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FIBER SURFACE MODIFICATION EFFECTS ON TRIBO PROPERTIES OF LUFFA/USP COMPOSITES

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ABSTRACT

Tribology investigation is one of the most important studies in natural fibers. In this studies using pin - on - disc wear tester the tribological behavior were tested and also mechanical, dry sliding wear behaviors of unsaturated polyester resin (USP), reinforced with natural luffa fibers were experimentally investigated. The chemical, physical and mechanical properties for luffa fiber were studied. For the luffa fiber composites the wear rate differentiations of 2, 3, 4m/s velocity for the 10N, 20N, 30N varying load with the different speed of 318rpm, 477rpm, and 637rpm for the same distance 3000m was determined. Wear rate, hardness, density difference between the NaOH, Trichlorovinyl Silane and Ca (OH)2 treated fiber composites are tabulated. Wear condition in tribological system and the wear mechanism in wear process these both things mainly depends on the analysis of surface topographies of wear components. Surface topographies are interface separation, inclined fracture of fibers, loss of matrix and etc.,

***Key words**: Luffa composite – alkali - Ca (OH)2 - silane - wear.*

1. Introduction

There are much ways to collect or produce the natural fibers from the environmental sources. And also by many ways the natural fibers were used with composite materials [1]. For making strong some treatments were done in natural fibers and increasing the curing time for the composites preparing. To know the properties of that fibers and composites some tests were conducted in that [2]. From those tests more things about those composites as well as the fibers were determined. In the luffa fiber for some different variables (NaOH treated, Silane treated, and untreated) were conducted the Chemical test as well as physical tests for finds out the contents what are all available in the natural fibers like cellulose, ash, moisture, lignin, and wax contents and to find out the tensile strength of the fibers as shown in Table. 1. Already there are much research has been reviewed on composites containing synthetic fibers such as polyester, glass, asbestos, carbon, Kevlar, etc [3]., but now the synthetic fiber replaced with natural fiber such as banana sisal, pineapple, palm tree, coconut sheath, luffa, etc., for produce the environmental friendly materials. Generally composites can be defined as the multifunctional material systems that provide characteristics not obtainable from any discrete material. Usually the composites are prepared based on the calculation of weight fractions or volume fractions. So weight fractions of the composites are equal to the sum of the weight fraction of resin & weight fraction of the fiber.

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Table 1. Chemical and physical properties of luffa fiber

Properties	Untreated (%)	NaOH treated (%)	Silane treated(%)
Cellulose	81.73	83.69	73.92
Lignin	15.55	11.39	21.89
Wax	0.24	0.37	0.48
Ash	1.79	4.70	4.74
Moisture	9.78	9.82	9.75
Density at room temp (g/cc)	1.2469	1.3373	1.3098
Tensile strength	1.74989	1.82339	0.76266

Weight fraction of the resin:
wr = Wr / (Wr + Wf) *100,
Weight fraction of the fiber:
wf = Wf /(Wr + Wf)*100.
Weight fraction of the composite:
wc = wf + wr.

Where, Wr = Weight of Resin, Wf= Weight of fiber, wr = weight fraction of the resin, wf = weight fraction of the fiber, wc = weight fraction of the composite. The mechanical testing of the composites will helpful to know about the mechanical properties, the application and advantages of those composites. The composite which is reinforced with natural fibers, tensile strength is four to six times greater than that of Steels or Aluminums [4]. Now a day these kind of composites are mostly used in our usual life like Building and construction industry: panels for partition and false ceiling, partition boards, wall, floor, window and door frames, roof tiles, mobile or pre-fabricated buildings which can be used in times of natural calamities such as floods, cyclones, earthquakes, etc. Storage devices: post-boxes, grain storage silos, bio-gas containers, Furniture, Electronic devices, every day home appliances, etc.

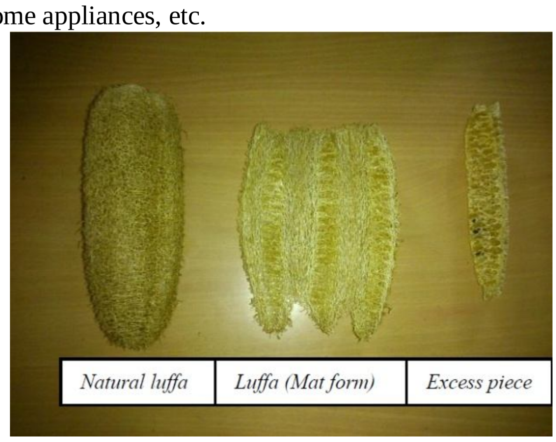


Fig 1. Photograph of luffa fiber used in this study

Tribology can be defined as the study about the friction, wear, lubrication of interacting surfaces in relative motion. The study of the process or mechanism of the wear is part of the discipline of tribology [10]. Commonly wear mechanism or process of tribology can be classified as following five types, 1) adhesive wear, 2) abrasive wear, 3) surface fatigue, 4) fretting wear & 5) erosive wear. From these all classification in this studies were conducted the wear behavior of luffa composites in surface fatigue type using pin – on – disc wear tester for variable velocities, variable loads with some variable speed.

2. Experimental Details

Materials

Luffa in the form of mat used as fiber, which is randomly taken from the nature. Unsaturated polyester (General Purpose grade: SBA2303) was used as resin. Methyl ethyl ketene peroxide (MEKP) as catalyst and cobalt-naphthenate as accelerator were used. Trichlorovinyl silane, sodium hydroxide and calcium hydroxide were used as chemicals for treatments which are supplied by Sigma-Aldrich, Bangalore and Modern Scientific centre, Madurai. The photograph of the fiber used for this work as shown in Fig. 1.

Surface modification

In this study luffa fiber were used as four types of modifications 1) Untreated 2) NaOH treated 3) Trichlorovinyl silane treated 4) Ca (OH)2 treated. In untreated type there is no change in that simply take the natural luffa as shown in Fig. 1 and cut it in the form of mat. Then we were reinforced the mat with unsaturated polyester.

NaOH treatment

Initially the mat form of luffa fiber clearly washed with distilled water and dried in room temperature still it get dried that is approximately 12 hour. The NaOH solution made by the ratio of 40gm/lit. 40gm of sodium hydroxide and a liter of distilled water then dried luffa fiber were immersed in that NaOH solution for an hour sharply. After taken out from the solution again washed with distilled water then dried in sunlight for minimum 12 hour.

Silane treatment

Silane treatment means that is the continuation or add sum more process to the NaOH treatment, is known as Silane treatment. In this study about the silane treatment, immerse the dried NaOH treated fiber into the Trichlorovinyl silane solution which is made by the ratio of 3drops per liter. 3 drops of Trichlorovinyl silane and 1 liter of distilled water with the pH value of 3.5 for sharply 1 hour then next taken out from the solution and dried in sunlight without washing for minimum 12 hour.

Ca (OH) 2 Treatment

Ca (OH) 2 treatment as same as NaOH treatment the only one change is instead of NaOH in this treatment Ca (OH) 2 was used and the ratiois 74gm/lit. That means 74 gram of calcium hydroxide and that same 1 liter of distilled water then the clearly washed normal fiber in the form of mat were immersed into the solution for an hour and taken out and washed with distilled water and dried in sunlight for minimum 12 hour.

Table 2. Formulation of composite specimens.

Composites	Fiber wt(gm)	Comp wt(gm)	Fiber wt%	Resin wt%
Untreated	36	122	29.5	70.5
NaOH treated	42	139	30.2	69.8
Silane treated	39	130	30	70
Ca(OH)2 treated	38	128	29.6	70.4

Fabrication method of the composites

Compression molding process was used to fabricate the natural luffa reinforced polyester composites. Natural luffa fiber was cut to the dimension of 150 × 150 mm2 and prepare 2 sets of 4 layers totally 8 layers of luffa were prepared. In this molding process the size of 300 × 150 mm2 close mold was used. And the releasing agent was protecting the mold cavity. Initially the releasing agent was applied on the closed bottom, middle and top piece of the mould then followed by unsaturated polyester resin and that prepared 8 layers of luffa. The standard pressure of 175 kg/cm2 load was applied for compressing. After the 3 hour of compressing the mould was brought out from the compression machine, the specimen is taken out from the mould and cut into the dimensions according to the ASTM D3039 standard for mechanical testing. As per the fiber wt% ratio the composites were prepared refer the Table 2.

Test details

Mechanical tests

The test for impact strength of luffa fiber reinforced unsaturated polyester composite was conducted at room temperature using a IZOD – CHARPY IMPACT TESTER with the constant mass of 3.567kg. From the each sample two pieces were taken for testing and the average value considered as a final result. Using a shore D hardness tester the shore hardness of composite also determined at five different points of the composite and the average value is considered as a final value. Some of the mechanical properties conducted in the composites are tabulated in Table3.The surface fatigue wear test was carried out on a pin on disc (as per ASTM G-99 standard,

Table 3. Mechanical properties of composite

Properties	Untreated	NaOH treated	TCV Silane treated	$Ca(OH)_2$ treated
Impact strength	0.081	0.10305	0.1	0.119
Hardness (shore D)	61.68	73.06	72.9	79.4
Density (g/cm^{-3})	1.1117	1.2013	1.2013	1.2149

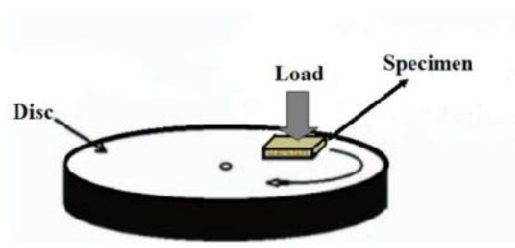
Make: Magnum Engineers, Bangalore) wear tester. The sliding was processed for the different velocity under the conditions over a period of 25 min at a sliding velocity of 2m/s, 16.40 min at a sliding velocity of 3m/s, 12.30 min at a sliding velocity of 4m/s. The standard temperature and humidity was respectively 23°C and 50±5%. The dimension of the specimen is 10 mm × 10 mm × 3mm. the surface of the specimen had a contact with a hardness alloying steel disc on a pin on disc wear tester with the hardness value of 68HRC.

The surface of the specimen was placed parallel to the alloying steel disc at sliding direction as shown in Fig 2. Before placed, the surface of the specimen and disc were cleaned with a emery paper soaked in acetone and thoroughly dried. The specimen was assembled by the use of gum with the pin for getting connects to the load. Then the test has conducted for the different loads of 10N, 20N, and 30N at the various velocities of 2m/s, 3m/s, and 4m/s with the different speeds of 317rpm, 477rpm, and 637rpm to the same sliding distance of 300m to 3000m. Before the testing and after the testing the weight of assemble (specimen, gum, pin) was measured. The difference between those two weights is considered as sliding wear loss. The wear has measured from this parameter only. Finally the specific wear rate was calculated from the following equation

$$Ks = \Delta M/\rho \times L \times D$$

Where, Ks is the specific wear rate, is the sliding wear loss, = Density in kg/m3, L is the Load in Newton, D is the sliding distance in Meter.

Fig 2. Rotating disc with composite specimen



The density of the composite was taken out is dipped into the water was threaded on the hanger. While dipped into the water the thread has some water content by the principle of porosity. Weight of this arrangement is taken and considered as a weight of the hanger. Then the specimen has attached with that thread then again measure the weight. The density of the composite was determined by the following formula

$$e = a/(a + b - w)$$

Where, e = Density in kg/m3, a = weight of the specimen in air, b = weight of the specimen in water + weight of the hanger, w = weight of the hanger.

3. Results and Discussion

As tabulated on the Table 3 the Ca(OH)2 treated fiber gets the better mechanical properties than

NaOH treated, Trichlorovinyl silane treated and Untreated fiber.

Impact strength of composites

The impact strength of the Untreated, NaOH, TCV Silane, Ca(OH)2 treated were taken for 2 samples from each. From that average values are 0.081, 0.1, 0.103, 0.119 respectively. By the use of NaOH treated fiber only the TCV Silane treated had done. But the result of TCV Silane treated fiber is not better than the NaOH treated. TCV Silane treated fiber didn't gained more than NaOH treated fiber. Compared to untreated and all treated the Ca(OH)2 treated fiber gave the best result in Impact strength of composites as shown in fig 4. untreated, NaOH treated, TCV Silane treated,hardness values were taken and the average value was tabulated on table 3. And the graph was plotted and shows on fig 5. The hardness value of Ca(OH)2 treated fiber composite has increased.

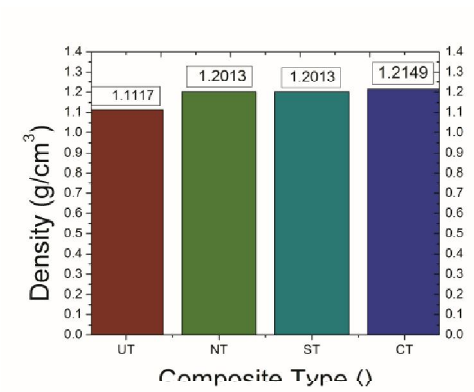


Fig 3. Comparison for Density of Untreated and 3 treated

Hardness (shore D) of composites

Table 3 tabulates the shore D hardness values of the luffa fiber USP composites for different treatment variables. From the each treatment composite five different places the From 58 to 67, 71 to77, 68 to 76, 78 to 82 respectively. Alkali solution treatment decreases the wax content of the fiber so the hardness of the fiber gets increased than untreated. While the fiber tends to TCV Silane treatment the properties of the composite gets decreased from alkali treated but increased than untreated. The hardness value of the fiber depends upon the physical and chemical properties of the fiber, those properties determined by the composition of both.

Density

Fig 3, Fig 4, Fig 5 shows that, the variations of mechanical properties for every treatment. Porosity of the fiber composite is varying for each treatment. untreated fiber composite has low porosity and the Ca(OH)2 treated is high. NaOH and silane treated is slightly higher than the untreated. May be, Because of the moisture content the porosity property of the fiber composite gets varied.

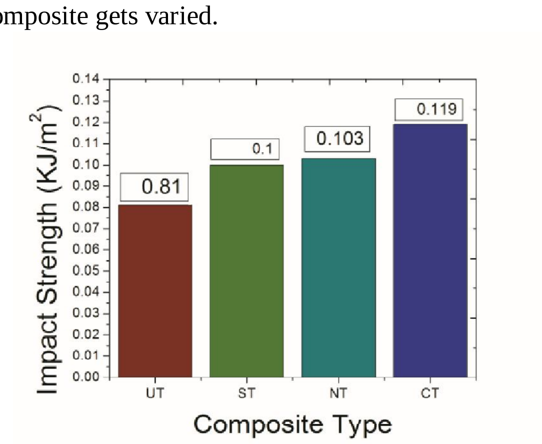


Fig 4. Comparison for Impact strength of Untreated and 3 treated.

Mechanical properties (Impact, hardness, density) of the fiber composite helped to finds out the load carrying capacity of the composite which is most used for applications.

Dry sliding property

The coefficient of friction

For the 10N load & the variable velocity (2m/s, 3m/s, 4m/s) the variation of co efficient of friction with respect to the sliding distance on hardness steel surface roughness of 0.54μm (Ra) for 4 variables of (Untreated, 3 treated) luffa fiber reinforced unsaturated polyester composites are shown in fig 6, 7, 8, 9. At the velocity of 2m/s for 300m of the sliding distance the co efficient of friction of the 4 variables (UT, CT, ST, NT) are 0.5, 0.7, 0.79, and 0.9 respectively. NaOH treated fiber gain the best result in tribological behaviour.

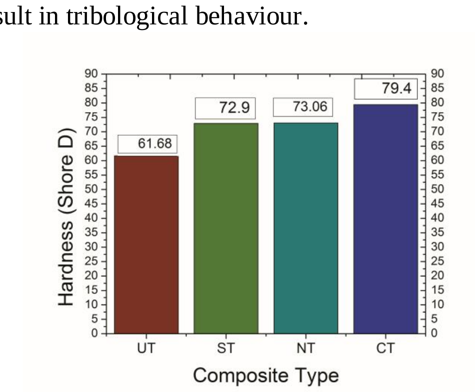


Fig 5. Comparison for hardness (shore D) of Untreated and 3 treated.

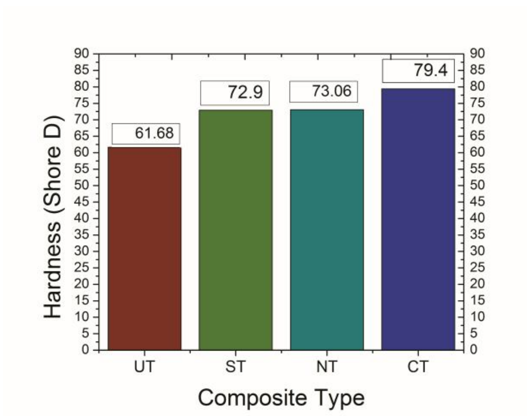


Fig 5. Comparison for hardness (shore D) of Untreated and 3 treated.

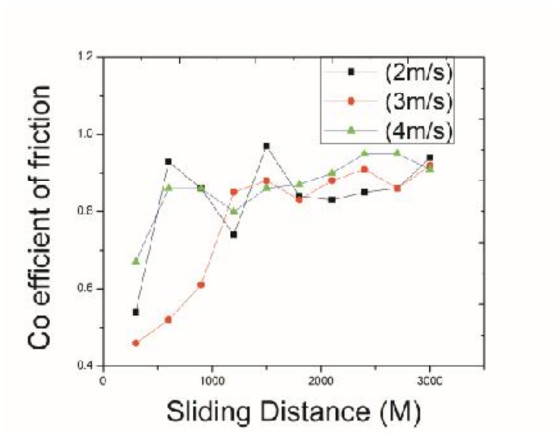


Fig 6. Wear graph for Untreated 10N Load & 2, 3& 4 m/s velocities

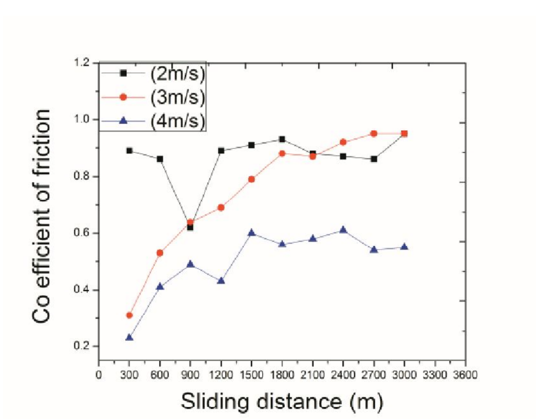


Fig 7. Wear graph for NaOH treated 10N Load & 2, 3 & 4 m/s velocities.

While the sliding distances increasing from 300m to 3000m the co efficient of friction gets increased randomly. Sometimes the co efficient of friction gets decreased because of the resin content in the specimen. At some places of the specimen the resin content may be high. So only while the sliding distances forwarding the co efficient of friction gets decreased. In the $Ca(OH)_2$ treated.

Fiber the moisture content is high. So, for 2m/s velocity forwarding of the sliding distances the co efficient of friction values gets decreasing and increasing.

As refer the fig 6, 7, 8 & 9 for untreated, Silane treated, Ca(OH)2 treated fiber the co efficient of friction value of 3m/s velocity gets decreased from 2m/s and the co efficient of friction value of 4m/s gets increased from 2m/s. but only the change for NaOH treated fiber is, the co efficient of friction value of 3m/s & 4m/s velocity gets increased evenly from 2m/s.

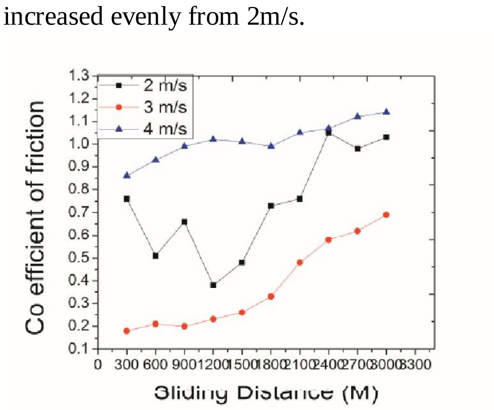


Fig 8. Wear graph for TCV Silane treated 10N Load & 2, 3 & 4 m/s velocities

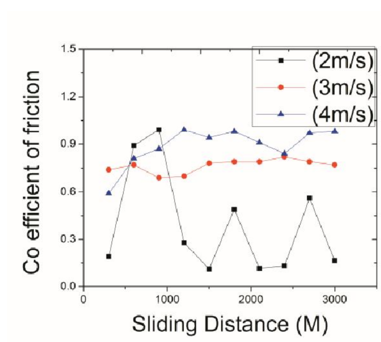
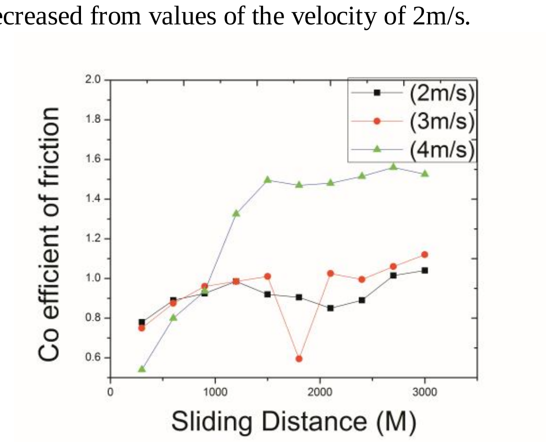


Fig 9. Wear graph for Ca(OH)2 treated 10N Load & 2, 3 & 4 m/s velocities.

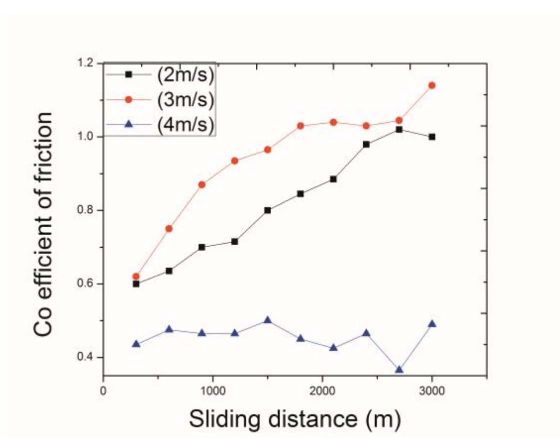
Commonly while the load increased the co efficient of friction value gets decreased. As shown in fig 10 for the constant load of 20N & the value for untreated & Ca(OH)2 treated nearly same variable velocity of 2m/s, 3m/s, 4m/s with respect to the sliding distance the co efficient of friction only Ca(OH)2 treated fiber getting small change only from untreated.

For the both co efficient of friction value of 3m/s & 4m/s velocity randomly gets increasing from 2m/s. so as compared to the value of co efficient of friction for the 2m/s velocity, velocity of 3m/s & 4m/s value is getting slightly increased only. But for the NaOH treated and Silane treated fiber the co efficient value of 3m/s velocity is gets increased from 2m/s & 4m/s velocity value is getting decreased from both value. For the 20N load also NaOH treated fiber only gains the best difference between 2, 3 &4m/s velocity.

Fig. 12 explains the variation of co efficient of friction against the abrading or sliding distance for the 30N load & 2, 3, 4m/s velocity of the unsaturated natural fibers. With the 30N load the co efficient of friction value of 2m/s, 3m/s & 4m/s velocities gets decreased respectively. That means as compared to the values of co efficient of friction for 3m/s & 4m/s is gets decreased from values of the velocity of 2m/s.



(a)



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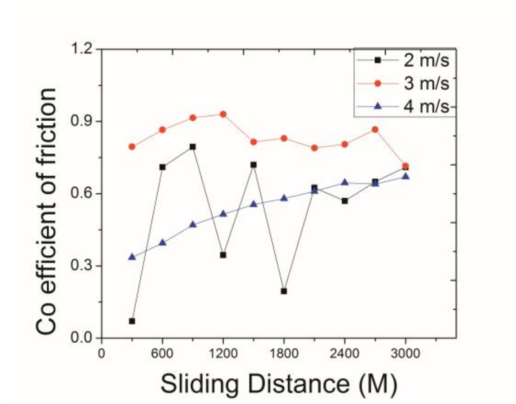

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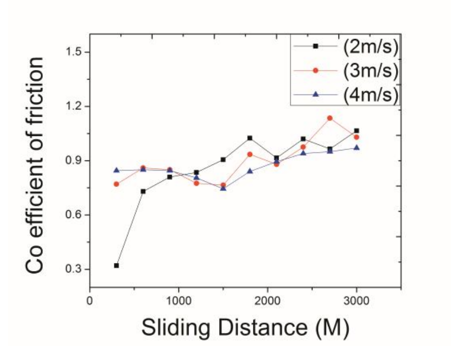


(d)

Fig 10. Wear graph for 20N Load & 2, 3, 4 m/s velocities [a) Untreated, b) NaOH treated, c) TCV Silane treated, d) $Ca(OH)_2$ treated]

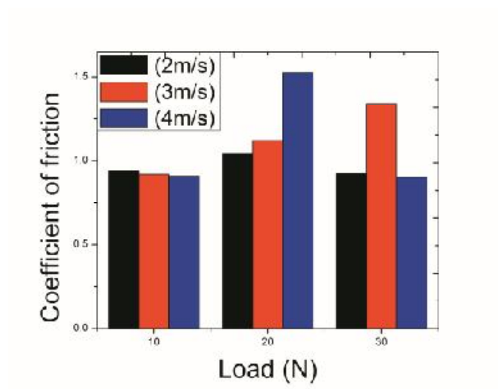
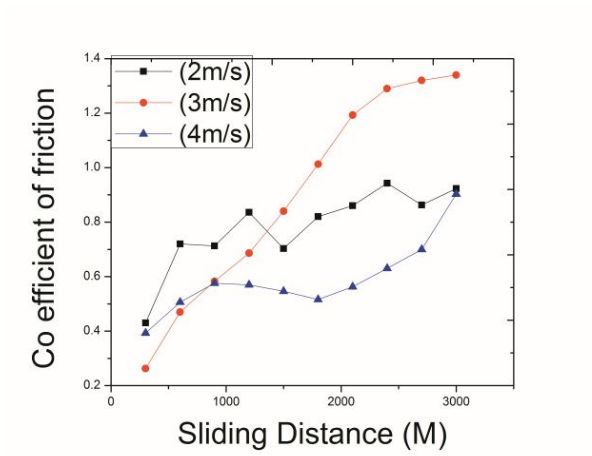
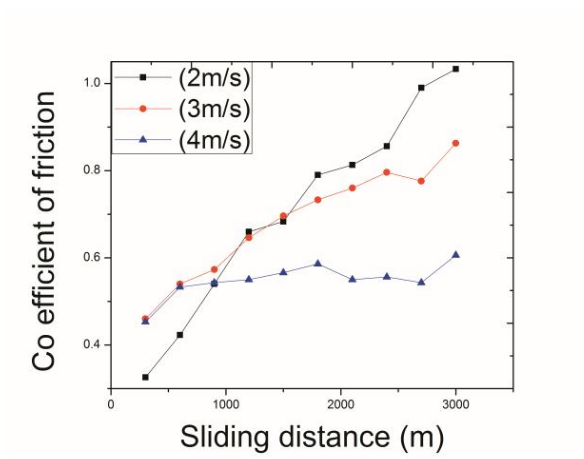


Fig 11. Compared cof for untreated all load & velocity.



(a)



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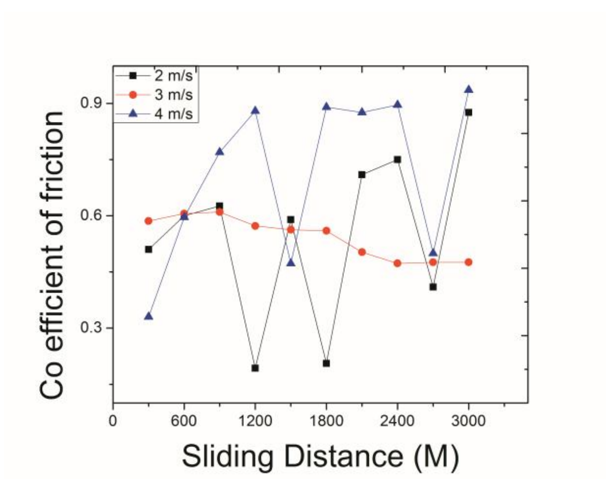

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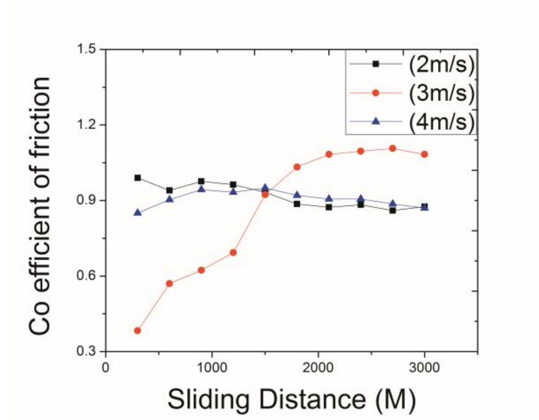
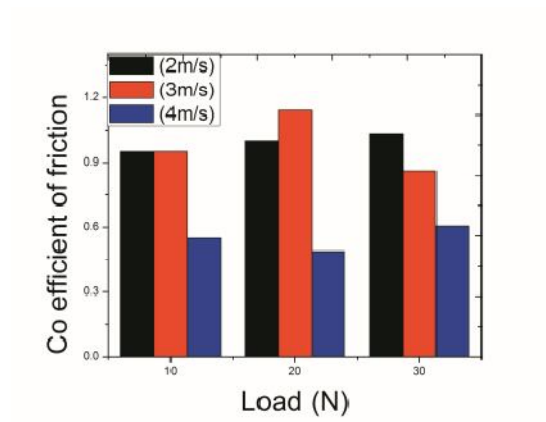
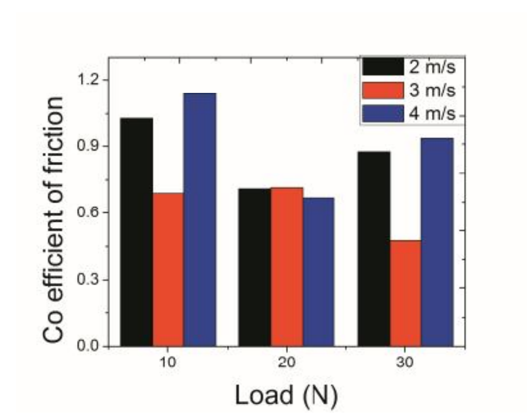


(d)

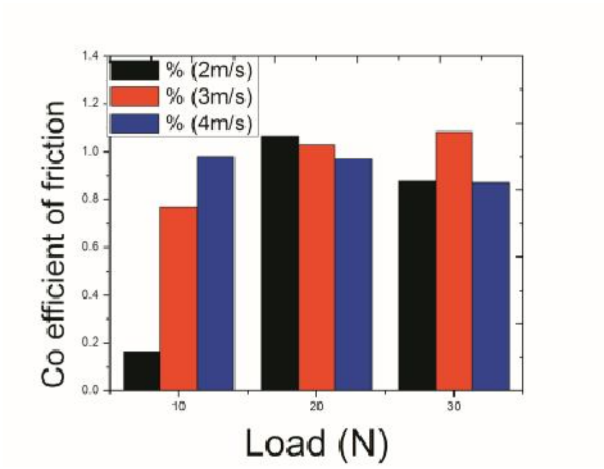
Fig 12. Wear graph for 30N Load & 2, 3, 4 m/s velocities [a) Untreated, b) NaOH treated, c) TCV Silane treated, d) $Ca(OH)_2$ treated]



(a)



(b)



(c)

Fig 13. Compared cof for all load & velocity [a) naOH treated, b) Silane treated, c) Ca(OH)$_2$ treated].

NaOH treated fiber gives the better difference between the value of co efficient of friction for all velocities and Ca(OH)2 gives slightly better result than NaOH treated fiber and the TCV Silane treated fiber's co efficient of friction values gain too difference between first and next result. So it couldn't be gain any improvement than other treated fibers.

The final friction

With the load of 10N, for the velocities of 2, 3, 4 m/s at the final friction value for the Untreated composites, the specimen gets decreased values respectively for 2, 3, 4m/s velocities. While increasing velocity of the sliding the contact between the sliding surface and the specimen is gets decrease. Then next for the 20N load the co efficient of friction for the untreated composites are compared with 10N load and 30N load showed in fig 11. the values for each velocity is getting increased for forwarding sliding distances. And for the 30N loads that every final value gets varied for each velocity. Sometimes errors may occured while sliding with the sliding surface or the error may be in the specimen also, the content of the matrix on the specimen may vary for every place so it may be the error. Some times because of the moisture content may be the friction values get changed. So these are all may be the error for friction of the specimen. As similar to the untreated fiber the fig 13 explains about the co efficient of friction comparison between 10N, 20N, & 30N final friction values of all other treated fibers. So finally the best result gained from the NaOH treated fibers in tribological behaviors.

4. Conclusion

The chemical treatments (NaOH, Trichlorovinyl Silane, and Ca(OH) 2) were done and analyze which is the best from these above treatments, and the mechanical properties & the tribological behavior of the luffa composites have been experimentally investigated and showed in graph. Finally finds out, the best result gained from which treatment of fiber composites. For the mechanical properties the Ca(OH)2 treated fiber composite gives the best result and for the tribological behavior the NaOH treated fiber composite gives the best result from all those treatments. Then within those 3 velocities 3m/s gained the best result as compared with other 2 velocities.

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