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EFFECT OF SURFACE TREATMENTS ON MECHANICAL &TRIBOLOGICAL BEHAVIOR OF THE COCONUT SHEATH REINFORCED POLYESTER COMPOSITES

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ABSTRACT

The results of experimental investigation on impact test and dry sliding wear of unsaturated polyester resin (USP) reinforced with natural woven coconut sheath treated with various chemicals has been given in this article. Among the various treatments, Sodium Hydroxide and Potassium Permanganate treatments enhanced the properties very well. The density and hardness of the coconut sheath reinforced composite was studied and its tribological behavior was tested on pin-on-disc sliding wear tester. For different sliding velocity and load, mass loss was determined. The chemically treated fiber reinforcement showed greater increase in mechanical properties of the composite in comparison to untreated fiber reinforced composite. Furthermore, the investigation showed that inter laminar adhesion was increased due to the chemical treatments on fiber.

Keywords: *Coconut Sheath; Impact and Wear; Polymer Composites; Chemical Treatments*

1. Introduction

Over the last thirty years composite materials, plastics and ceramics are the dominant rising materials. The degree and range of applications of composite materials have big, steady, penetrating and gaining control over new markets unrelentingly. Fashionable composite materials represent a major proportion of the designed materials market starting from everyday merchandise to stylish niche applications. Whereas composites have already well-tried their value as weight-saving materials, this challenge is to create them price effective. The efforts to supply economically engaging composite parts have resulted in many innovative producing techniques presently getting used within the composites business. It’s obvious, particularly for composites, that the advance in producing technology alone isn't enough to beat the price hurdle. It’s essential that there be an integrated effort in style, material, process, tooling, quality assurance, producing, and even program management for composites to become competitive with metals.

Natural fibers have gained attention of the researchers around the world. They can be used as an alternative to glass fibers as reinforcement in composite materials for their low cost, recyclability, low density and high strength to weight ratio [1, 2].

Fiber matrix interface influences the mechanical properties of the composites [3, 4].Chemical treatments of fiber enhance the interlocking between fiber and matrix which gives good resistance against breakage[5]. Also, the interfacial strength can be improved by using different coupling agents which in turn improves the mechanical properties of the composites.

Fig. 1 Naturally woven coconut sheath

In general natural fibers have a good potential for chemical treatments due to the presence of the hydroxyl groups in lignin and cellulose [12].

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Wear can be defined as the unwanted loss of material or deformation of the solid surface due to mechanical interaction [6]. Wear is strongly influenced by the density of the composite and sliding distance. The orientation and the dimension of the fiber affect the abrasive behavior of the composite [13].

Impact test is done to determine the energy needed to fracture the composite and can be used to measure the toughness of the material which depends on the density of the material.

2. Experimental Details

2.1 Materials

Unsaturated polyester resin was used as matrix, Methyl Ethyl Ketone Peroxide (MEKP) as catalyst and Cobalt Naphthenate as accelerator. Naturally woven coconut sheath was collected from the coconut farms in the region. The coconut sheath is shown in FIG.1. Sodium hydroxide, calcium hydroxide, potassium permanganate and benzoyl chloride were supplied by Thomas baker, Mumbai.

2.2 Fabrication

Coconut sheath is taken from coconut tree. They were irregular in shape and size. We brought them to the required size of 30×12.8 cm (i.e.) size of mold.The mold surface is coated with mansion wax polish.

Table 1. Formulations of composite specimens

Composites (wt %)	Specimen code	Unsaturated polyester (Wt %)	Coconut sheath (Wt %)
Coconut sheath fiber – USP	UT	54	46
Coconut sheath fiber USP - $Ca(OH)_2$ treated	CT	50	50
Coconut sheath fiber USP - NaOH treated	NT	52.5	47.5
Coconut sheath fiber USP – Benzoyl chloride treated	BT	51	49
Coconut sheath fiber USP – $KMnO_4$ treated	PT	51.2	48.4

Then a mixture of 200ml resin, 3ml catalyst and 3ml accelerator is taken in a beaker. The coconut sheaths were kept one by one in the mold with resin spread in-between each layer. The mold is closed and placed in compression molding machine with minimum pressure of 170 kg/sq.cm for 12 hours. After curing, the specimen was taken out and cut into dimensions according to the ASTM D256 Standard for Impact testing. The fabricated composite is shown in FIG. 2 and the weight percentage of each composite with specimen code is shown in table 1.

Fig. 2 Fabricated Composite

2.3 Surface modifications

2.3.1 Calcium hydroxide treatment (Alkali)

The coconut sheath is treated with calcium hydroxide[$Ca(OH)_2$] to remove the impurities present in it. The coconut sheath is kept immersed in 1N (74g) calcium hydroxide solution for an hour and washed with distilled water thoroughly. Then they are dried in sunlight for minimum 24 hours and used for fabrication of composite.

2.3.2 Potassium Permanganate Treatment

Fibers are first alkali treated with calcium hydroxide for 1 hour. It is then washed with distilled water and dried in sunlight for 24 hours. Acetone and potassium permanganate are mixed with water (2g $KMnO_4$ + 20ml of acetone for 980ml of water) [8]. The alkali treated sheaths are kept immersed in the mixture for 10 mins [7]. The sheaths are then kept in a thermostatic water bath for an hour at a temperature of 50°C. The sheaths are taken out, washed with distilled water and dried in sunlight. The dried sheaths are ready for fabrication.

2.3.3 Benzoyl chloride treatment

Alkali treated fibers are agitated in benzoyl chloride solution for 30 mins. It is then treated with ethanol to remove the unreacted benzoyl chloride in the fiber [9]. The sheaths are taken out and washed with distilled water and dried in sunlight for 24 hours.

2.3.4 Sodium Hydroxide Treatment

The coconut sheath is treated with sodium hydroxide (NaOH) to remove the contaminants (lignin, wax) present in the coconut sheath. The coconut sheath is kept immersed in 1N (40g) sodium hydroxide solution [1, 7] for an hour and washed with distilled water. Then they are dried in sunlight for minimum 24 hours and used for fabrication of composite.

2.4 Test details

Impact test was carried out in anIzod-charpy impact tester (Make: Deepak Poly Plast Pvt.Ltd.) at room temperature with a known load of 3.567kg. The sample dimension was taken according to ASTM D256 which is 65×13×3mm.

Wear test was conducted on a pin-on-disc (as per ASTM G-99 standard, Make: Magnum Engineers, Bangalore) as shown in FIG.3. Sliding was performed under ambient conditions over a particular period of time for different sliding velocities with abrading distance of 3000m and applied load of 10N. The different sliding velocities are 2, 3, 4m/s. The pin assembly was initially weighed in an electronic balance (SHIMADZU AUX 220). The difference between the initial and final weights of the pin assembly is the measure of wear loss. Nine samples were run for each treated composite with various test parameters and readings were tabulated. The loss in weight of the specimen is the measure of wear which was then converted into wear volume using the measured density data. The specific wear rate (K_s) was calculated from the equation:

$$\boldsymbol{K_s = \frac{\Delta V}{L \times d} \frac{m^3}{Nm}}$$

$\boldsymbol{where\ \Delta V\ is\ the\ volume\ loss\ in\ m}^3$, L is the load in Newton and d is the sliding distance in meters.

The Coefficient of Friction (F_f) was calculated from the equation:

$$\boldsymbol{F_f = \frac{F}{N}}$$

Where F is the Frictional force occurred in Newton and N is the applied load in Newton.

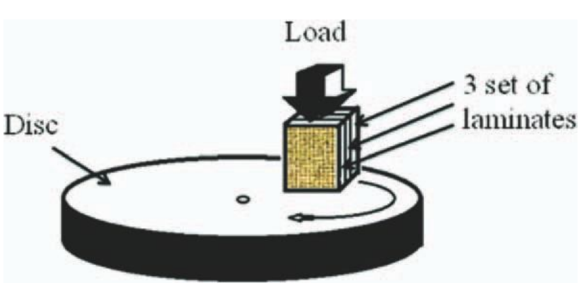


Fig. 3. Rotating disc with composite sample

3. Results and Discussion

3.1 Hardness (Shore D) of composites

The Shore D hardness of the composites for different chemical treatments is given in table 2. It was seen that the value of shore hardness of the composite decreased from 88 (only resin) to 71.54 (UT).This indicated the coconut sheath significantly decrease the load carrying capacity of the coconut sheath reinforced USP. The chemical and physical composition of the natural fibers such as cellulose content, cross section, and structure of fiber and angle of fibrils determine its physical properties [11]. The chemical treatments showed change in the hardness of the coconut sheath reinforced USP as shown in table 2.

3.2 Impact Test

The Impact strength of different chemical treated coconut sheath reinforced USP composite is shown in FIG. 4. It shows that NT composite gave the best result with Impact strength of 32.1 KJ/m^2. The improved impact strength was further enhanced by means alkali wash[$Ca(OH)_2$]followed by Potassium

TABLE 2. Mechanical properties of composites

Properties	USP	UT	CT	NT	BT	PT
Density (g/cm^3)	1.2	1.059	1.133	1.489	1.105	1.337
Hardness (shore D)	88	71.54	80.18	67.4	74.24	78.98

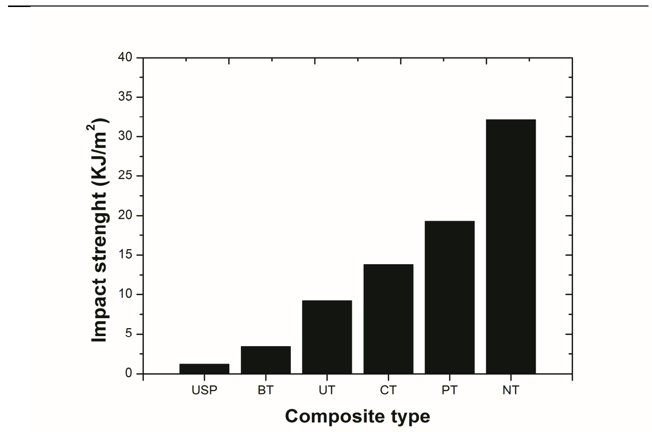


Fig. 4. Effect of Surface Treatment on Impact Strength

permanganate treatment. An average of 50% improvement in impact strength was achieved for coconut sheath-reinforced composite when compared to untreated composite. The coconut sheath –reinforced composites holds superior impact strength over the glass fiber composite [1]. The Impact strength is given by the formula,

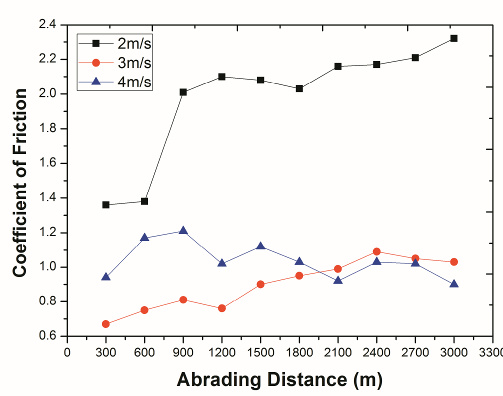
$$\textbf{Impact Strength} = \frac{\textbf{Energy Absorbed}}{\textbf{Cross Sectional Area}} \frac{\textbf{KJ}}{\textbf{m}^2}$$

3.3 Dry sliding wear

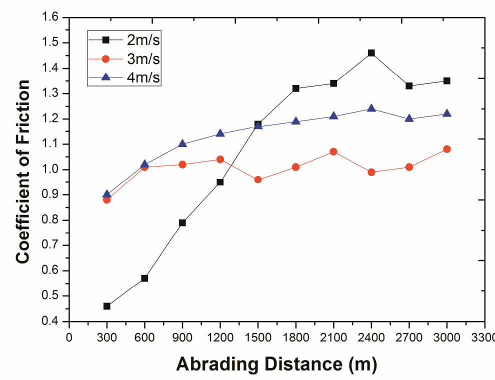
3.3.1 Coefficient of friction

The change in coefficient of friction with abrading distance for various chemical treated coconut sheath reinforced USP composites is given in FIG. 5 and FIG. 6. The surface roughness of the steel surface on which the composite slides is 0.54 µm (Ra).With constant applied load and abrading distance, the coefficient of friction for untreated coconut sheath reinforced USP composite [FIG.5.(A)] reached a maximum of 2.32 for 2m/s. The minimum friction coefficient observed was 0.67 for 3m/s. The increase in coefficient of friction was steady till 900m after which a drop was noticed for all the three sliding velocities. The friction coefficient for 4m/s decreased gradually giving a final friction coefficient of 0.9 at 3000m which is lower than its initial value.

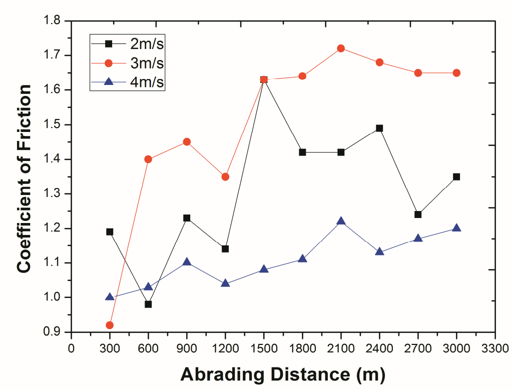
In case of Sodium hydroxide treated coconut sheath reinforced USP composite [FIG.5.(B)], the friction coefficient increased greatly for 2m/s from 0.46 to 1.35.It was the maximum coefficient of friction observed for NT composite. For 3m/s the fiction coefficient kept on increasing but for 4m/s slight drops were seen at 1500m and 2400m.



(A)



(B)



(C)

Fig. 5 Effect of untreated USP composite on wear (A) UT (B) NT (C) CT

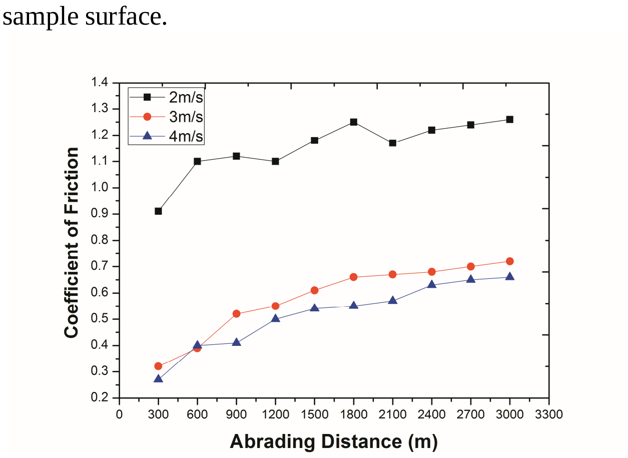
In case of Sodium hydroxide treated coconut sheath reinforced USP composite [FIG.5.(B)], the friction coefficient increased greatly for 2m/s from 0.46 to 1.35.It was the maximum coefficient of friction observed for NT composite. For 3m/s the fiction coefficient kept on increasing but for 4m/s slight drops were seen at 1500m and 2400m.

Calcium hydroxide treated coconut sheath reinforced USP composite [FIG.5.(C)] showed a different trend in coefficient of friction with respect to the abrading distance. For 2m/s, the friction coefficient increased abruptly that reached a maximum of 1.63 at 1500m.For 3m/s, a notable drop was at 1200m. For 4m/s, sudden increase was observed at 900m and 2100m. The maximum and minimum value recorded for CT was 1.65 and 0.92 respectively for 3m/s.

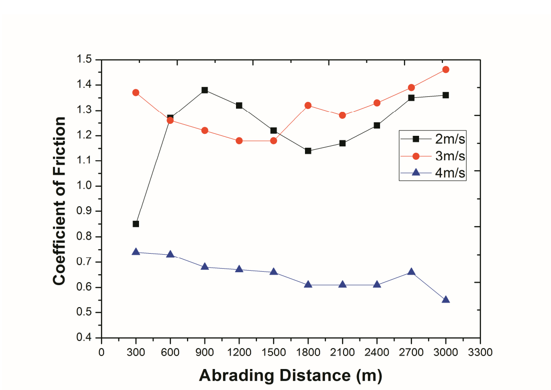
Potassium permanganate treated coconut sheath reinforced USP composite [FIG.6.(D)] showed similar trend for all the three velocities that kept increasing. The maximum coefficient of friction was 1.26 for 2m/s and the minimum was 0.27for 4m/s. significant increase was observed at 600m and 1500m for 2m/s.

In Benzoyl chloride treated coconut sheath reinforced USP composite [FIG.6.(E)], the coefficient of friction for 2m/s increased till 900m and then decreased till 1800m which then increased again. The maximum value for 2m/s was 1.38 at 900m. For 3m/s, the friction coefficient dropped till 1500m and then increased till the end. A steady decrease in coefficient of friction was observed for 4m/s from 0.74 to 0.55.

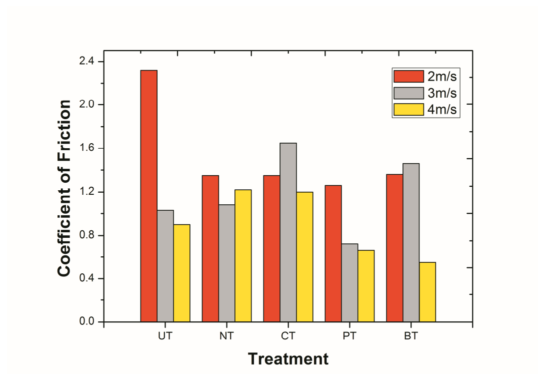
The coefficient of friction of all the composites is compared in FIG.6. (F). It can be seen that the maximum friction coefficient was for untreated composite at 2m/s. untreated and potassium permanganate treated composites showed similar trend that decreased with increasing sliding velocity due to the protective layer formed by the wear debris on the sample surface.



(D)



(E)



(F)

Fig. 6. Effect of untreated USP composite on wear (D) PT (E) BT (F) Comparison

3.3.2 Specific wear rate

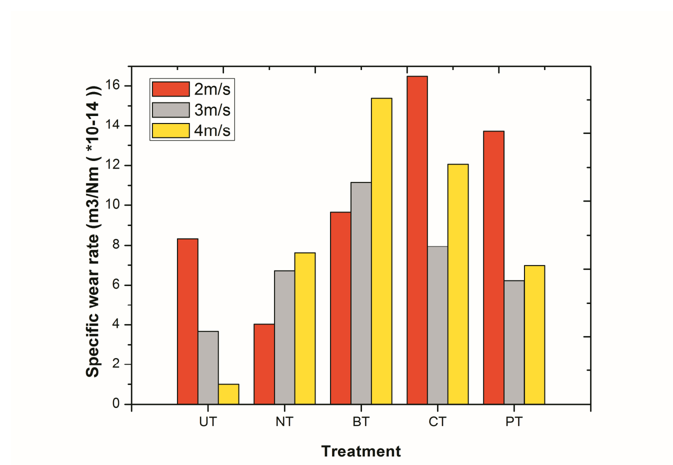


Fig. 7. Comparison of specific wear rate

Likewise, CT and BT were similar in which the maximum friction coefficient was for 3m/s. In NT, the minimum value was observed for 3m/s followed by 4m/s and 2m/s.

The comparison of specific wear rate of various chemical treated coconut sheath reinforced USP composites is given in FIG. 7.CT gave the maximum wear rate of 16.478 for 2m/s and minimum was 1 for 4m/s in UT. The trend showed was similar to comparison chart of coefficient of friction. UT's specific wear rate decreased with increasing velocity.

For NT and BT, the wear rate was proportional to the sliding velocity. CT and PT showed maximum wear rate for 2 m/s followed by 4m/s and 3m/s. This phenomenon was due to the formation of protective layer for 3m/s by the wear debris that smoothened encountering sample surface. As a result, the wear rate was reduced.

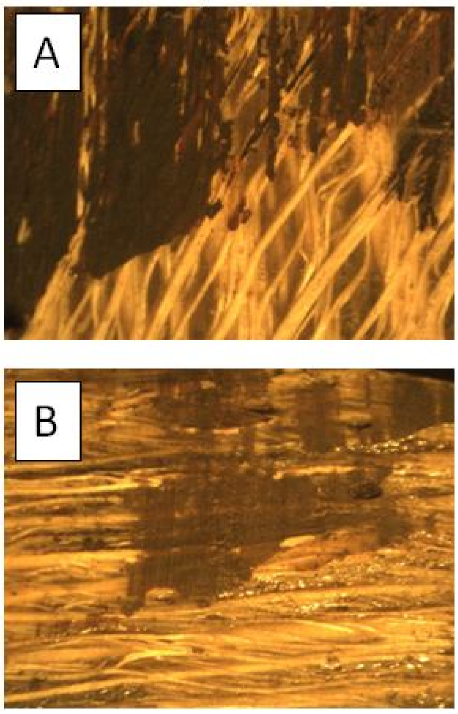


Fig. 8 Microscopic image for wear; (A) and (B)

But for 4m/s, away thereby not allowing the formation of protective layer and so the wear rate increased than for 3m/s. The minimum value for each velocity is as follows: 2m/s – 4.0295(NT), 3m/s – 3.67(UT) and 4m/s – 1(UT) and the maximum is: 2m/s – 16.478(CT), 3m/s – 11.16(BT) and 4m/s –15.38(BT). The microscopic image of sample surface after testing is given in FIG.8.

4. Conclusions

The mechanical and tribological properties of the coconut sheath reinforced USP matrix composites are investigated. The effect of surface-modified fibers using various chemical treatments (CT, BT, PT, and NT) on the tribological behavior has been discussed. The following conclusions were drawn:

Alkaline treatment removes waxylayers and other impurities and enhances the possibility of deposition of chemicals (Benzoyl chloride & Potassium permanganate) on fiber surface.

Naturally woven coconut sheath-reinforced composites could be used as a suitable replacement for the conventionally used glass fibers reinforced composites.

Tribological performances strongly depend on the test parameters (sliding distance, applied load, and sliding velocity).

All the properties such as density, hardness, impact and wear was improved in potassium permanganate and sodium hydroxide treated when compared to other treated fiber composites.

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