



AN INVESTIGATION ON TRIBOLOGICAL AND MECHANICAL PROPERTIES OF ARECANUT AND BORASSUS FLABELLIFER FIBER HYBRID COMPOSITE REINFORCED WITH EPOXY

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Abstract

In the modern world, application of composite material plays a prominent role in developing a product which is having low weight to strength ratio. In this investigation, borassus flabellifer and arecanut fiber was considered to develop the specimen. The specimen was developed for different composition and proportion. From the husk natural fiber was extracted by using the chemical treatment process. The extracted fiber is strengthened with epoxy resin and hardener to develop physical bonding among the fiber and resin. Later, the specimen was allowed to dry in the room temperature. Further, the investigation was conducted by appraising the specimen for tribological and mechanical properties. Mechanical properties of the sample was studied by using tensile and flexural test as per ASTM procedure. Pin-on-disc experiment was carried out to study the tribological properties of the specimen. Based on the experimentation, we can determine that tensile, flexural and wear properties of the specimen increases for different composition and curing time.

Keywords: Areacanut fiber and Borassus Flabellifer fiber, Epoxy, Mechanical and tribological properties.

1. INTRODUCTION

Natural fiber are generously available, eco-friendly and have sustainable in their nature. On one end the natural fiber are light in weight which is enormously auspicious but its low density can be adverse in deal with the fiber influence to emerge from the matrix. Hence appropriate method used for extract the fiber and convenient processing method to fabricate the composites and reinforcing the fiber by epoxy resin. Many researchers have focus their effort in manufacturing composite using lot of natural fiber and adopt into with or without chemical treatment, and characterized them for their mechanical, physical, chemical, and tribological properties.

2. LITERATURE REVIEW

K.Praveenkumar et al. [1] conclude that mechanical, thermal properties of various reinforced nature fiber and hybrid composite materials on Sic/Glass/Sisal fiber, sansevieria/jute fiber, jute/ sisal fiber, bamboo/jute fiber are enhanced their performance by increase the filler as silicon carbide. Particularly nature fiber of jute reinforced hybrid composites showed great thermal behaviour compared to other fiber reinforced epoxy composites. Especially the Glass/sisal/ fiber without filler material has enough tensile strength and alkali treated sisal, jute fiber minimize that water absorption property. The alkali treated nature fiber composites are produces higher strength than untreated nature fiber composites.

S. Pavankalyan et al. [2] made the analysis of natural fiber composite i.e., areca fiber reinforced with polypropylene polymer matrix is done to evaluate the mechanical, thermal properties of polymer composite. The refinement of composite is complete by Maleic Anhydride (MA) when preparation of composite material. Distinct fractions of nature fiber composites with 5wt%, 10wt% and 15wt% fiber content were processed in

twin extruder and 3wt% of maleic anhydride is added while the mixing process. In that 5% fiber content in the nature fiber composite offer better mechanical properties. However based on the results, the presence of maleic anhydride as compatibilizer displays excellent fiber dispersion for polypropylene polymer / areca fiber between the matrices.

S.Stephano et al. [3] made the experimental investigation on effect of surface changes on chemically handled fiber for increase the mechanical properties like impact strength, tensile, hardness and flexural strength of the composites were calculated. It is finalized that the properties such as impact, tensile, hardness and flexural strength of nature fiber reinforced composite has improved by chemically treated and increase the construction of chemical bonds amid the nylon/coir epoxy resins.

M. R. Sanjay et al. [4] the author correlate and examine of many research articles were closely associated to utilization of natural fiber composites. It view to provide details and use of natural fiber composite materials and their mechanical, physical properties of its applications in various engineering sectors.

Raghuvir H. Desai et al. [5] in this survey to observe that the particular areca fibers are have very less slenderness ratio (SR) can be continued to use as a short fiber or powder in the establishment of natural fiber composites. There is an inadequacy in the surface treatment of areca fiber polymer composite, which can be sufficiently filled by the different surface treatments like physical and mechanical process. Furthermore, there is a space in using additional treating methods such as injection molding method, extrusion process, etc., for arecanut fiber reinforced polymer composite using good enough thermoplastic as a matrix to manufacture them more accessible to engineering applications.

Pradeep P et al. [6] the author investigate the characterization of palm fiber as reinforcement by polymer matrix through this improve the superior mechanical strength on large rich cellulose content and minimum lignin content in nature palm fibers. The mechanical behaviour of nature palm fiber is significantly huge than other natural fiber are investigated in this present study and so it is used for reinforcement in nature fiber polymer matrix.

Keerthi. A et al. [7] in this research the characterization and processing of epoxy based composites with arecanut fiber and casuarina fiber especially finding in tribological properties in natural fiber. The flexural and tensile properties were improved by addition of fiber with neat epoxy resins. The arecanut nature fiber composite shows better tensile of 17 MPa and also addition of casuarina fiber on it, the tensile improved is 18 MPa. By the tribological test, performance of composite has improved with addition of arecanut fiber and hybrid of arecanut fiber with casuarina fiber.

Emad Omrani et al. [8] made the comparison of natural fiber composite to calculate tribological properties by test parameter along with sliding speed, normal load. Different results are obtain on various type of reinforcement. In this study various effects of fiber orientation, fiber treatment, and fiber volume fraction at different loads and temperatures on tribological properties of nature fiber reinforced polymer matrix composites is discussed. In addition, nature fiber treatments is important factor to fabricate polymer matrix composites by virtue of it can increase the tribological behaviour to an extent by making great interfacial bonding among fiber and matrix. Also, orientations of nature fiber is one of the important factors that can be affect wear of the composite and friction behaviour.

Sneha.H.Dhoria et al. [9] author investigate on natural fiber of borassus flabellifer fiber reinforced polymer composite materials, that mechanical properties of chemical treated borassus flabellifer fiber composites high mainly when compared to the untreated fibre composites. The tensile properties of chemically treated fiber composite increases by 13.5% than untreated fiber composites and also flexural strength of the chemical treated fiber composite increases by 19% than untreated fiber composite. It is also valued that impact strength of treated fiber composites increases by 23.3% of untreated fiber composite material.

C.V. Srinivasa et al. [10] in this experimentation the impact strength and hardness properties of epoxy based arecanut nature fiber was observed that the post curing time and its volume fraction of nature reinforced composite fiber is directly proportional to mechanical properties. Chemically treated arecanut fibers appearance gives better results when it is correlated with natural untreated fibers.

Nadendla Srinivasababu, et al. [11] the author investigate the composite were constructed by reinforcing chemically treated and untreated of palmyra palm petiole fiber. Experiment were conducted for dielectric and mechanical properties as per ASTM procedure. The tensile strength and modulus of chemically treated palmyra palm petiole was 1052.83 MPa and

56.69 MPa respectively. The flexural strength, impact strength and modulus of the specimen was increased by 3.16 %, 97.07 % and 34.76 % respectively due to the chemical treatment process.

Reddy et al. [12] the author reported that the mechanical strength of epoxy based nature fiber composites is filled with the short fiber of betel nut at various compositions with the aid of extrusion process and hot stamping press molding techniques. Sansevieria cylindrica is blended with short fiber of betel nut in epoxy based composites to grant better mechanical properties. The results shows that the prepared nature fiber composite with 10% of betel nut show better mechanical properties. Better dielectric strength was noticed with 30% of betel nut. The hybridization of nature betel nut fiber and sansevieria cylindrica along epoxy matrix in the composition of (Sc10:Bn10:EP80) gives improved mechanical properties.

3. MATERIALS USED AND METHODOLOGY

1.1 Epoxy resin and hardener

The nature fiber polymer composite matrix made was an arecanut fiber and borassus flabellifer fibre with medium viscosity epoxy resin araldite [LY556] the and the hardener [HY951] are purchased from covai seenu & company, Covai.

1.2 Areca nut fiber

Areca empty fruit bunch fiber (husk) and borassus flabellifer fiber were obtained from agri farm house, Salem, Tamilnadu, India. It is the outside of areca fruit. It creates 60 to 80 % of the whole size and also mass of the fruits (fresh weight basis). The husk of the arecanut is a hard tough portion enclosed with the endosperm. Arecanut fiber contains 40 to 64% of hemicelluloses, 15 to 25% of lignin, left over 9 to 24% of water content and 4.5% of ash content. Arecanut husk fiber was mostly longer than coir fiber, woolenised jute. Nearby 50% of arecanut shell fiber was better than other fiber and the remaining 50% of fiber was stiffer than those fiber. The fiber connecting the inner layer are unevenly lignified group of cells called hard fiber and the portions of the interior layer hold soft fiber.

1.3 Borassus flabellifer fiber

The fiber is take out from the palm fruit. The borassus flabellifer outer surface layer is thin, smooth, and brown, turning approximately black afterward yield. Inner side is a juicy form of long, coarse, tough, fibers layered with orange pulp. In-side the complete seed is a hard white kernel which look like coconut core but is abundant harder. The chemical configurations of the borassus flabellifer fibers are hemicellulose 29.6%, lignin 17% and α -Cellulose 53.4%. The quantity of hemicellulose can be reduced by handling with strong alkali. The modulus 10.8 GPa, strength of fiber is 70.8 MPa, and the elongation 34.8%. The modulus, elongation, and strength can be enlarged by alkali action. It can be used as an alternative of synthetic fiber where more strength is essential, e.g. blending with cotton fiber it can be used to produce fabric which reduce cost and increase strength.

1.4 Fiber Extraction

Fiber extraction selected areca fruit husks and borassus flabellifer fiber were utilized for create the nature fiber composites. Dried areca husk and borassus flabellifer fiber was soaked in deionized water for about three to four days. The soaking process is used to make free the fibers and can be extracted out easily. The fibers are washed once again with deionized water and adopt into dried at room temperature approximately at 3 to 4 days in order to remove any moisture present in the fiber. That the dried fibers are designated as untreated fiber.

4. ALKALI TREATMENT

4.1 Areacanut fiber alkali treatment

Initially, the areacanut fiber are chemical treated with the solution of 15% KOH (potassium hydroxide is a clear aqueous solution) to total volume of chemical solution. In this fiber were preserved that alkaline solution for maximum of 10 to 12 hours at temperature of 30° C, it was then extremely washed in with water after that negate with a 2 to 3% of acetic acid chemical solution. Then, it was over washed in medium forced water in order to eliminate the acid sticking on surface of fiber, hence fibers Ph range is relatively 7 (neutral). Then, it was dried at exactly an atmosphere temperature about 36 hours to acquire the alkali treated fibers. Generally the potassium hydroxide solution is the powerful alkaline followed by NH4OH, NaOH. Potassium hydroxide (KOH) chemically treated nature fiber composite is generated the good tensile strength and stiffness properties on the material.

4.2 Borassus flabellifer fiber alkali treatment

Appropriate amount of borassus flabellifer husk are collected and afterwards dried for 5 days in sun light. Then fibres are extracted from the husk by cutter. Subsequently treated with 10 to 15% KOH solution for 5 to 6 hours (based on fiber thickness). Then the fiber is washed with medium forced water and it is placed in the sunlight for half an hour in order to remove all the moisture content presents on fiber. Then the chemically treated

nature fiber is used for construct of the composite.

5. PREPARATION OF COMPOSITES

5.1 Preparation of nature fiber composites

Fiber composition and volume fraction of fiber are the two important factors that it was influence the composite properties. In this present research, the areca fiber and borassus flabellifer fiber were reinforced with epoxy resin with two different weight proportions (50 wt. % and 60 wt. %) to develop the composites. Three types of nature fiber + epoxy based composites board are prepared for adopting the samples into mechanical, physical test. The followings are separate areca nut fiber board, borassus flabellifer fiber board and hybrid board of arecanut fiber and mix with borassus flabellifer fiber evenly. Areacanut composite- 50% of alkali treated arecanut fiber + epoxy resin. Borassus flabellifer-50% of alkali treated borassus flabellifer fiber + epoxy resin. Hybrid composite board encompassing 25% of alkali treated arecanut fiber and 25% of alkali treated borassus flabellifer fiber with epoxy resins. The mould box that was construct by a plywood and it's had a dimensions of 300 mm x 100 mm and with a depth of 30 mm. First, the moulding cavity is cleaned and then a mould-releasing by polyvinyl alcohol (is a synthetic polymer that is soluble in water) applied on the cavity surface it is made simplify to eradication of the reinforced composite from the molding cavity complete curing. The minimum temperature curing epoxy resin and related hardener are added in a ratio of 10:1 by weight as approved. The mixing is done fully before the filled in mould cavity of 300 x 300 x 3 mm size and squeezed in a hydraulic operated press at the 300c atmospheric temperature and a 0.5MPa pressure for 10 to 15 minutes is applied before it was removed from the moulding cavity. Then the measurement take over to identify the uniform thickness, before convert into test specimens in order to all the three composite.

5.2 Preparation of composite test specimen

The test composite specimens are prepared as per ASTM norms as shown in table 1.

Table 1 ASTM Specimen standards

Material Property	ASTM Standard	Specimen size (mm)
Tensile	ASTM D3039 / D3039M - 17	300x25x3
Flexural	ASTM D790 - 17	127x13x3
Impact	ASTM D256	64x12.7x3
Hardness	ASTM D785	20x20
Density	ASTM D792 - 13	20x20x3
Wear	ASTM G65 - 16e1	10x10x3
Water Absorption	ASTM D570 – 98 (2018)	20x20x3

6. RESULT AND DISCUSSION

6.1 Tensile test

The constructed natural fiber composites is cut through a saw cutter tool and obtained exact specific dimensions of

the specimen for complete the tensile testing as per ASTM standards. The tensile testing is carried out on nature fiber composite for finding the mechanical properties by a universal testing machine at an atmospheric room temperature with 45% of relative humidity. The tensile stress is results are

recorded with respect to increases in strain. Three different type of specimens are constructed by fiber used namely, areca fiber reinforced polymer, borassus flabellifer fiber reinforced polymer, areca nut and borassus flabellifer fiber reinforced polymer (hybrid composites). The work specimen is placed on gripper of the tensile testing machine and test is executed by applying tensile force up to fracture of composite material. Tensile test used to find the stress and strain, and ultimate breaking stress of the nature fiber composite material. The

work piece was put through the continuous tensile load. The load and percentage of elongation is noted down at different steps. As per the tensile test result concern hybrid composite has greater young's modulus (3656.11MPa) and tensile stress (20.15MPa) due to of higher number of nature fiber takes place in hybrid composite. Graph 1 shows the tensile test specimen result. Table 1 display that tensile properties of the composite specimen at high load. The corresponding load is tabulated.

Table 2 Tensile test

Specimen	Young's Modulus (MPa) (Automatic)	Tensile Stress (MPa)	Extension(mm)
Borassus Composite	3317.27	16.16	1.34
Arecanut Composite	3407.18	18.41	1.40
Hybrid Composite	3656.11	20.15	1.51

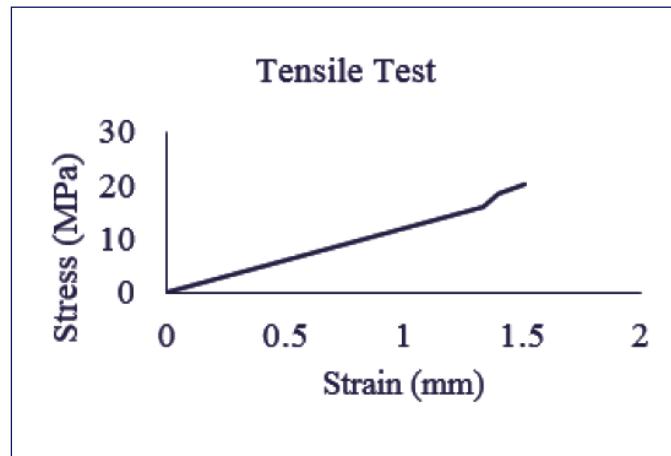


Figure 1 Tensile test

6.2 Impact Test

Impact force resistance is the potential of a natural fiber composite material and it to resist breaking under a shock load or the capability to resist the fracture under stress applied at high force. Impact behaviour is the most widely defined mechanical property of the engineering materials. This graph express that, the energy absorbing, toughness property of natural fiber hybrid composites has greater significance that comparatively other two composite specimens. Increases the toughness, energy absorbing property of the material is respect to curing time and fiber volume fraction. Here hybrid composite specimen has absorbed maximum of energy while applying force due to high density of natural fiber.

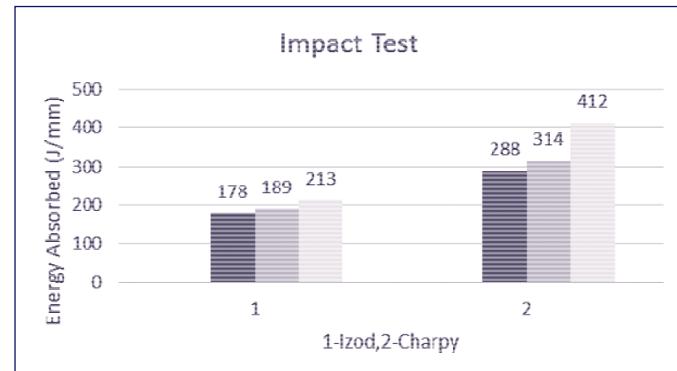


Figure 2 Impact test on different natural fiber specimen

6.3 Hardness Test

The hardness of surface on the nature fiber composites is investigated as the supreme significant factors that control the wear property of the composite material. Nature fiber composite specimen hardness properties is done by rockwell hardness tester and specimen must be ASTM D-785 norms. The specimen dimensions is concern of 20mm breadth and length of 20mm. The surface hardness property of the composite specimens are tested through applying the indentation load on specimen. Table illustrate that increases in fiber loading boost the hardness rate of the nature fiber epoxy based reinforced composites. The weight rate of the nature fiber is boost the ductility rate of the composite material which suggestions that resistance for indentation. The deviations of the hardness against different composite specimen.

Table 4 Hardness test

Specimen	Hardness (HRB)			Average (HRB)
	Borassus Flabellifer	Arecanut Fiber	Hybrid Composite	
Borassus Flabellifer	65.26	77.41	94.09	68.32
Arecanut Fiber	68.80	78.27	96.81	78.17
Hybrid Composite	70.91	78.84	96.46	95.78

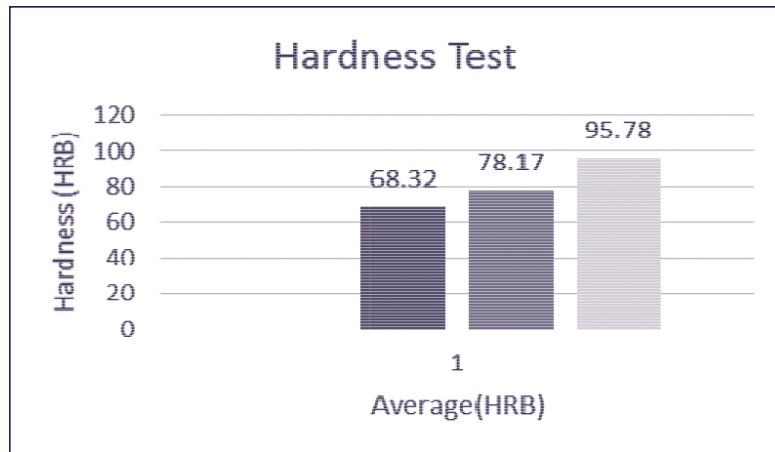


Figure 3 Hardness test on various natural fiber specimen

6.4 Flexural Test

The flexural test is carried out at room temperature using Instron 3366 apparatus. Test were done at a rate of 1mm/min for all the specimens i.e., areca fiber composite, borassus flabellifer composite fiber, and hybrid composite of areca fiber composite + borassus flabellifer composite fiber with various trials for each specimens. The results are obtained is shown in Figure. Table shows that flexural properties of natural composite at maximum load. From the figure, it is understood clearly that borassus fiber has the maximum flexural load (64.189N) than that arecanut fiber (52.818N) and hybrid (34.156N). Both arecanut fiber and

borassus flabellifer fiber composite specimens hold out lower flexural load due to the brittle behaviour of arecanut fiber.

Table 5 Flexural Test

Specimen	Flexural Load(N)	Flexural Strength (MPa)	Modulus (MPa)
Borassus fiber	64.189	42.641	3392.28
Arecanut fiber	52.818	34.812	3617.08
Hybrid Composite	34.156	23.416	3963.22

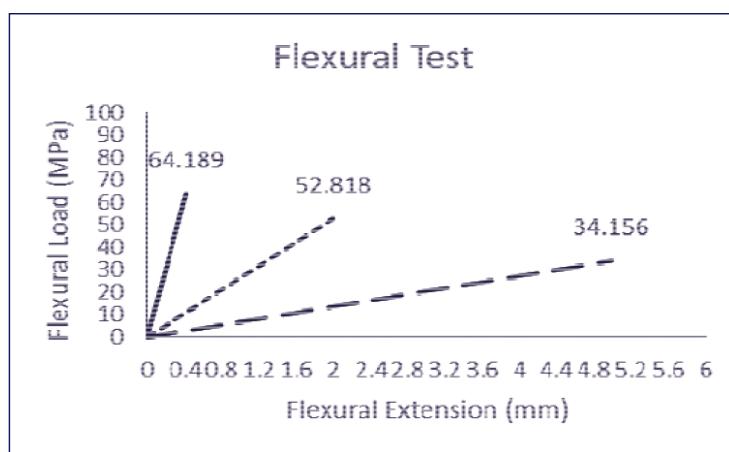


Figure 4 Flexural test on various load conditions

6.5 Water Absorption Test

Usually the natural fibers are absorb excessive moisture (water) compared to synthetic based fiber. Nature fiber absorbed the water content through interface and matrix. The specimens were prepared from a 3-mm thick plate with size 50 mm wide and 50 mm long. The samples were dipped in purified water for 10 to 12 days. The moisture (water) content in the nature composite was deliberated by the weight increase of the material at systematic intervals. The measurement of moisture content is stated that percentage of moisture (water) content is expressed at the time, that the ratio of raise in weight to the weight of initial specimen.

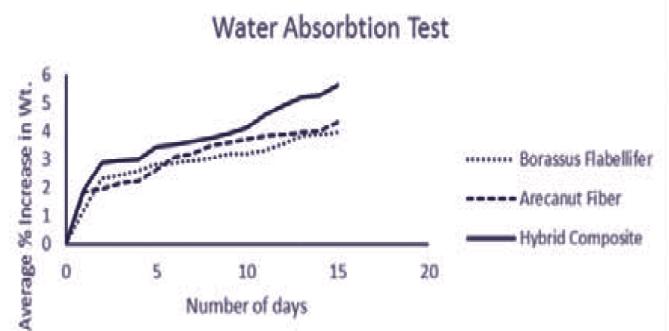


Figure 5 Water absorption test

6.6 Abrasive based wear test

Abrasive based wear test were done on pin on disc apparatus of different composite specimen like areca nut fibers, boras-sus

6.6.1 Influence of load and sliding distance on wear loss

Table 6 Abrasive wear test

Specimen	Load(N)	Wear loss(G)	Load(N)	Wear loss(G)	Load(N)	Wear loss(G)
Hybrid	30	0.08	40	1.04	50	1.68
Arecanut	30	1.16	40	1.24	50	2.13
Borassus flabellifer	30	1.41	40	1.58	50	2.64

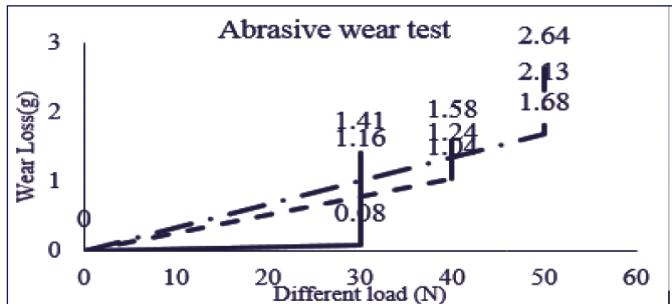


Figure 6 Wear test at different load

Table 7 Abrasive wear test results

Specimen	Load(N)	Wear loss(G)	Load(N)	Wear loss(G)	Load(N)	Wear loss(G)
Hybrid	60	0.05	80	0.08	100	0.1
Arecanut	60	0.78	80	1.05	100	1.89
Borassus flabellifer	60	1.02	80	1.17	100	2.01

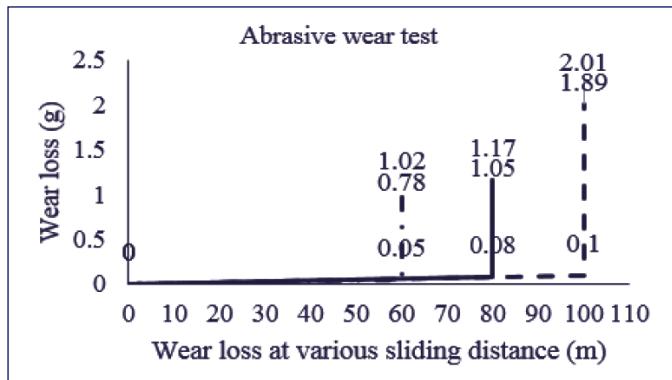


Figure 7 Wear test at different load

The wear loss is displayed in figure due to impact of sliding distances. Basically wear loss improves with the maximum in sliding distance. Specifically, the wear loss of individual epoxy based nature fiber composite specimen is find to be greater than the hybrid fiber occupied epoxy based composite sample. From the test, the wear loss minimize gradually with the addition of the fiber content. So that the graph shows the capability of the nature fiber to guard the matrix material under various sliding distance.

flabellifer and hybrid reinforced fiber by varying parameters such that load and sliding distance, with additional of trials for each specimen.

Influence of load on wear loss is demonstrated in Figure, the wear loss improves as the load increases in maximum of the circumstance. It is also noticed that for arecanut fiber and borassus flabellifer composite specimen has wear loss at maximum load. Specifically wear loss of borassus flabellifer composite is high due to the low thickness of fiber comparatively arecanut fibers. Addition of arecanut fiber and borassus flabellifer to epoxy as a hybrid natural fiber composite is increases wear resist of the composites, resultant in minor wear loss.

7. CONCLUSION

The results in the current research express that, it is possible to improve the mechanical and physical properties of natural fiber reinforced composites through the addition of different fiber with proper ratio of epoxy. The mechanical and physical properties of nature fiber composites of chemical treated areca nut fibers, borassus flabellifer fiber and hybrid reinforced fiber show good results once compared to natural or untreated fiber. Hybrid polymer composite shows greater tensile strength, impact, hardness that comparatively the arecanut fiber and borassus flabellifer fiber respectively. In flexural test, it is noticed that the arecanut, borassus flabellifer and hybrid composites are brittle due to increase in fiber volume. If the lower loads, the flexural strength is maximum and higher loads flexural strength of the specimen is low due to brittle property of specimen. Both arecanut fiber, borassus flabellifer fiber and hybrid composite specimen gives a good enough resistance to water absorption. It has absorbs approximately 8-9.3% of water to the total volume of composite, which is lower than related to wood based material. The tribological abrasive wear test, wear resistance of epoxy based natural fiber hybrid composite is enhanced in order to addition of fiber count.

REFERENCES

[1] K.Praveen Kumar, M.Manzoor Hussain, Sridhara Reddy, G.Gopala Krishna "An overview on thermal and mechanical properties of natural fiber reinforced hybrid composite" Technical research organisation india. ISSN (PRINT): 2393-8374, (ONLINE): 2394-0697, VOLUME-5, ISSUE-1, 2018.

[2] S.Pavankalyan, R.Christu Paul, Kamalakkannan "Experimental Investigation of Areca fiber Reinforced Polypropylene polymer composite for Automotive Components". International Journal of Pure and Applied Mathematics. ISSN: 1314-3395 (on-line version), 2018.

[3] S.Stephano, V.G.Thurbius Galdius "Fabrication of hybrid coconut fiber with epoxy composite" International Journal of Innovative Works in Engineering and Technology. (IJIWET) ISSN: 2455-5797, 2017.

[4] M.R.Sanjay, G.R.Arpantha, "Applications of Natural Fibres and its Composites: An Overview, Visvesvaraya technological University. Belagavi. Vol.7 No.3, March 2016.

[5] Raghuveer H. Desai, L. Krishnamurthy, T. N. Shridhar, "Effectiveness of Areca (Betel) Fibre as A Reinforcing Material in Eco-Friendly Composites: A Review", Indian Journal of Advances in Chemical Science S1, pp. 27-33, 2016.

[6] Pradeep, P. and Edwin Raja Dhas, J, "Characterization of Chemical and Physical Properties of Palm Fibres", Advances in Materials Science and Engineering: An International Journal (MSEJ), Vol. 2, No. 4, December 2015.

[7] Keerthi.A, Imaad Shaik, Markryan Mendonca, Keerthan K.S., Pavana Kumara B. "Processing and Characterization of Epoxy Compo-site with Arecanut and Casuarina Fibres", American Journal of Materials Science, 5(3C): 96-100 DOI: 10.5923/c.materials.201502.20, 2015.

[8] Emad Omrani, Pradeep.L, Menezes, Pradeep.K, Rohatgi, "State of the art on tribological behaviour of polymer matrix composites reinforced with natural fibers in the green materials world" Engineering Science and Technology, an International Journal 19, 717–736, 2015.

[9] Sneha.H.Dhoria, M.Vijaya, "Investigation of Mechanical Properties of Borassus Flabellifer Fibre Reinforced Polymer Composites" Jetir (ISSN-2349-5162), Volume 2, Issue 12, December 2015.

[10] C.V.Srinivasa, K.N.Bharath, "Impact and Hardness Properties of Areca Fibre-Epoxy Reinforced Composites", G.M.Institute of Technology, Karnataka. ISSN: 2028-2508, Aug 2011.Procedia Technology, Volume 14, 2014, Pages 252-259, 2014. 2nd International Conference on Innovations in Automation and Mechatronics Engineering, ICIAME 2014 (Conference Proceedings).

[11] Dr.G.Ramachandra Reddy, Dr.M.Ashokkumar, and K.V.P.Chakradhar "Fabrication and Performance of Hybrid Betel Nut (Areca Catechu) Short Fibre/ Sansevieria Cylindrica (Agavaceae) Epoxy Composites" International Journal of Materials and Biomaterials Applications, 2011. 1 (1): 6-13.

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