Investigation of the Mechanical Properties of Natural Fiber Reinforced Composites of Morinda Citrifolia with Epoxy and Bisphenol Resin

V. Jaiganesh, R. Ravi Raja Malarvannan, G. Manikandan, S.Krishnamoorthi

Abstract: The application of natural fibre is increasing day by day since they are eco-friendly. The natural fibre-reinforced composites have in many advantages like lightweight, renewable, biodegradable, and cheap and eco- friendly. There is a need to investigate the potential of natural fibre composites, where can be used in highly demanding situations. An attempt has been made in explore the possible use of a variety of wild grown fibres in nature in the development of new composites for load carrying structures. The natural fibers have been abundantly available in the world. It has unique properties compared to synthetic fibre and reduces the plastic usage. This article reports the extraction process of natural fibers, characterization of natural fibre-reinforced composites. Reinforcement of natural fibers like Moninda citrifolia made with epoxy and bisphenol resin. The investigation of the natural fiber composites was carried out by means of FTIR (Fourier Transform Infra-Red Spectroscopy), SEM (Scanning Electron Microscope) and the mechanical properties like tensile, flexural, compression and hardness properties of the composites without chemically treated fibers were reported.

Keywords: Natural Fibers, Epoxy and Bisphenol Resin, Mechanical properties, FTIR, SEM

A. INTRODUCTION

Applications ranging from making aircraft structures to golf clubs, electronic packaging to medical equipment and from space vehicles to various structures that are used in construction industries [1, 2]. Widely the metal ores are collected from sand [3]. Ores are available in fewer sources and also from non-renewable sources. The composite materials should be environmentally benign. The scientists are focusing on some new types of materials, that should not affect environment and it should be from a renewable source. To meet this requirement natural fibers are only the option available to human beings. The natural fibers will take a major role in the emerging 'green' economy based on energy efficiency. Natural fibers are not only abundantly available in India but it is available at affordable cost. They are also bio-degradable and have not health hazard. When compared to traditional fiber composites, the natural fiber composites demands are rising today because of more benefit. Scientists and engineers are emphasizing the natural fiber as a replacement for synthetic fibers [4]. Commonly, the most widely used plant fibers are cotton, flax, hemp, although sisal, jute, bamboo and coconut [5].

The composite plates consist of treated and non-treated fibers. Non treated fibers are used as such without any chemical or physical modification while treated fibers are treated chemically and usual methods are treated with alkali, process like Benzylation and silane [6]. The Alkaline treatment has an effect on the fiber to increase the surface roughness and to increase the amount of cellulose exposed on the fiber surface. The Benzylation treatment proves the plant fibers into thermally formable materials [6-8]. In the process of formation of composite plates two types of polymer resins viz.., Thermoplastic and thermosetting polymers, are used. The thermoplastic can be reheated back into a liquid, like polyvinyl chloride, polypropylene and the thermosetting plastics always remain in the permanent solid state, like epoxy, phenol and polyester [1, 9]. Thermosetting plastics used in composites with natural fibers have got more corrosion resistance properties compared to composites with metals [10].

The fiber reinforced composites have a vital role in improving the mechanical properties [11]. The natural fiber composites have got the benefits of reinforcement of fiber with matrix [12, 13]. Weight is a key factor in aerospace industries for aircraft manufactures. Weight reduction is necessary for final efficiency of the aircraft. Henry Ford to implemented natural fiber in automotive industries for manufacturing exterior body panels in 1930 and 1940s [14]. Many countries have adopted natural fiber reinforced composites. By adopting natural fiber composites the European Union has achieved 80% efficiency in 2006 and this is increased to 85 % in 2015. Japan has achieved 88% efficiency in 2005 and this is increased to 95% in 2015 [15, 16]. At present bio based polymers are used in large amounts and this is especially in the automotive industries [15].

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The present work pertains to fibers from Morinda Citrifolia, it has 80 types of species of shrubs or vines of Morinda citrifolia are distributed in all the tropical regions of the world. Most species of this genus originate from India, Borneo, New Guinea, Northern Australia and New Caledonia. Morinda citrifolia is a medium height tree (Fig. 1) growing up to six meter height and distinctive varieties exist with differing leaf morphology. The shape of leaves may be elliptic, rounded or long and strap-like. Fruits are green until maturity. Then they rapidly change to a light yellow, then light yellow and translucent white [17]. Natural fiber reinforced composites using Morinda Citrifolia with epoxy resin and Bisphenol resin have been carried out.

Fig. 1. Photographic view of Morinda citrifolia Tree.

B. MATERIALS AND METHODS

a. MATERIALS

The unsaturated resin are used to Hardener (VBR 1209), Epoxy resin (VBR 8912) and Catalyst, Promoter, Accelerator and Bisphenol resin we are collected from Vasavibala Resins (P) Ltd. Chennai, Tamil Nadu, India. Morinda Citrifolia tree fibers were are collected from Kanchipuram district, Tamil Nadu.

b. FIBER EXTRACTION

Initially for reinforcement the materials are cut with hand and the process of impregnation as wet matrix are made with a specially made device. The wet matrix is then laid into a mold which is covered with releasing agent viz., a resin gel applied manually onto the mold [18]. The tree branches were then air dried. The tree branches are then beaten to get small thin thread like structures. The fibers were cut with the help of scissors to the length of 0.5 cm and 1.5 cm. After cutting the fibers to the required lengths they were produced to dry in air. Finally the fibers are then washed again with water in room temperature at 4 to 5 days. (Fig. 2).

Fig. 2. Photographic view of Morinda Citrifolia extracted fibers.

c. PREPARATION OF COMPOSITE

The plates are prepared by using Hand lay-up methods. This technique was adopted to fill up the prepared mold with required amount of Bisphenol and Epoxy resin mixtures are taken in the appropriate proportion [19]. A Bisphenol resin mixture quantity for 50-50 ratio is 100 ml is Bisphenol resin, and hardener (catalyst) 4.5 ml, 4.5 ml each. Epoxy resin mixture quantities for 50:50 ratio is 100 ml of epoxy resin. The resin mixture and random fibers are arranged in starting and ending with layers of resin. Fiber deformation and movement should be minimized to yield good quality, random fiber composites (Fig. 3. (a) and (b)). The time of curing, 50-80 kg, while load applied to the mold and the composite specimens were cured for 7 to 8hr [19].

a b

Fig. 3. Photographic view of (a)Morinda citrifolia with Epoxy resin and (b) Morinda citrifolia with Bisphenol resin.

d. SCANNING ELECTRON MICROSCOPE (SEM)

Fiber morphology was analyzed by SEM using a Shimadzu model SS-550. Analyses were performed under an accelerating voltage of 20kV. The composites are coated gold and analyzed the width of 5.8mm.

e. MECHANICAL TESTING

This method is done as per ASTM –D695. The specimen's length is 50mm in length; 12.80mm in width and with a thickness of 7.50mm was tested. The specimen is fixed between the top and the bottom jaws of the Tinius Olsen UTM machine to ensure that the failure will happen in the middle of the specimen. After the specimen is set, the UTM software is used for report.

The composites of 100mm in length, 28.70mm in width and 7.80mm in thickness is tested. Further, The UTM software is used to obtain the better results.

III. RESULTS AND DISCUSSION

a. FOURIER TRANSFORM INFRA-RED SPECTROSCOPY (FTIR)

Mwaikambo used FTIR to confirm that hemicellulose was removed by the alkali treatment. FTIR was used to confirm fiber/matrix bonding by Mohanty. Hence the chosen tree fibers were given for Fourier Transform Infra-Red Spectroscopy (FTIR) test. In FTIR spectroscopy, the fiber is taken with the fiber length is up to 0.5 cm. The fiber is placed in its respective place, inside the FTIR spectroscopy and closed. The FTIR spectroscopy device is connected to the computer system. The Infra-Red (IR) ray is passed to penetrate into the fiber.

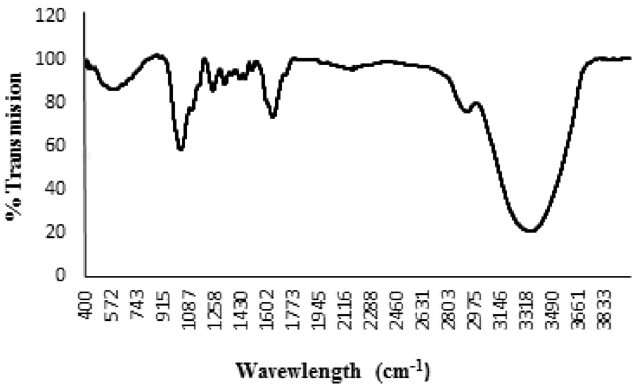

Fig. 4. Fourier Transform Infrared (FTIR) spectra for untreated Morinda Citrifolia fibers.

The IR ray scans the elements that are naturally present in the natural fiber. It displays the amount of elements that are present in the fiber, in the form of graph, in the computer system as shown in Fig 4. Stretching vibrations observed at wave numbers of 1642.09 cm-1 and 1031.73 cm-1 shows absorption bands of characteristics groups present in sclerenchyma structure, such as cellulose, hemicellulose, and lignin in Morinda Citrifolia. A stretching vibration signal was observed at 3341.07 cm-1 and 2928.38 cm-1corresponding to fiber's hydroxyl groups and C-H bond respectively in Morinda Citrifolia [20].

b. SCANNING ELECTRON MICROSCOPE (SEM)

Fiber morphology of Morinda Citrifolia is evaluated using SEM and they are shown in Fig. It's obtaining the impurities on fiber plate surfaces as well the presence of parenchyma cells [22, 24]. The morphological differences in between fibers and resin are also observed and discussed for each of these fibers. For the composite samples, SEM images are presented in general, the micrographs reveal that homogeneous distribution of the treated fibers in the matrix was achieved, indicating that good processing conditions were used [25]

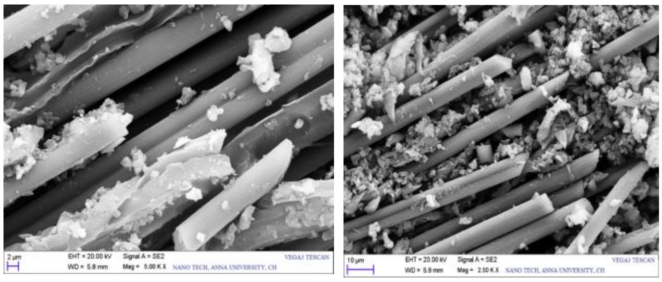

Fig. 5. Photographic view of Morinda Citrifolia with Epoxy Resin SEM images in (a) 2µm, (b) 10µm

Fig. 5 shows the SEM micrographs of the composite fiber Morinda Citrifolia made from the Nona fiber and Epoxy resin. The void spaces in the fiber are clearly visible at 20µm. The poor fiber and resin bond are visible in the morphology. It is appear impurities bonded in the composite fiber. There is less bonding between the Nona fiber and the Epoxy resin resulting in more void spaces allowing the impurities to bond within the composite [26].

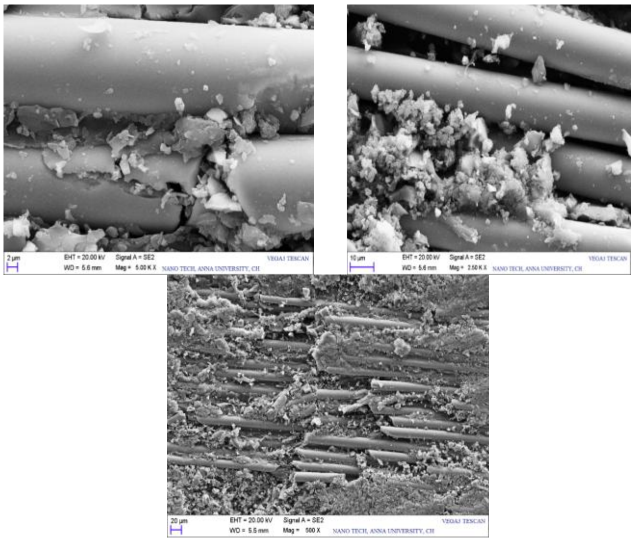

Fig. 6. Photographic view of Morinda Citrifolia with Bisphenol resin SEM images in (a) 2µm, (b) 10µm and (c) 20µm.

Fig. 6 shows the photographs of Morinda Citrifolia SEM image the ranges 2 µm, and 10 µm and 20 µm respectively. It is clearly visible in the bonding between the Nuna fiber and the Bisphenol is stronger and closer compared to Morinda Citrifolia (Nuna Fiber – Epoxy resin). The close bonding of the fiber and resin decreases the total void spaces and Inclusion of foreign or impurities. In 2 µm image, so fine and smooth which leads to great smoothness in the surface of the composite fiber [27].

c. MECHANICAL PROPERTIES

The mechanical properties various tests are conducted on the composite fibers Morinda Citrifolia. These are the tensile, flexural, compression and the hardness testing methods. The tests conducted and the results are exhibited in Table. 1. Sample (a) is Morinda Citrifolia (Epoxy), Sample B is a Morinda Citrifolia and (Bisphenol).

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The shore D^0 hardness graph (Fig.13), is the hardness of the composite fiber are increased, and, the composites of Bisphenol has good compression properties. The Epoxy resin has beter tensile and flexural strength. The hardness of Bisphenol resin is high bonding .The Scanning Electron Microscope (SEM). Used o determined the boding structure of composites

Table. 1. Tensile strength, flexural load, compression load and hardness values for Morinda Citrifolia sample A and B.

Sample	Tensile Strength (MPa)	Flexural Load (KN)	Compression Load(KN)	Shore D° Hardness
A	5.78	0.15	1.92	45, 46, 46
B	4.24	0.18	8.02	57,55, 56

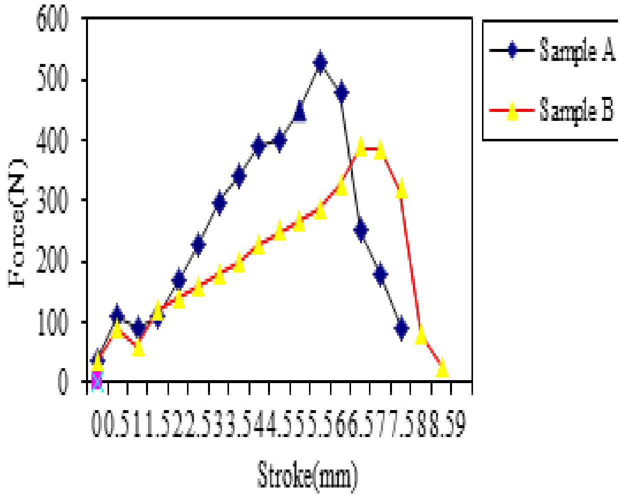

Fig. 7. Tensile Strength of sample A and B

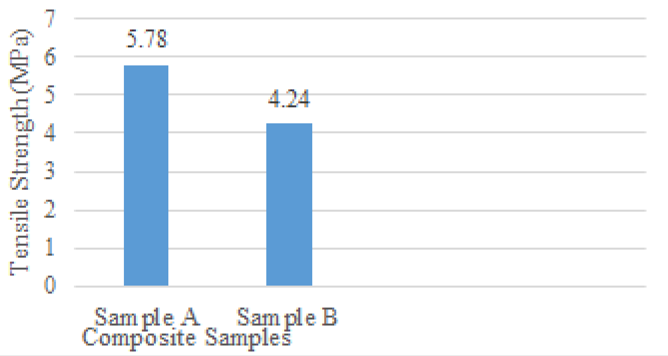

Fig. 8. Comparison of a Tensile strength of sample A and B composite fibers.

From Fig. 7 and 8, the sample A has better tensile strength. Sample A and sample B appear that properties with help of stress. Whereas, Samples A, B show similar properties. As sample A has high tensile strength.

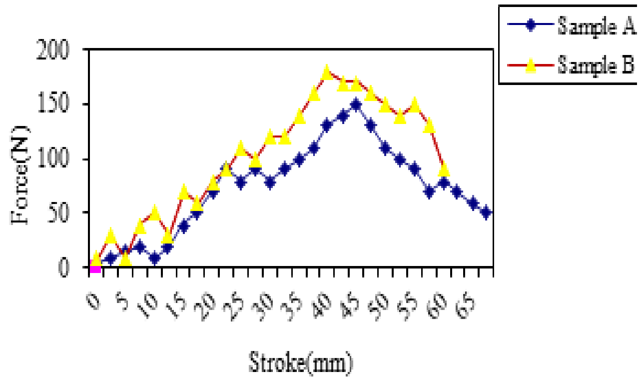

Fig. 9. Flexural Load for sample A and B Composites

From Fig. 9 and Fig. 10, the sample B having better flexural strength. But, sample A and exhibit similar properties at lower to moderate load. The epoxy resin has good bonding properties compared than others resin. In Morinda moderate results only gives.

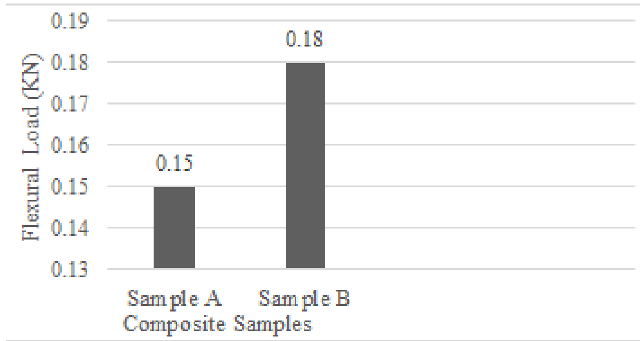

Fig. 10. Comparison of a Flexural load of sample A and B composite fibers.

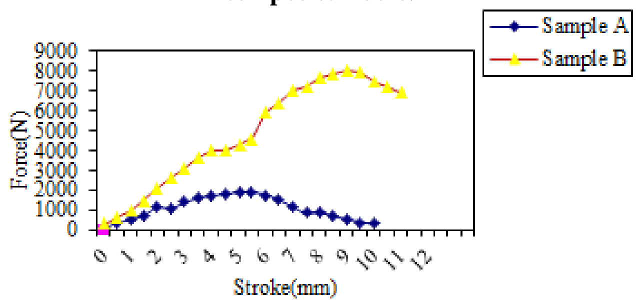

Fig. 11. Compression Load for sample A and B Composites plates.

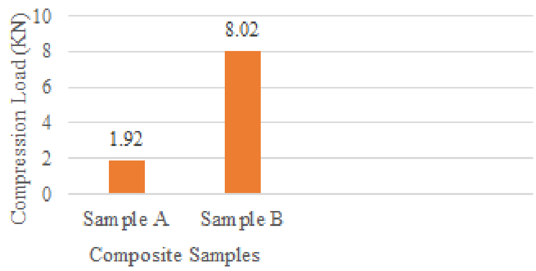

Fig. 12. Comparing the Compression load of sample A and B composite fibers

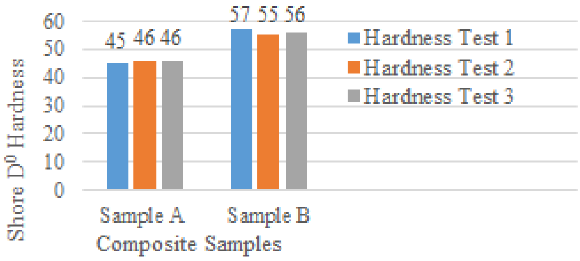

Fig. 13. Shore hardness of sample A and B composite fibers under various conditions

Three hardness tests were done for the given fibers. From Fig. 13 get conclusion that sample B has good hardness compared to other samples. The Nuna (Bisphenol) shows maximum hardness in the entire test. In hardness test also show in ascending order of outcome, but the deviation is lesser value only. Almost Bisphenol composites have good hardness compared with Epoxy

d. DISCUSSION

The hardness of the composite is increased Bisphenol resin compared to epoxy resin. Bisphenol resin has high hydrogel group compared to epoxy resin. When epoxy resin makes contact with Morinda hydroxyl groups on the surface of epoxy resin and these fibers form hydrogen bonds and this leads to improvement in interfacial properties. From the SEM micrographs of the composite fiber Morinda Citrifolia made from the Nuna fiber and Epoxy resin possess more void spaces in the fiber and these are clearly visible at 20µm. The poor fiber and resin bond are visible in the morphology; it's visible to see the impurities bonded in the composite fiber. There is less bonding between the Nuna fiber and the Epoxy resin resulting in more void spaces allowing the impurities to bond within the composite. Because of these effects they have lesser mechanical properties. Sample B has good flexural strength, But, sample A exhibit similar properties at lower. In the tensile and flexural test have some of fibers shows in similar properties but in compression test no one contain the comparable value. In order to increasing the compression value ascending order from sample A to sample B, but Morinda with Bisphenol mixture give in higher values.. Morinda Epoxy only shows least value of compression.

Three hardness tests were done for the given fibers. From Fig. 13 get conclusion that sample B has good hardness compared to other samples. From the graph, in hardness test also show in ascending order of outcome, but the deviation is lesser value only. Almost Bisphenol composites have good hardness compared with Epoxy. Results obtained are in accordance with literature in general with respect to epoxy and Bisphenol resins but there are some little differences in values compared to other natural fiber composites. This may be because of these fibers are made by manual layup process. The difference in mechanical properties may also be due to parallel or perpendicular orientation of the fibers and these could have been occurred during the manual layup process. Maximum improvement is obtained in parallel orientation of fibers in unidirectional fibers reinforced epoxy composites compared to perpendicular orientation. The best results of tensile strength/density ratio are also achieved in unidirectional parallel orientation of both nuna fibers with Epoxy or Bisphenol resins.

IV. CONCLUSION

The characterization is the developed natural composites demonstrate the important. We are conducted various tests on Morinda Citrifolia we are preoduce new one like this Morinda Citrifolia (Nuna Fiber- Epoxy resin) has high tensile strength when compared with other composite fibers. By this investigation, it can be concluded that Morinda Citrifolia (Nuna Fiber – Epoxy resin) has good tensile strength, flexural load, compression and hardness compared to other composite fibers. The mixture of both the Nuna fiber and Epoxy resin composite are different properties. The SEM images appear good behaviors. In this paper the results is composites has better light weight and good mechanical properties. Hence, the newly developed composite materials can be used for the applications of such as automobile interior parts, home appliances, electronic packages, building construction and sports goods.

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