MECHANICAL, THERMAL CONDUCTIVITY, BIODEGRADABILITY PROPERTY, DMA ANALYSIS AND FRACTOGRAPHY ANALYSIS OF NANOCLAY- COTTON FIBER / HYBRID RESIN COMPOSITES

P. Prabhu[1], B. Karthikeyan[2], R. Ravi Raja Malar Vannan[3], A. Balaji[4]

[1]Research Scholar, Department of Mechanical Engineering, Faculty of Engineering and Technology, Annamalai University, Annamalai Nagar, Tamilnadu, India - 608002.
[2]Department of Mechanical Engineering, Faculty of Engineering and Technology, Annamalai University, Annamalai Nagar, Tamilnadu, India - 608002.
[3]Department of Mechanical Engineering, Saveetha Engineering College, Chennai, Tamilnadu, India – 602105
[4]Department of Mechanical Engineering, A.V.C. College of Engineering, Mayiladuthurai, TamilNadu, India - 609305.
Corresponding author Email: prab_er@yahoo.co.in

Abstract: Natural fiber-based composites are essential to everyday life from the simplest building components to those used in the construction and automotive industries. In this research, the effects of adding nanoclay to epoxy lannea coromandelica (ELC) composites with cotton fiber reinforcement are examined. Using a mechanical stirrer, nanoclay (N) is introduced to ELC resin as a nano reinforcement in weight fractions percentages (0, 1, 2, 3, 4 and 5). It is chosen to use woven cotton (C) fiber mat as secondary reinforcement. Hardener HY951 (1 %) is added in specific volume fraction to ELC resin and nanoclay mixture. Following that, hand layup (HLU) process is used to make cotton fiber infused epoxy Lannea Coromandelica (CFRELC) composites. Testing is done on samples to determine their thermal conductivity, biodegradability, compression qualities and DMA analysis. Utilizing a scanning electron microscope, researchers look at the Fractography analysis of compressive fracture in hybrid composites. The ELC resin reinforced with cotton fiber and containing 4 wt% nanoclay has shown the best mechanical capabilities.

Keywords: Epoxy Lannea Coromandelica resin, Cotton Fibers, Mechanical Testing, SEM, Nanoclay, etc.

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1. Introduction

The addition of clay particles of a certain size can significantly improve a polymer's characteristics [1-3]. Polymer clay nanocomposites have attracted a lot of attention. Numerous studies in thermoset polymer systems including epoxy [4], polyesters [5–6] and others, as well as thermoplastics including polypropylene [7] have been conducted based on this concept. Natural sisal fiber, resin and nanocomposites have many advantages including low cost, high thermal conductivity properties and reduced processing power requirements. In recent times, attempts have been made to use hybrid bio – nano materials in place of synthetic materials [8]. The composites, which had four distinct reinforcements made with vol.% (0.1-0.4) levels of cotton fiber were created using the compression moulding technique. DMA tests and TGA tests were utilized to analyze the performed composites. However, the damping factor was decreased while the mechanical and storage (Pa) modulus of the composites property were improved [9]. Cotton fiber (CFRPC) have garnered researchers' attention due to their straightforward applications and dramatically improved mechanical characteristics utilized in applications [10]. Because of their high aspect ratio and platy appearance, layered silicate clays are typically used as fundamental inclusion elements [11]. Organo-modified montmorillonite can be dispersed uniformly into polymers to efficiently enhance its mechanical and physical properties [12–13]. In hybrid clay - glass fiber infused polymer materials, the influence of nanoclay addition on fiber created vibration damping behaviour [14]. Nanoclay's impact on the mechanical and water characteristics of glass fiber infused epoxy composites were investigated by Manfredi et al. [15]. According to Ayemerich et al., study's [16], adding nanoclay considerably increased the glass fiber - epoxy composites' ability to absorb energy. . The impact of adding nanoclay on the mechanical property and thermal property of fiber infused epoxy composites had also been the subject of numerous research studies [17–19]. There haven't been much research reports on nanoclay and cotton fiber reinforced ELC resin composites, in contrast to the previous works on nanocomposites mentioned above. Cotton reinforced EPL resin nano composites are created in the current work using a hand layup compression approach as a follow-up to this research. The goal of this current research work is (1) Cotton fiber mats with weight fractions of 0%, 1%, 2%, 3%, 4% and 5% are the primary materials of this research project. Each mixture enhanced ELC matrix's of nanoclay (N) loading is created manually and compressed using a moulding machine (2) To find out the compression properties and chemically broken down features like biodegradability. (3) For cotton fiber mats resin nanocomposites, DMA is used to calculate the storage (Pa) modulus and damping (δ) factor. (4) To identify and analyze the morphological examination of the hybrid cotton fiber matting resin nanocomposites, SEM is used. (5) The thermal conductivity of hybrid nanocomposites made of cotton fiber mats and ELC resin are also examined.

2. Experimental Methods

2.1 Materials

The materials used for creating the cotton fiber mats resin nanocomposites are Epoxy (E) resin (LY556), Bentonite (N) nanoclay (pH-value 8- 9.5), Cotton (C) fiber of 425 GSM (fiber mat roving), Hybrid (ELC) resin (pH 2 -2.5) and Hardener - (HY951).

2.2 Preparation of Hybrid (ELC) Resin

Ten days are spent for drying the Lannea (LC) coromandelica at ambient temperature and then an hour is spent for drying it at 30 degrees Celsius in an oven. For five minutes, dynamic mixer is used to combine the rough gum into nice powder. Using the mixer technique, hybrid (ELC) resin is produced by combining LC nice powder and Epoxy (E) resin matrix in a 1: 1 ratio [20].

2.3 Preparation of Over layers of composites for cotton fiber mats resin nanocomposites and ELC resin

Over layers of composites (300 X 300 X 3.2 mm) are placed in order with four layers of cotton fiber mats. To create hybrid composites, ELC resin is mixed with nano clay (N) for 30 minutes at speed of 1100 revolution per minute with a 12:1 weight ratio of hardener (HY951), followed by coating on cotton fiber mats. In order to keep the pressure (10 bar), which compresses the over layers of composites, the necessary quantity of ELC resin - (N) clay mixture is put into the mould, and a strong plate weighing 1000 N is then held on the mould. As shown in Table.1, the compressive (CP) hand lay-up (HLU) approach is also used to create different nano ELC resin cotton composites in a similar fashion.

Table 1 – Details of composition of cotton fiber mats reinforced ELC nano composites

Basic Material	Composites Specification	ELC Matrix (300 ml)	Reinforcement Roving Mat - RM N – Nano Clay (0 – 5) wt %
Hybrid Resin	ELC	ELC	--
Cotton Fiber Mats (C) or (CFM)	C1	ELC	CFM RM + 0 wt %
	C2	ELC	CFM RM + 1 wt %
	C3	ELC	CFM RM + 2 wt%
	C4	ELC	CFM RM + 3 wt%
	C5	ELC	CFM RM + 4 wt%
	C6	ELC	CFM RM + 5 wt%

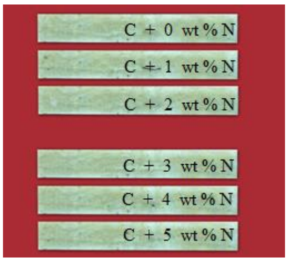

Fig. 1 Over layers of composites of cotton fiber mats reinforced ELC nano composites

2.4 Compression test

Specimens of Hybrid (ELC) resin and hybrid nano ELC resin composites are examined for compressive characteristics (ASTM D695) using the Universal (Olsen) testing machine.

2.5 DMA - Dynamic Mechanical Analysis Test

The DMSC 6100 (SEIKODMAI) test is conduct to find the qualities of Hybrid (ELC) resin and hybrid nano ELC resin composites with tensile load applying temperature being maintained in the span of (25 – 240) °C and increment of 5° centigrade per minute at amplitude of 2 Hz.

2.6 Thermal Conductivity Test

Hybrid (ELC) resin and hybrid nano ELC resin composites are evaluated for 12cm diameter specimens using Lee - method for detecting the thermal conductivity.

2.7 Biodegradability Test

The tests are evaluated to find the weight loss percentages of the hybrid nano ELC resin composites by keeping 125 days placing under the ground conditions.

Weight loss in percentage = $[(W_B - W_A) / W_A] \times 100$

where W_A - Initial Weight "A" of specimen

W_B - Final Weight "B" of specimen

2.8 Fractography Study

Hybrid nanocomposite specimens with gold coatings are kept in the sputter coating machine for up to one hour. Hybrid nano ELC resin composites are analyzed (SEM model : Apreo S (Alternating current voltage: (0.1-30 kV), magnification range (50 x - 25000X), and frequency maximum 2 nm) to find the microstructure for analyzing the compressive fracture properties and fractography behaviors.

3. Results and Discussion

3.1 Compression strength of cotton fiber (CFM) mats reinforced ELC nano composites and ELC resin

The compression strength of ELC resin is 12 MPa. The findings of inclusion of the nanoclay (N) to cotton fiber mats infused with EPL matrix are depict in Figure 2. The compression strength of ELC resin composites with 4% wt Nanoclay (N) inducement in matrix is to the maximum of 28.5 MPa. When compared to previous hybrid nano ELC resin composites, cotton fiber mats reinforced with 4% by weight N show greater compression strength readings. The compression strength is proceeding to deteriorate after intensifying steadily up to 5 weight percent nanoclay, despite the fiber inducement being raised to 4 weight percent nano-filler. The results show that huge nanoclay was induced to the resin that could easily be absorbed by the fibers, which led to defective joining and reduced compression strength. It was also known that the fragmented and compressed nano - filler dispersed in the ELC matrix induced the strengthening mechanisms in the various matrix materials [21].

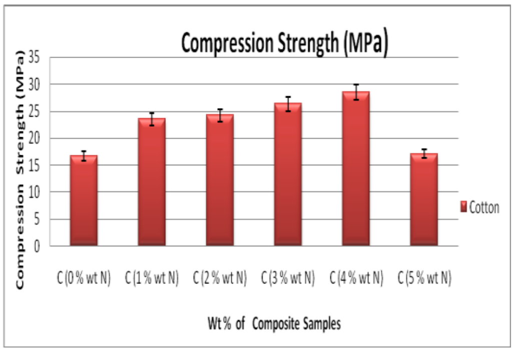

Fig. 2 Comparison of compression strength of cotton fiber (CFM) mats reinforced ELC nano composites

3.2. Fractography Observation

Hybrid nano ELC resin composites have the structural morphology. The compressive strength of composites is strengthened by adding cotton fiber mats with 4% weight percentage of Nanoclay (N) to ELC resin. As seen in the cross sectional region of Fig. 3, the ELC Resin matrix having nano - filler (4 wt %) replicated uniformly in cotton fiber mats' shows the strong strength between the hybrid (ELC) resin matrix and the cotton fiber mats. Fig. 3(b) has demonstrated that SEM fractography images of the cotton fiber (CFM) mats with 5% weight nanoclay percentage N mixing in ELC resin illustrates the fiber pullout-highlighted poor interfacial interaction between the fiber and resin ELC matrix. Additionally, the basics of power losses during the process of fermentation were found [22, 23].

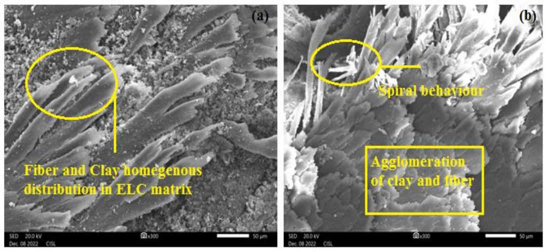

Fig. 3 SEM Images of ' cross-sectional areas of (a) cotton fiber mats (4 wt %) reinforced ELC nano composites and (b) cotton fiber mats (5 wt %) reinforced ELC nano composites

3.3. Dynamic mechanical (DMA) analysis results

3.3.1Storage modulus

Figure 4 shows the storage (Pa) modulus of ELC resin nanocomposites with cotton fiber mat reinforcement at bandwidth 2 HZ and temperatures span from 28 °C to 185 °C. The same treatment is given to ELC resin. In comparison to other hybrid nano ELC resin composites, the storage (Pa) modulus of hybrid ELC resin has the least value suggesting the lowest rigidity. The cotton fiber mats reinforced with N percent (4 wt) inducing in each composition of ELC resin composites have notably better thermal efficiency than the ELC resin and other hybrid nano ELC resin composites. Until the temperature reaches 135°C, the energy storage is superior for ELC resin and hybrid nano ELC resin composites and above this temperature, the energy loss is about to be identical. The results show that huge nanoclay was induced to the resin than could easily be absorbed by the fibers, which led to defective joining and reduced compression strength. It was also known that the fragmented and compressed nano - filler dispersed in the ELC matrix induced the strengthening mechanisms in the various matrix materials [24, 25].

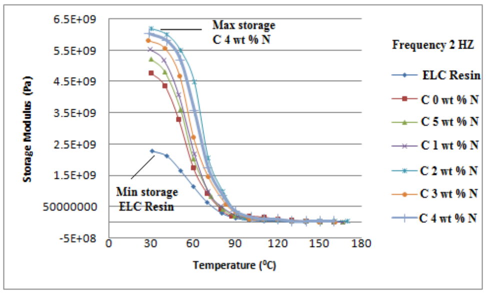

Fig 4 Storage modulus(Pa) of cotton fiber mats reinforced ELC nano composites

3.3.2 Damping (δ) Factor

Figure 5 illustrates the investigation of energy loss for ELC resin and hybrid nano ELC resin composites (Damping (δ) factor). When compared to other hybrid nano ELC resin composites and ELC resin at temperatures between 70°C and 85°C, cotton fiber reinforced with Nano 4 wt% inducement in each composition in ELC has the lesser peak indicating minimum power loss. More resistance between the interfaces of resin matrix, filler and fiber suggest the less energy loss. This implies that when compared to hybrid ELC resin, the hybrid resin nano composite material including nanoclay (N) loses less energy [10].

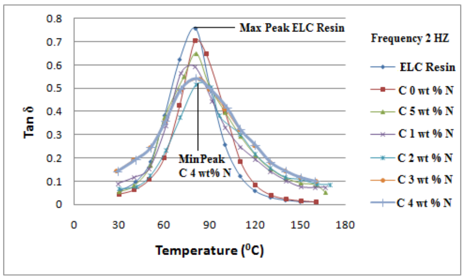

Fig. 5 Damping (δ) factor of cotton fiber mats(CFM) induced ELC nanocomposites

3.4. Thermal conductivity

The composites made of cotton fiber having the results of heat conductivity are shown in Figure 6. It is important to note that pure hybrid ELC resin has a heat conductivity of 0.19 W/mK. The inclusion of Nano N particles enhances heat conductivity. With the heat conductivity of 0.35 W/mK, hybrid nano ELC resin composites induced with 5% N particles and cotton fiber mats have the highest heat conductivity. The NCF particle effectively creates the heat transfer bridges as a result of these significant improvements in thermal conductivity. Despite the fiber's large pores, effective carbonization during the manufacture of laminates improves heat bond transmission. The heat conductivity of composites was greatly raised by employing nanoclay (NCF) particles [26].

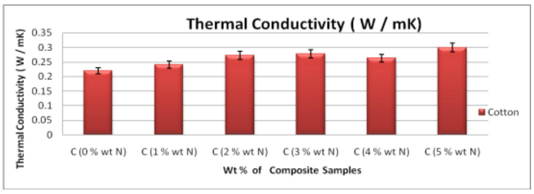

Fig. 6 Comparison of thermal conductivity of cotton fiber mats reinforced ELC nano composites

3.5 Biodegradability Testing

The cotton fiber mats with weight of Nano particles (0, 4 and 5 %) inducing in every composition in ELC resin composites are identified and then tested, taking into account the best and least mechanical quality of specimen. The cotton fibre mats with 4 percent N mixed in ELC resin has a minimal weight loss of 5.5 percent after 125 days when buried in the ground. Figure 7 clearly shows that due to moisture intake, the samples' weight loss percentage is lowest in the early days and gradually rises in the latter days. Superior biodegradability and an indication of environmentally friendly and sustainable practices are discovered in cotton fiber mats with a 4 percent N mixing in the ELC matrix [27].

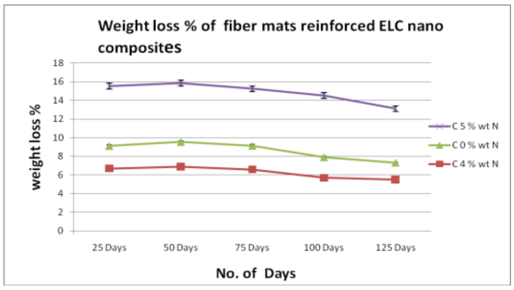

Fig. 7. Biodegradability of cotton fiber (CFM) mats with wt % (0,4 and 5N) ELC resin composite

4. Conclusion

ELC resin and ELC resin nanocomposites of cotton fiber mats with wt % (0, 1, 2, 3, 4 and 5) of N mixing in each composition in ELC matrix) are made by HLU compression technique. The results of the compression tests demonstrate that the presence of 4 wt% Nano (N) particles in the ELC matrix of cotton fiber mats of composites has greatly increased the compression strength. The highest compression strength of CFM composites with 4 wt percent Nano (N) particles reinforced in ELC matrix is 28.5 MPa compared to other hybrid nano ELC resin composites. Microstructural research affirms that the improved adhesion strength between cotton fiber, ELC resin and Nano N filler in hybrid composites. It is made of Cotton fiber mats / 4% wt N reinforcement in ELC matrix composites which has played a major role in the most cohesive composite to improve the strength of compression of samples. The introduction of Nano N particles and cotton fiber in the ELC matrix enhances the storage (Pa) modulus and reduces power loss of cotton fiber composites, according to the comparative result of DMA analysis of ELC resin and other ELC resin nanocomposites. The maximum thermal conductivity of treated cotton fiber mats of composites with 5 wt percent nano(N) particles reinforced in ELC matrix is 0.3 W/mK compared to other hybrid nano composites. In biodegradability test, the hybrid ELC resin nanocomposites of cotton fiber mats (CFM) with 4 wt% N inducing the ELC matrix resin has resulted little weight loss and more environmentally responsible. I recommend that because they are biodegradable, environmentally acceptable and higher mechanical strength, the available hybrid natural polymer composites be used in more useful applications (for instance wind shields, body panels etc.).

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