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RESEARCH ARTICLE

# EFFECT OF CHEMICAL TREATMENTS ON HARDNESS AND TOUGHNESS PROPERTIES OF GREWIA SERRULATA REINFORCED POLYMER COMPOSITES

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**ABSTRACT**

Natural fiber reinforced composite materials were manufactured by reinforcing Grewia Serrulata with unsaturated polyester matrix material. To improve the adhesion between fiber/matrix interphase; fibers were treated with Silane, Acetylation and Potassium Permanganate solutions. Partially biodegradable composite materials were prepared using hand lay-up technique. Toughness and hardness of the materials were investigated according to ASTM standards. Acetylation and Silane treatment of Grewia Serrulata improved the compatibility between the matrix and the fibers and resulted in significant enhancement of hardness and impact strength.

**KEYWORDS**

Polyester, Natural fiber, Impact strength, Micro hardness, Acetylation.

## 1. INTRODUCTION

The urge for careful life cycle management of the modern-day materials used in engineering applications favors bio-degradable materials like natural fiber reinforced composites. Ease of disposal at the end of service life and less objectionable side effects augurs well for using natural fibers in making lightweight materials with good mechanical properties. Such partially or fully green materials offers ecological and economic benefits and hence are getting wide acceptance in automobiles, marine applications, sporting goods and for other light structural applications [1]. Natural fibers were becoming one of the most sought-after raw material, as they are economical, easy to process, non-allergic, biodegradable and abundantly available [2,3].

Mechanical properties of the natural fiber composites depended on compatibility between the fiber reinforcement phase and the polymeric matrix phase. Poor adhesion between two phase leads to decrement in the strength of the materials. This necessitates the modification of the interface between the natural fibers and the polymer matrices. Researchers have conducted different chemical treatments on natural fibers using alkali and coupling agents. Alkali treatment increases the surface roughness of the cellulosic fiber [4-6]. Silane coupling agent treatment used to create a strong covalent bond between the natural fiber surface and the adjacent matrix [7]. Acetylation modifies polar hydroxyl groups at the fiber surfaces and increases resistance towards moisture ingression. Oxidation treatment with Permanganate solution also inhibits moisture uptake.

Bio- based natural fibers can prospectively become reinforcement phase in polymer matrix composites for light load bearing and interior applications such as Partition walls, storage bins, boxes, false ceilings etc. However, hydrophilic nature of such fibers limits their vast applications possibility. Research work carried out on natural fibers as reinforcement in composites have proposed different fiber surface improvement methods to overcome such deficiencies [8-11]. The mechanical properties of the composites based on tensile strength and modulus of the fibers used, treatment methods used to modify the fibers, dimensions and orientation of the fibers, matrix properties, process used for forming the composites and curing methods [12-16]. In the present study, influence of treatment media and weight fraction on hardness and toughness properties of the Grewia Serrulata reinforced composites were investigated.

## 2. MATERIALS AND METHODOLOGY

### 2.1 The reinforcement fibers

In the present work, long fibers were extracted from the Grewia Serrulata tree and are used as the reinforcement material with polyester matrix. Figure 1 shows extracted bast fibers from the Grewia serrulata tree branches. The fibers were extracted by water retting process. The tree stalks were immersed in water for three days. By using metal wire brush, individual fibers were separated from the stalk. The extracted fiber surface was pretreated with Sodium Hydroxide (5%) solution. Pretreated fibers were further subjected to three chemical treatments namely silane coupling agent treatment, acetylation and oxidation treatment. Oxidation treatment was carried out with Potassium Permanganate (1%) solution. The details of treatments are reported in [17,18].

**Figure 1:** Extracted natural fibers

### 2.2 Synthesis of composite laminates

Hand lay-up technique was used to prepare unidirectional natural fiber reinforced laminates. General-purpose polyester resin (Density 1.089 g/cc) was used as the matrix material for the composite preparation. To initiate curing reaction the resin was mixed cobalt solution (2%) as accelerator and Methyl Ethyl Ketone Peroxide (2%) as catalyst. Composites were prepared with two weight fractions of fibers as reinforcement. Two laminates containing 7.5% and 15% of fiber weight fraction were prepared with two and four unidirectional mats respectively. Figure 2(a) and (b) shows preparation of unidirectional mats and composite laminates respectively.

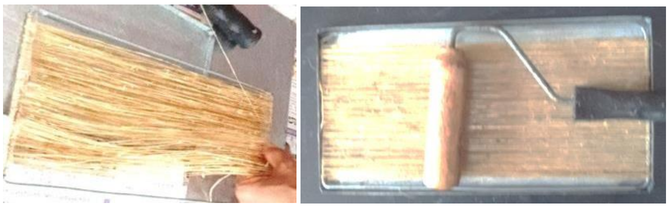

Figure 2(a) Preparation of Fiber mat, (b) Preparation of composites

### 2.3 Hardness

Hardness of a material is the resistance offered by the material to deformation, indentation, or scratching when encounters another body. Micro hardness tests are conducted to determine the hardness of the polymer reinforced composite materials. In all the hardness tests, either the load that would produce a given depth of indentation or the indentation produced under a given load is used as a measure of hardness.

### 2.4 Toughness

Toughness is the measure of energy absorbing capacity of the natural fiber composites before fracture. Measure of toughness and brittleness is obtained by conducting the impact test. The test consists of breaking standard specimen by one blow from a swinging hammer under specified test conditions. The energy absorbed by the specimen before rupture is then determined. To induce fracture under a single blow, test specimens of the composites were prepared with V-notch. The use of a notch causes high-localized stress concentration that causes most of the energy of rupture to be absorbed in a localized region of the material. Materials with high impact strength minimise the forces transmitted to the internal parts of a machine or a vehicle in the event of a sudden collision or impact.

## 3. RESULTS AND DISCUSSION

### 3.1 Micro hardness test

The micro Vickers hardness test set up uses a square based diamond pyramid as the indenter. The included angle between the opposite faces of the pyramid is 136°. Because of the indenter's shape, the impression on the surface of the specimen is a square. In the present study, to check the hardness of the specimens, a load of 100 grams was applied for 15 seconds to create the indentation on the specimen surface. Rectangular shaped specimens of 30 mm X 20 mm were cut out from the molded laminates and were subjected to micro hardness testing. The length of the diagonal of the square indentation was measured through a microscope. This in turn is calibrated by the setupto display as the hardness value of the specimen. Hardness values were recorded at three different locations on each tested specimen. The range and the mean values of the hardness of the specimens tested are shown in table 1.

**Table 1:** Hardness values of composites

| Specimen | Hardness value Hv (range) |
|---|---|
| Neat resin(Polyester) | 9-10 |
| 7.5% UT FRP | 21.7-22.68 |
| 15% UT FRP | 12.88-17.64 |
| 7.5% ST FRP | 37.82-45.21 |
| 15% ST FRP | 31.68-33.12 |
| 7.5% Ace FRP | 32.11-35.56 |
| 15% Ace FRP | 39-43 |
| 7.5% KMnO4 FRP | 18-20 |
| 15% KMnO4 FRP | 15-18.8 |

Abbreviations used: UT- Un Treated; FRP- Fiber Reinforced Polyester; Ace- Acetylated; ST- Silane treated; KMnO4- Potassium Permanganate treated. The mean values of the micro hardness of the specimens tested are shown in the figure 3. It was found that the hardness of the polyester specimen (neat resin) improves significantly upon reinforcement with the Grewia Serrulata fibers. Both Silane treatment and acetylation of fibers enhances the hardness, which could be due to plasticization effect caused during molding. The improved bonding strength between the fibers and the matrix due to Silane coupling agents and esterification caused due to acetylation have resulted in enhanced surface hardness.

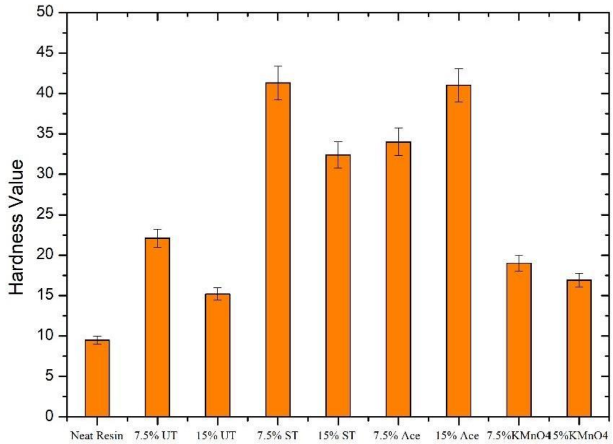


**Figure 3**: Mean values of hardness

### 3.2 Impact test

Charpy impact tests were performed on rectangular specimens prepared with V-notches at the centre. Tests were performed adapting ASTM D-256 standards. Specimens of 63.5 mm X 12.7 mm with V-notch at the center. Jig saw machine was used to prepare the samples. The impact strength of the specimens was calculated by equation (1) and shown in table 2.

$$\text{Impact strength} = \frac{\text{Energy absorbed}}{\text{Cross Sectional area below the notch } (S_O)} \quad (1)$$

Where $S_O$ = Cross sectional area of test piece below the notch, measured before the test.

The results show that the toughness of the neat resin specimen, which is indicated by the impact strength, increases upon fiber reinforcement. The fiber fraction also affects the impact strength. An increase by about 4.5 times in impact strength was observed with 15% Acetylated and Silane treated fibers reinforcement in comparison to neat resin specimens. The ability of natural fibers in absorbing impact energy resulted in higher impact strength as the percentage of reinforcement increases. The improvement in adherence between the acetylated fibers and the matrix have enhanced the shock absorbing behavior of the specimens. The higher values of impact strength are attributed to better interfacial bonding as a result of improved mechanical interlocking between the treated fibres and polyester resin due to increased roughness of the treated fibres. Similar results were reported in a research carried out using sisal fiber reinforced epoxy polymer composites [19].

**Table 2:** Impact test results

| Specimen | Impact strength (kJ/m$^2$) |
|---|---|
| Neat resin (Polyester) | 8.34 |
| 7.5% UT FRP | 18 |
| 15% UT FRP | 30 |
| 7.5% ST FRP | 22 |
| 15% ST FRP | 48 |
| 7.5% Ace FRP | 34 |
| 15% Ace FRP | 50 |
| 7.5% $KMnO_4$ FRP | 23 |
| 15% $KMnO_4$ FRP | 32 |

## 4. CONCLUSIONS

In the present research work natural fiber, reinforced polyester composites were prepared and hardness and toughness were estimated. The following conclusions were drawn from the study;

- The chemical treatment of Grewia Serrulata fibers changes the surface morphology of the fiber. The hardness of acetylated and Silane treated fiber reinforced composites shown significant improvement as compared to neat polyester resin specimen hardness as well as untreated fiber reinforced composite.
- Impact strength of polyester matrix material can be enhanced by reinforcing them with Grewia Serrulata fibers. The increase in impact strength of acetylated and silane treated fiber reinforced composites is about five-fold times higher than neat polyester resin specimens and about 1.85 times higher than untreated fiber reinforced composites.
- Potassium permanganate treatment of Grewia serrulata fibers before the fabrication of the polyester matrix composites has less significant effect on their impact strength and hardness.
- Results shows that Grewia serrulata fiber reinforced polyester composites can be used in interior applications of automobiles such as door trims, flaps, dashboard trays etc.

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