Mechanical behaviour of sisal – glass fiber reinforced hybrid Nano composites

K. Mohan1*, T. Rajmohan2
1-2Department of Mechanical Engineering, Sri Chandrasekharendra Saraswathi Viswa Mahavidyalaya, Kancheepuram, Tamilnadu - 631561, India.

Email: mohank84@gmail.com

Abstract. Natural fiber reinforced composites are playing a vital role in recent years due to its biodegradable, recycling and eco-friendly in nature. In this present work biodegradable hybrid composites is developed with sisal fiber and commercially available glass fiber as reinforcing fibers and nano (Multi walled carbon nanotube) incorporated epoxy used as a matrix. Using compression molding technique, composites were fabricated. Ultrasonic probe sonicator is used for incorporate the MWCNT into epoxy resin by varying their Wt% as 0%, 0.5% and 1% respectively. The composites were subjected to various mechanical testing like tensile, compressive and flexural. The Importance of this work can be predominantly affected by factors which include variation in nano additives and extreme fiber layers. The results indicated that, mechanical properties are enhanced by increasing the wt% of MWCNT. The microstructure of the developed composites were analyzed using scanning electron microscope (SEM) and the EDS analysis were used to confirm the presence of carbon nanotube and glass fiber in the developed composites.

1. Introduction
Depa ray et al, [1] Investigated the flexural strength of jute fiber vinylestar composites. The jute fibers are treated with NAOH (5%) solution at 30°C for 0, 2,4,6,8 hours respectively. Flexural strength and modulus improved by 20% and 23% for jute fiber reinforced composite at 35wt% for 4 hours treating with NAOH solution. HariSankar et al, [2] investigated the mechanical properties of shot carbon fiber reinforced composites filled with a nano clay. They have concluded, while increasing the wt% of nano clay indicates asignificant improvement in the impact strength of the composites. Beyond the optimum level of nano clay contents shows the negative sign in the ultimate strength. From the TGA analysis it was observed thermal stability of the composite is increased at 6Wt% of nano clay. MD.FarukHossen et al, [3] investigated the tensile properties of chemically treated jute fiber reinforced polyethylene/clay nano composites. Treated fiber composite which is having 15% fiber content exhibiting the maximum tensile strength and modulus rather than raw fiber composites. On the other hand the nano clay filled composites shows the improvement in the mechanical properties over the composites without nano clay. Sathish et al, [4] investigated the mechanical and thermal properties of banana, kenaf and glass fiber reinforced composites with different volume fraction and fiber
orientation. The hybrid composite which is arranged in 45° orientation shows the enhanced mechanical properties.

Dramatic increase in lignin mechanical properties regardless of the presence of NCC after the thermal treatment. The strength and modulus of electro spun fiber mats are increased 400 and 143% respectively after the oxidation process and the carbonization dramatically improved the mechanical properties concluded by Mijung Cho et al [5]. Balaji et al, [6] examined the mechanical properties and water absorption of cardanol bio-composites reinforced with bagasse fiber. The highest tensile strength and flexural strength is achieved 15wt% and 20 mm fiber length of bagasse fiber reinforced cardanol composite. Further increasing with the wt% of fibers the tensile and flexural strength is decreased.

The glass fiber reinforced composite was prepared filled with various composition of cloisite clay particles (1, 3, 5, and 7%). The 5% Nano clay reinforcement exhibits the enhanced tensile and flexural strength along with their modulus. Impact strength also improved. Further increasing the Nano clay the mechanical properties are decreased have been reported by jeyakumar et al [7]. Lee et al, [8] investigated structural and mechanical properties of the composites filled with acid treated and untreated MWCNT with various compositions of MDI. The treated MWCNT composites shows the improved mechanical properties and better adhesion between the MWCNT and PU matrix. Li-Xiu Gong et al, [9] investigated the fracture behavior and interfacial strength between fiber and epoxy resin modified by silica nano particles. Addition of nano particles exhibiting improved in tensile, fracture toughness and elastic modulus of the composite. Silica content composites shows good interfacial strength between fibers and epoxy resin.

Islam et al, [10] have prepared nano composites using coir and wood fiber with MMT nano clay. They observed the tensile strength is reduced due to the similar cellulose content presence in the fibers. By adding the MMT, the composites shows the better tensile strength and highest rate of water absorption. Jute, banana and flax composites were prepared by varying their stacking sequence and wt% of MWCNT. Extreme layer of jute fiber reinforced composites with 1wt% of MWCNT exhibiting the maximum mechanical properties rather than others reported by Mohan et al, [11]. Rajmohan et al [12] investigated glass banana reinforced composites by incorporating the various wt% of MWCNT. Mechanical properties were enhanced while increasing the wt% of MWCNT. Vetivera fiber subjected to various surface chemical treatment then it is fabricated and tested. Benzoyl chloride treated composites exhibiting superior mechanical strength than the other treatments reported by Vinayagamoorthy [13]. In the review of natural fiber laminates, various fabrication methods, different surface treatments of fibers and various composition of fibers effect the mechanical properties of the composites [14]. CFRP composites filled with fly ash were subjected to analyse the surface roughness during drilling process. It’s observed, highly influencing parameter is a feed rate which influences on the surface roughness [15]. Recent years many researchers have focused on machining of natural fibers reinforced composites. From the literature, it’s observed very limited work has been carried out to find the characteristics of MWCNT filled composites.
2. Materials and methods
Sisal fiber is obtained from Eco craft enterprises, Osur. From M/s. Sun Tech fibers, Chennai. Glass fiber, Epoxy resin Araldite LY556 and Hardener Aradur HY951 are obtained. Multi Wall Carbon Nano Tube (MWCNT) is purchased from M/S US Research Nano materials Inc, USA. The modified nano additive resin is prepared by using ultrasonic probe sonicator. Initially in the separate beaker, the respective wt% of MWCNT are added with the epoxy resin and allowed to vibrate 3 hours. Then the same blend is allowed to mechanical stirrer for the next two hours for homogeneous mixing of the MWCNT into the epoxy resin. Using compression molding technique the composites were fabricated in the size of 30x30 cm. During fabrication process the glass fibers were kept in the extreme layers, in-between sisal and glass fibers were arranged alternatively. The composites has been cured 24 hours in compression molding machine at the pressure rate of 350 psi. Then the specimens are prepared as per the ASTM standards.

![Materials used for fabricating the composites](image)

Table 1. Composition of composites

| S.No | Particulars in Wt% | G/S 0% CNT | G/S 0.5% CNT | G/S 1% CNT |
|------|-------------------|------------|--------------|------------|
| 1    | Glass Fiber       | 25         | 25           | 25         |
| 2    | Sisal Fiber       | 15         | 15           | 15         |
| 3    | Epoxy resin       | 60         | 59.5         | 59         |
| 4    | MWCNT             | 0          | 0.5          | 1          |

3. Results and Discussion
3.1 Tensile properties
The fabricated composites are cutted and sized into standard as per ASTM D638 for tensile test. The tensile test values are shown in the fig2. The maximum tensile strength is achieved 234.5Mpa for glass / Sisal composite which is having 1wt% of MWCNT followed by 198.6Mpa and 155.7 Mpa for 0.5Wt% and 0Wt% of MWCNT composite respectively. The results indicates while increasing the Wt% of MWCNT which increasing the tensile strength of the composites due to the high tensile and toughness properties of MWCNT. Similar result reported by Raj Mohan et al, [12].
3.2 Flexural properties
Flexural specimens were prepared according to the standard as per ASTM D790. The test has been carried out using 3point flexural testing method. The obtained results are revealed in the fig 3. The maximum flexural value is 76 Mpa for 0% incorporated MWCNT followed by 58 Mpa and 56 Mpa for 0.5% and 1% MWCNT incorporated composites. From the results it is concluded incorporating the MWCNT is not improving the flexural properties of the composites. This fall is due to the presence of higher hemicellulose and lignin content in the sisal fiber which is not making a proper adhesion with the matrix. Hence it is confirmed from the SEM analysis in fig 5c. Treated sisal fiber used as a reinforcement which improves the flexural strength and modulus of the composite rather than untreated sisal fiber reported by jhon et al, [16] Increasing the volume of sisal fiber also lead to decrease the flexural properties reported by venkatareddy et al, [17].

3.3 Impact properties

The impact test of the different composite specimens has been carried out using Charpy impact test method. The specimens are prepared as per ASTM A370 standard. During the test, the energy loss is found and the obtained results are plotted in the fig 4. G/S with 0% MWCNT composites exhibiting the maximum value compare to other two specimens which are incorporated with MWCNT 0.5% and 1%
respectively. The results indicates, initially the value is decreased then it is increased while increasing the wt% of MWCNT. The reduction of impact value due to the fiber breakage and delaminating of the composites. From the SEM images the breakages were observed and the similar results have been reported by Ramesh et al. [18]

4. Microstructure Analysis
The microstructure, fractured surface and interfacial properties of the sisal glass fiber reinforced filled with MWCNT composites were analysed using scanning electron microscope (SEM). The Fig.5 (a) shows the more elongation of fibers during tensile testing which indicates the improvement in the tensile properties of the composites also indicating the reinforcements are well bonded with the epoxy matrix.

![Microstructure Analysis](image)

Proper blending of epoxy resin and MWCNT are shown in the fig 5(b) which indicates the homogeneous mixing of MWCNT into the epoxy resin. Mechanical properties enhanced by proper blending of nano particles with the resin.

5. Conclusion
The sisal and glass fiber reinforced composite filled with an MWCNT were fabricated using compression molding technique. The effects of MWCNT on mechanical properties were analysed and the following conclusions are drawn.

- The tensile properties of developed composites increased while increasing the wt% of MWCNT. The tensile property of the composites increases up to 33.6% with addition of 1wt% of MWCNT.
- Flexural strength of the composites considerably reduced while increasing the wt% of MWCNT. The composite which is having 0%MWCNT show the maximum flexural strength of the composite.
- Impact strength of the composite initially decreases when increasing the wt% of MWCNT at 0.5%. Further increasing with the wt% of MWCNT shows the significant improvement in the impact strength.
SEM analysis shows the pulled out fiber during tensile and blending of MWCNT with the epoxy resin also it's confirmed the presence of MWCNT in the composite through EDS analysis.

References
[1] Dipa ray B, Sarkar K, Rana A K, and Bose N R 2001 Mater. Sci. 24 129.
[2] Hari Sankar P, Mohana Reddy Y R, and Hemachandra Reddy K 2015 Fib. Polym. 16443.
[3] Faruk Hossen Md, Sinin Hamdan Md, Rezaur Rahman, Md. Mizanur Rahman, Fui Kiew Liew and Josephine Changhui Lai 2015. Fib. Polym. 16475.
[4] Sathish P, Kesavan R, Vijaya Ramnath B and Vishal C 2017 J. Silic. 9 577.
[5] Mijung Cho, Muzaffer A. Karaaslan, Scott Rennecka and Frank K 2017 J. Mater. Sci. 52 9602.
[6] Balaji A, Karthikeyan B, Swaminathan J and Sundar Raj C 2017 Fib. Polym. 18 1193.
[7] Jeyakumar R, Sampath P S, Ramamoorthi R and Ramakrishnan T 2017 J. Adv. Manuf. Technol. 93 527.
[8] Sang Do Lee, Oh Jin Kwon, Byoung Chul Chun, Jae Whan Cho and Jong Shin Park 2009 Fib. Polym. 10 71.
[9] Li Xiu Gong, Li Li Hu, Jing Zang, Yong Bing Pei, Li Zhao and Long Cheng Tang 2015 Fib. Polym. 16 2056.
[10] Islam S, Ahmad M B, Hasan M, Aziz S A, Jawaid M, Haafiz M K M, Zakaria S A H 2015 J. Prop. Bio. Res. 10 1394.
[11] Mohan K, and Rajmohan T 2017 J. Nat. Fib. 14 864.
[12] Rajmohan T, Mohan K and Palanikumar K 2015 Appl. Mech. Mater. 766-767 193.
[13] Vinayagamoorthy R 2017 J. Nat. Fib. 10 108.
[14] Vinayagamoorthy R 2017 J. Reinf. Plast. Compos. 36 1577.
[15] Rajmohan T, Mohan K, Venkatraman Mahalingam, Satendra Kumar Bajpai 2015 Appl. Mech. Mater. 813-814 8105.
[16] John K and Venkata Naidu S 2004 J. Reinf. Plast. Compos. 23 15.
[17] Venkata Reddy G, Venkata Naidu S and Shobha Rani T 2009 J. Reinf. Plast. Compos. 28 16.
[18] Ramesh M, Palanikumar K and Hemachandra Reddy 2013 Compos. Part B 48 9.