardeners were weighed. Epoxy and hardener were mixed by using glass rod in a bowl. Special care was taken to avoid formation of bubbles. Air bubbles were, usually, trapped in the matrix which causes the failure of the material. So, these air bubbles should be avoided. The next fabrication step is putting a releasing film on the mould surface. And then, a polymer coating was applied on the sheets. After that, fiber ply was put and proper rolling was done. The resin was again applied, next to it fiber ply put and rolled. Rolling was done using cylindrical mild steel rod. This procedure was repeated until six alternating fibers have been laid [1, 2]. On the top of the last layer a polymer coating is done which serves to ensure a good surface finish. Finally a light rolling was carried out. Then a 25 kgf weight was applied on the composite. It was left for 24 hours to allow sufficient time for curing and subsequent hardening. The natural composite were fabricated in the following percentage: Banana fiber 35% named as B(35), combination of Banana fiber 20% and Sisal fiber 15% named as BS(20:15), combination of Banana fiber 20% and Sisal fiber 20% named as BS(20:20), combination of Banana fiber 15% and Sisal fiber 20% named as BS(15:20) and Sisal fiber 35% named as S(35).

2.3. Tensile Test

The tensile strength of a material is defined as “the maximum amount of tensile stress that it can withstand before failure”. The tensile test is conducted in the Universal Testing Machine (UTM). The photographic view of UTM used for this study is shown in Fig. 5.The dog-bone type specimen is used. During the test a uniaxial load is applied through both the ends of the specimen. The important output of tensile test is (i) Ultimate Tensile Strength (UTS) or peak stress, (ii) Yield Strength (YS) which represents a point just beyond the onset of permanent deformation and (iii) the Rupture (R) or fracture point where the specimen separates into pieces.

Fig. 5: The photographic view of UTM used for this study

2.4. Impact Strength

Impact strength is defined as “the ability of a material to resist the fracture under stress applied at high speed”. The impact strength of composite materials is directly related to its overall toughness. The quality of fiber length is the important criteria and produce significant effect on the mechanical properties of composites. The photographic view of impact testing machine used for this study is shown in Fig. 6

Fig. 6: The photographic view of impact testing machine used for this study

2.5. Rockwell Hardness

Hardness is defined as the ability to oppose to indentation, which is obtained by measuring the stable depth of the indentation. In the Rockwell hardness test a square base pyramid shaped diamond is used for testing. Fabricated composite was cut in dimension of 20 mm × 20 mm for hardness tests. The hardness test was conducted in rockwell hardness testing machine. The load was applied 150 kgf on the composite and the holding time was 10 second. The photographic view of Rockwell hardness testing machine used for this study is shown in Fig. 7

Fig. 7: The photographic view of Rockwell hardness testing machine used for this study

3. RESULT AND DISCUSSION

3.1. Influence of Fiber Percentage on Tensile strength

The mechanical behavior of the banana and sisal fiber based epoxy composites depends on fiber percentage. The influence of fiber percentage on tensile properties of natural composites is shown in Fig. 8. It has been observed that the tensile strength of banana composites is high and sisal fiber is low. However, when sisal fiber percentage is increased, tensile strength is also increased. But, equal percentage of banana and sisal combination provides better result.

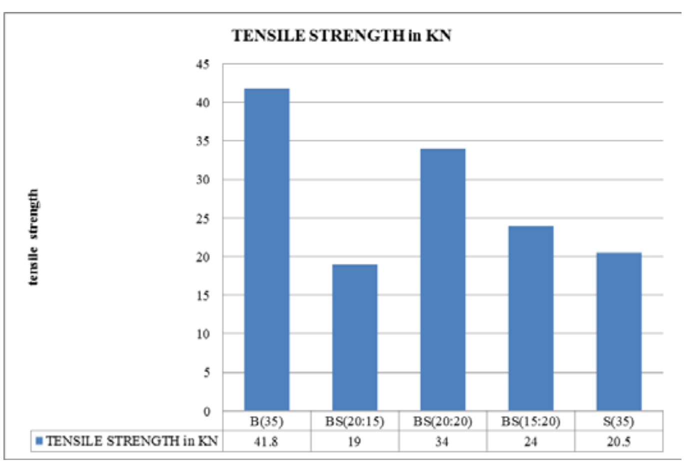

Fig. 8: Influence of fiber percentage on tensile strength

3.2. Influence of Fiber Percentage on Impact Strength

The results measured in impact tests are shown in Fig. 9. From the Fig. 9, it is observed that the impact energy is increased with increase in fiber percentage. It also show that the impact energy increases with increases in fiber loading. Unlike tensile strength, the impact energy is observed almost equal for both banana and sisal fiber. However, the maximum impact energy was absorbed for BS (20:20) fiber combination.

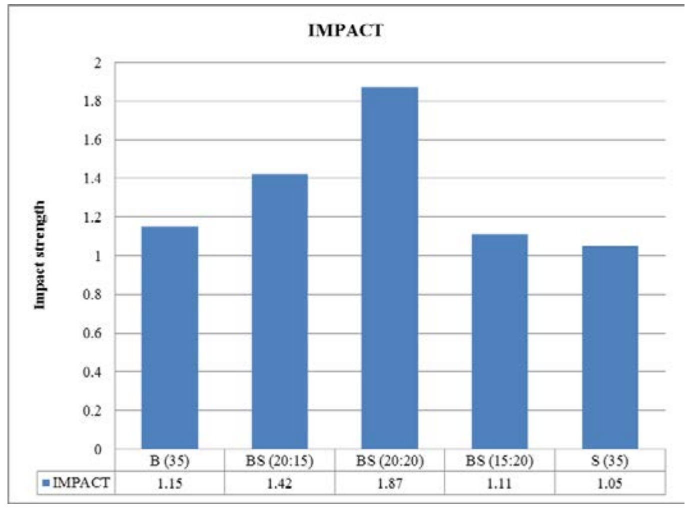

Fig. 9: Influence of fiber percentage on Impact Strength

3.3. Influence of Fiber Percentage on Hardness

The hardness values of composites are show in Fig. 10. It can be understood from the Fig. 10, that the hardness value increases with increase in sisal fiber Percentage and it is maximum BS(20:15) sample. However, with increase of sisal fiber, hardness value is increased in all samples.

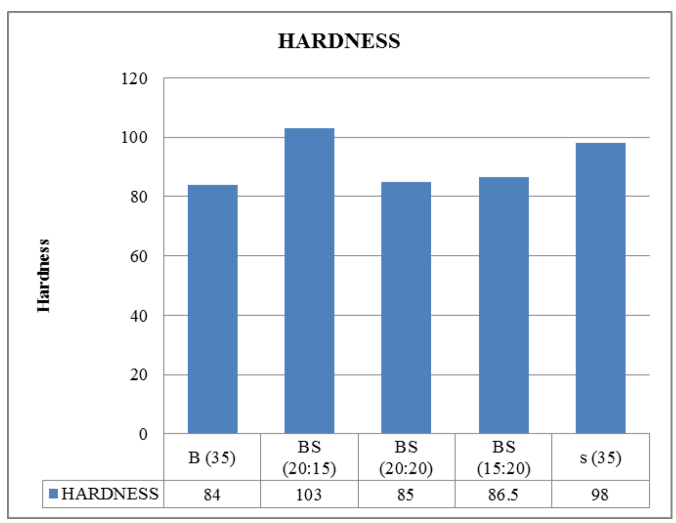

Fig. 10: Influence of fiber percentage on Hardness

4. CONCLUSION

Epoxy based sisal fiber and banana fiber composite were fabricated by hand layup process. The Mechanical testings were carried out and the following observations are concluded from this study.

- The comparison of tensile strength reveals that B(35) orientation fibers/ epoxy composite has 41.8 Mpa and exhibit higher tensile strength than all other composition of natural fiber.
- Impact test reveals that BS(20:20) possesses higher impact strength than other composition of natural fiber.
- The hardness test reveal that banana sisal BS(20:15) can withstand higher impact load than other composition of natural fiber.
- Finally it can be concluded that the equal combination of Binana- Sisal (BS) fiber provides the better mechanical properties.

5. ACKNOWLEDGEMENTS

I express our sincere thanks to P.Purushothaman, S.Satheesh Kumar, M.Udhayaneethi and Y.Vijay Kumar, Adhi College of Engineering and Technology (ACET), for their support to do the experimental study at ACET. I also wish to thank our Prof. P.Murali, ACET for his valuable suggestions and support in carrying out this work.

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