Evaluating Tensile Properties of Animal and Hybrid Fiber Reinforced Polyester Composites

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Abstract
Partially degradable composites were made with short Goat hair at different weight percentages in polyester matrix and also hybrid composite with Madar fiber and Goat hair at different weight ratios in polyester matrix using hand layup technique. The tensile properties of goat hair-polyester composite and hybrid fiber composites were evaluated. From the results, it is observed that the tensile strength of goat hair-polyester composite was increased up to a fiber content of 7.5% (24.7 MPa) and then reduced with further fiber addition in the composite. The strength of hybrid composite is increased up to 12.5% (27 MPa) madar fiber and goat hair loading and then reduced with further hybrid fiber loading. The strength of hybrid composite is 9.31% higher than the goat hair fiber composite. The tensile modulus is increased in both the composites with increase in fiber loading. The tensile modulus of goat hair fiber reinforced composite at 15% of fiber loading is high and the value is 367 MPa and for hybrid fiber it is 444.13 MPa at 15% of hybrid fiber loading which is 21.01% higher than the goat hair fiber composite. The %Elongation at break of goat hair fiber composite gradually decreased and higher value of elongation is obtained at 2.5% of the fiber loading. For the hybrid fiber it is first increased and then decreased to 4.4% at 15% of fiber loading.

Key words: Polyester, Madar Fiber, Goat Hair, Hybrid Composite

1. Introduction

Bio fibers like agave, sisal, coir, hemp, flax, jute, banana etc. are now considered to be best alternatives to synthetic fibers for reinforcing polymer composites. Natural fibers have numerous advantages over established reinforcing synthetic fibers such as carbon fiber, glass fiber etc. For applications such as the automotive, construction or packaging industries they possess high strength and toughness, light weight, non-corrosive nature, good thermal properties, low cost, low density, biodegradability and renewability [1].

The chief chemical constituents of the plant fiber are cellulose portion, hemicellulose portion and lignin. The amount of these constituents will alter from one plant to another and also from various parts of same plant based on age, species. These basic components partially determine the physical properties of the fiber. Table 1 shows an average of chemical composition of few plant fibers [2-7].

Animal fibers like wool, feathers, hair, silk etc., are said to be next most significant resource of natural fibers after plant based fibers for reinforcing composites. Even in terms of availability the animal fibers are next most important natural fiber after plant fibers. Many sources from each type of animal fibers are wool, silk, hair, and feather [8].
Table.1. Chemical composition of few natural fibers

| Fiber   | Cellulose (wt%) | Lignin (wt%) | Hemicellulose (wt%) | Wax (wt%) |
|---------|----------------|--------------|---------------------|-----------|
| Bast    | 71.0           | 2.2          | 18.6-20.6           | 1.7       |
| Flax    | 70.2-74.4      | 3.7-5.7      | 17.9-22.4           | 0.8       |
| Hemp    | 61.0-71.5      | 12.0-13.0    | 13.6-20.4           | 0.5       |
| Jute    | 31.0-39.0      | 15.0-19.0    | 21.5                | —         |
| Ramie   | 68.6-76.2      | 0.6-0.7      | 13.1-16.7           | 0.3       |
| Leaf    | 56.0-63.0      | 7.0-9.0      | 20.0-25.0           | 3.0       |
| Abaca   | 73.6           | 7.5          | 9.9                 | —         |
| Carina  | 77.6           | 13.1         | 4.0-8.0             | —         |
| Hennequin| 70.0-82.0    | 5.0-12.0     | —                   | —         |
| Pineapple| 67.0-78.0   | 8.0-11.0     | 10.0-14.2           | 2.0       |
| Seed/Fruit | 36.0-43.0 | 41.0-45.0    | 0.15-0.25           | —         |
| Coir    | 82.7           | —            | 5.7                 | 0.6       |
| Cotton  | 65.0           | —            | 29.0                | —         |
| Oil Palm| 55.2           | 25.3         | 16.8                | —         |
| Grass   | 26.0-43.0      | 21.0-31.0    | 30.0                | —         |
| Bagasse | 41.0-57.0      | 8.0-19.0     | 33.0                | 8.0-38.0  |
| Bamboo  | 39.0-45.0      | 13.0-20.0    | 15.0-31.0           | —         |
| Rice    | 35.0-45.0      | 20.0         | 19.0-25.0           | 14.0-17.0 |

Onuegbu et al. examined the consequences of animal hair fiber on properties of polyester resin. The animal hair fiber was taken from the Hausa – specie she-goat [9]. The hair fiber was added to the polyester resin which is cured with accelerator and catalyst, stirred and cast into Teflon mould. The composite specimen were cured at normal room temperature for 24 hours and then heat treated in an oven at 80°C for a period of one hour to get dimensional stability of the composite. The results depicted an increase in the tensile strength of the composite from 3% - 9% with a quick drop in 12% volume ratio. Also the tensile strength of the plain sample was higher than that of reinforced composites.

Madar fiber reinforced polymer composites were fabricated and mechanical properties were investigated [10]. In this work, newly identified madar fiber is used for making composite material the fiber is extracted from the stem by manual process. The fiber is separated into small parts and then it is mixed with polyester resin . Five plates were going to be made by 20%, 30%, 40%, and 50% by mass of the fiber. The mechanical properties of the plates such as tensile strength, compressive strength, impact strength and compressive strength of each plate were tested. Initially the tensile strength values increase from 20% fiber to 40% fiber plate and finally decreased at 50% fiber plate. The result shows that the tensile strength value is better at 60% resin and 40% fiber plate. The flexural strength value for the madar fiber increase initially from 20% fiber plate to 40% fiber plate and suddenly decreased at 50% fiber and 50% resin this implies flexural strength value is better at 60% resin and 40% fiber.

A mixture of two or more fibers in a polymer matrix will lead to hybrid composites. The probable mixtures of hybrid composites may include artificial–artificial, natural–natural fiber and natural–artificial types. They possess high strength to weight ratio, low cost and ease of manufacturing and have wide range of applications in engineering [11]. Also, these hybrid composites possess stiffness, ductility and strength that cannot be obtained by single fiber reinforced composites. They also have improved fatigue life, improved fracture toughness and lesser notch sensitivity when compared to that of single fiber reinforced composites [12].

With the combination of natural–natural and artificial–natural fibers, hybrid composites based on natural fiber may be obtained. The natural fiber itself can be considered as composite which make them tough when compared with synthetic fibers, but a rightly configured high quality natural fiber
reinforced hybrid composite can possess good strength and stiffness competitive to glass fiber reinforced composites [13].

In this work an effort is made to use hybrid natural fiber reinforcement one is from plant and the other is from animal in polyester matrix. The plant fiber used is Madar and goat hair is another fiber to form hybrid fiber polyester composite. Tensile properties of these hybrid composites were evaluated at different weight ratios of both plant and animal fibers in polyester matrix.

2. Experimental Work
2.1. Materials Used
2.1.1. Polyester
Polyester is a category of polymers that contain the ester functional in their main chain. They are exceptionally important polymers. Their well-known applications include clothing, plastic water, food packaging and carbonated soft drinks bottles. It is often known as polyethylene terephthalate (PET). polyester is purchased from Bindu Agencies, Vijayawada.

2.1.2. Catalyst
The catalyst is the agent that is mixed directly in to the polyester in a composition of 1.2ml for 100gm of resin. The job of is that it starts the curing action of the polyester composite to get set hard. The name of the catalyst used for curing of polyester is Methyl Ethyl Ketone Peroxide [MEKP].

2.1.3. Accelerator
Accelerator is also directly mixed with the polyester in combination with the catalyst MEPK. The job of the accelerator is to make the process faster. The name of the accelerator used is cobalt octate (C₁₆H₃₀CoO₄). When cobalt octate is mixed with MEKP a chemical reaction takes place and heat is evolved and it is a good and preferred combination for polyester.

2.1.4. Goat hair
Goat hair is said to be a natural fiber extracted from the skin of goat. It is Eco-friendly, Biodegradable, elastic, soft, smooth, low-cost and is abundantly available. Disposal of goat hair in tannery process is a big headache for them in waste management. Hence the goat hair can be a good choice for reinforcing polymer in the green composites.

2.1.5. Madar fiber
Madar fiber is a natural fiber extracted from the stem of Calotropis gigantean plant. Calotropis gigantean is a medium sized bush that grows up to a length of 4m with usually waxy exterior and abundant milky sap. The stem is ash colored, smooth, branching almost from the base of the plant. The leaves appear grey-green, opposite, waxy, thick and rounded-ovate.

2.2. Methodology
2.2.1. Extraction of fibers
Goat hair is obtained from local Kabela point in Vijayawada, India. The Madar fibers were extracted by retting process. The stem is cut into certain small length pieces and soaked in water for nearly 20 days and later they were beaten gently with mallet to extract the fibers from the stem.

Prior to the development of the composites, both the fibers were washed thoroughly and cut to 5mm length.
2.2.2. Preparation of mould

The moulds were prepared to fabricate the composite using hand layup technique. The moulds were prepared with rubber sheet of 3mm thickness which is cut to a size that can accommodate 5 specimens as per the ASTM D638 standard for tensile test (figure 1).

![Figure 1. Preparation of moulds](image)

2.2.3. Preparation of samples

The samples were prepared using hand lay-up technique. The goat hair fiber reinforced polyester composite and goat hair- madar fiber hybrid reinforced polyester composite samples were prepared for tensile test as per ASTM standard in six different compositions from 2.5% to 15% as mentioned in the tables 2 and 3.

| Composition | Goat Hair fiber (GHF) | Polyester |
|-------------|----------------------|-----------|
| W%          | 2.5                  | 97.5      |
| W%          | 5                    | 95        |
| W%          | 7.5                  | 92.5      |
| W%          | 10                   | 90        |
| W%          | 12.5                 | 87.5      |
| W%          | 15                   | 85        |

| Composition | Goat Hair fiber (GHF) | Madar Fiber (MF) | Polyester |
|-------------|----------------------|------------------|-----------|
| W%          | 1.25                 | 1.25             | 97.5      |
| W%          | 2.5                  | 2.5              | 95        |
| W%          | 3.75                 | 3.75             | 92.5      |
| W%          | 5                    | 5                | 90        |
| W%          | 6.75                 | 6.75             | 87.5      |
| W%          | 7.5                  | 7.5              | 85        |

2.2.4. Testing of composites

Diameter testing of fiber: Tool maker microscope is used for finding the diameter of fiber

Density testing of fiber

Fiber density is determined by using Archimedes’ principle which states that the volume of an object which is fully immersed in a fluid or to that fraction of the volume below the surface for an object partially submerged in a liquid is equivalent to volume of displaced fluid.

Tensile testing

These samples are tested for tensile property on a universal testing machine and the results are analyzed as per ASTM standards (ASTM D638). The samples are loaded on the machine and the maximum load is set to 200 kg and the load is applied and the samples were tested at a crosshead.
speed of 0.5 mm/min and the strain was measured with an extensometer of the machine. The elongation and their respective loads are noted.

3. Results and Discussion

3.1. Calculations

The diameter and densities of madar and goat hair fibers were depicted in the table 4. The density of madar fiber is about 50% higher than goat hair considered in the study.

|                  | Goat hair | Madar fiber |
|------------------|-----------|-------------|
| Diameter, Microns| 76-107    | 150-237     |
| Density, gm/cc   | 0.73      | 1.45        |

From the figure 2, it is observed that the tensile strength of goat hair reinforced polyester composite is increased up to a fiber loading of 7.5% and then reduced with further fiber loading. The tensile strength of hybrid composite is increased up to 12.5% fiber loading and then reduced with further hybrid fiber loading. The highest tensile strength of 24.7 MPa is obtained for goat hair fiber reinforced composite at 7.5% fiber loading and 27 MPa for the hybrid fiber at 12.5% of fiber loading which is 9.31% higher than that of goat hair fiber polyester composite.

![Figure 2](image-url)  

**Figure 2.** Variation of Ultimate tensile strength of goat hair fiber and hybrid fiber reinforced polyester composite with fiber loading

Form figure 3, it is observed that the tensile modulus is increased in both the composites with increase in fiber loading. The tensile modulus of goat hair fiber reinforced composite at 15% of fiber loading is high and the value is 367 MPa and for hybrid fiber it is 444.13 MPa at 15% of hybrid fiber loading which is 21.01% higher than the goat hair fiber composite.

The %Elongation at break of goat hair fiber composite gradually decreased and higher value of elongation is obtained at 2.5% of the fiber loading and the value is 8.27. For the hybrid fiber it is first increased and then decreased to 4.4% at 15% of fiber loading (figure 4).
As the fiber is much stronger than that of the matrix material, and because there is an adequate fiber-matrix interfacial bond due to the existence of hybrid fiber, it is clear that an increase in fiber content leads to increase in the composite strength. However, the trend is only up to definite quantity of fiber, after which there is insufficient polymer in the composite to provide adequate wetting of the fibers. The increase in fiber content beyond certain limit also resulted in reduction of fiber dispersion in the composite and leading to fiber-fiber interaction, which may have further contribution to the observed decrease in composite strength.

![Figure 3](image3.png)

**Figure 3.** Variation of Tensile Modulus of goat hair fiber and hybrid fiber reinforced polyester composite with fiber loading.

![Figure 4](image4.png)

**Figure 4.** Variation of % Elongation of Break of goat hair fiber and hybrid fiber reinforced polyester composite.

The results from figures 2 and 3 have shown that an increase in fiber content can greatly improve the tensile strength and tensile modulus of the composites. It is also observed that the mixing of hybrid composite increase the interface adhesion between the fiber and the matrix. Therefore, hybrid composites may be taken into consideration to modify the properties of natural fibers.
4. Conclusions

With the results obtained from the experimental procedure, the following conclusions are made.

- The tensile strength of goat hair reinforced polyester composite is increased up to a fiber loading of 7.5% and then reduced with further fiber loading.
- The tensile strength of hybrid composite is increased up to 12.5% fiber loading and then reduced with further hybrid fiber loading.
- The highest tensile strength of 24.7 MPa is obtained for goat hair fiber reinforced composite at 7.5% fiber loading and 27 MPa for the hybrid fiber at 12.5% of fiber loading which is 9.31% higher than the goat hair fiber composite.
- The tensile modulus is increased in both the composites with increase in fiber loading. The tensile modulus of goat hair fiber reinforced composite at 15% of fiber loading is high and the value is 367 MPa and for hybrid fiber it is 444.13 MPa at 15% of hybrid fiber loading which is 21.01% higher than the goat hair fiber composite.
- The %Elongation at break of goat hair fiber composite gradually decreased and higher value of elongation is obtained at 2.5% of the fiber loading and the value is 8.27.
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