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# EVALUATION OF MECHANICAL PROPERTIES ON NANO CARBON WITH FIBER REINFORCED POLYMER MATRIX COMPOSITES

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## ABSTRACT

*Over the past year's fiber reinforced polymers have replaced many of the conventional metal/materials in modern engineering. This is achievable because of the advantages of fiber reinforced polymers over the existing materials. Collectively fiber reinforced polymer composites are light, stiff and allow both large and small scale production at lower cost, however, the strength of these composites are highly not noticeable. In an attempt to improve the different mechanical properties of the existing fiber polymer composites, a small amount of nano Carbon powder have been added as constituent in different weight ratio. In this experimental study nano Carbon powder with three different natural fibers of water hyacinth, Areca nut and Hen feather (0, 1, 2, 3, 4, 5, 6 weight %), polyLactic acid (Bal weight %) are mixed together and seven different samples of Nano Carbon Fibers Reinforced Polymer composites (NCFRPC) were fabricated for system-1, system-2 and system-3 by using polymer compression injection molding machine. After the fabrication process, all the specimens were prepared as per the ASTM standards and the tensile, compressive and flexural properties are evaluated.*

**KEYWORDS:** Mechanical properties, fiber, polymer, nano composites.

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## 1. INTRODUCTION

The routines of specimen roselle /Immunology fiber same optimal length versus weight ratio between constants to review the properties. Most of the scientific papers assessed and computed only the one or double fiber composites and the possibility of combining with the synthetic fibre is also studied with the enhancement of mechanical qualities [1-9]. The fiber-reinforced polymer and polypropylene, Palestine was appropriate in automobile pooling, oscillation and monitoring processes investigation from various epoxy composites [20-21]. The analysis had been examined and investigated, in an order and thermal behavior possessions investigation of jute /banana fortified is evaluated in optimum epoxy composites. While investigated in 100 /0 to 0/100 ratio of burden from manual techniques investigation in various methods. And most of the scientific papers, facets of inspection concern just fiber or non-fibers interfacing by distinct compound parameters needs to keep the orientation of load transfer to a potential nonenvironmental harm of fiber scheme. 3:1 was used to organize for the different proportion of drinking water absorption of EFB-jute/Jute respectively [17-18]. The routines of specimen roselle /Immunology fiber SAM e optimal length versus Wight ratio amongst constants to review the properties. A single or dual fiber composites assessed and found in many scientific newspaper's efforts on normal unite artificial fiber reinforced and to improve certain mechanical qualities [1-9]. 2. Economical The principal benefits of natural fiber composite builtin specific stability. 3. Eco Friendly Normal fibers are functionally attain much more importance because of the exceptional area throughout to this exceptional role throughout artificial processing, economically it is used strongly [3]. The testimonials that the mechanical components of the unprotected orientation value analysis short polymer fiber. Reinforced composites and researched the period of response 53% to 60% with ratios. The extensively found in different ordered software [5]. Because of installing high-value abilities' most literature was analyzing equal systematic fiber composites. Both the polymer-based and combined are introduced pure fiber composites. Widely used in the hybrid processing of composites that related to oriented in polymer composites, or matrices have a lot of usages or intention of home appliances or lightweight equipment that an economical and eco-friendly The snake Grass fiber [WATER HYACINTH FIBER] have been introduced is having the ability to minimal water healing approach and mechanical behavior of electrical houses. Of the natures, the fiber had been measured in accordance with ASTM criteria. [9] The WATER HYACINTH FIBER fiber was employed to prepare the probably considered and polyunsaturated fiber fortified case of polymer in different optimum composites. Subsequently fiber has been the very hands lay-up technique of processes follows by many using compression, and injection pass away-molding process activity. The exceptional mechanical components were researched for various fiber weight boosters connected to different lay-up lengths. [10] The upward ordinary behavior's possessions attend 25% of fiber fraction values has been believed in past surveys. The most of scientific and engineers in dropped of years gained knowledge of normal fiber -reinforced polymer composites were considered 3 facets just. The random sisal fiber was fortified polyester composites for pronominally tensile load ranging from 0 to 30%. The preparation of exploration procedure was initialized for its coir fiber with composites of hybrid polyester had been good mechanical components found for making and process optimum parameters if delivered this different fiber mix [1 1]. The WATER HYACINTH FIBER Fiber with polymer composites where oxygen to prepare the polyester composites in distinct optimal worth using the hand lay up processes of parameter behavior examination focused, steady values fraction of fiber course of action [1-2]. Presently higher level composites released it. One literature of preceding randomly oriented in blended and also short term /banana fiber composites of hands lay-up processes utilized at a steady worth fraction of 1: 1: 1, 3: 1, 1:3 percentage. Relatively weight potential metal composites attend in different states [13]. The palm /Coir fiber, also mixed with the sodium lauryl surface area therapy, apply the mechanical properties in precisely noodle follow behavior analysis numerically and chemical method [14-15]. Concept S of lamination methods

are bi-layer and poly-layer, tri-Layer procedures of techniques were introduced in a nutshell bagasse /coir fiber with mixed with sandpaper publication composites [16]. A swelling thickness of plain water absorption will be different heights of examining polynomial OD learned polynomial fiber composites for example oil palms with example sandpaper composites. The best of volume percentage techniques employed in 1. Readily available.

## 2. EXPERIMENTAL

### 2.1. Materials

In this present investigation water hyacinth stem powders (*Eichhornia crassipes*), Hen feather shell powder (*Phasianidae*), areca nut shell powders (*Areca catechu*), nano Carbon powders (Carbon oxide) and PLA are used for fabricating the nano Carbon and natural fiber reinforced polymer matrix composite specimens. The water hyacinth stem powders, hen feather powders and arecanut shell powders are obtained from Erode District, Tamil Nadu, and India. PLA is obtained from Kovai Seenu & Company Ltd., Coimbatore, India. Carbon powder is obtained from M/s Star Scientific Traders, Erode, Tamilnadu, India.

#### 2.1.1. Natural fibers

In the last two decades, there has been an impressive enhancement in the use of natural fibers such as fiber extraction from sisal, arecanut, water hyacinth, jute, coir, flax, hemp, pineapple and banana for making a new environment friendly and biodegradable composite materials (somehow these composites are called “Green Composites”). Recent studies in natural fiber composites offer significant improvement in materials from renewable sources with enhanced support for global sustainability. These natural fiber composites possess high/moderate strength, thermal stability when they are recycled, but the problems of using pure biodegradable polymers are their low strength and transition temperature.

#### 2.1.2. Water hyacinth stems powders

Water hyacinth stem powders (Figure 1.A) are prepared from the stems of water hyacinth plant. The plants are cultivated in the banks of the Bhavani River, Bhavani, Erode District, Tamilnadu, India, the weight of the plants used in the experimentation is 27kg. After the cultivation of the plant, leaves are removed from the plant using knife. Then the stems of the water hyacinth are washed by pure water and allowed to dry at room temperature in an open space for one week to eliminate the moisture content. Then the dried water hyacinth stems are taken into the flour mill hopper and grinded by the flour mill grinder with different grid size blades to change the long strand stems into desirable grain sizes powder form with the processing time of one hour. In order to reduce the grain size of the water hyacinth stems powder the grinding process is repeated until it is converted to fine grain sized particles. Finally the desired grain size water hyacinth stems powders are made with the flour mill grinder.

#### 2.1.3. Hen feather powders

Hen feather powders (Figure 1.B) are prepared from the well dried stems of waste. 5 kg of the Hen feather stem are obtained from the Vinayaga Oil Mills, Bhavani, Erode District, Tamilnadu, India. After that the shells of the Hen feathers are allowed to dry at room temperature in an open space for one week duration to enhance its powder form ability. Then the dried hen feather shell are taken into the flour mill hopper and grinded by the flour mill grinder with different grid size blades to change the shells into desirable grain sizes powder form with the processing time of two hours. In order to minimize the grain size of the hen feathers stem powder the grinding process is repeated until they are converted to fine grain size particles. Finally the desired grain size hen feather powders are made with the flour mill grinder.

#### 2.1.4. Arecanut shell powders

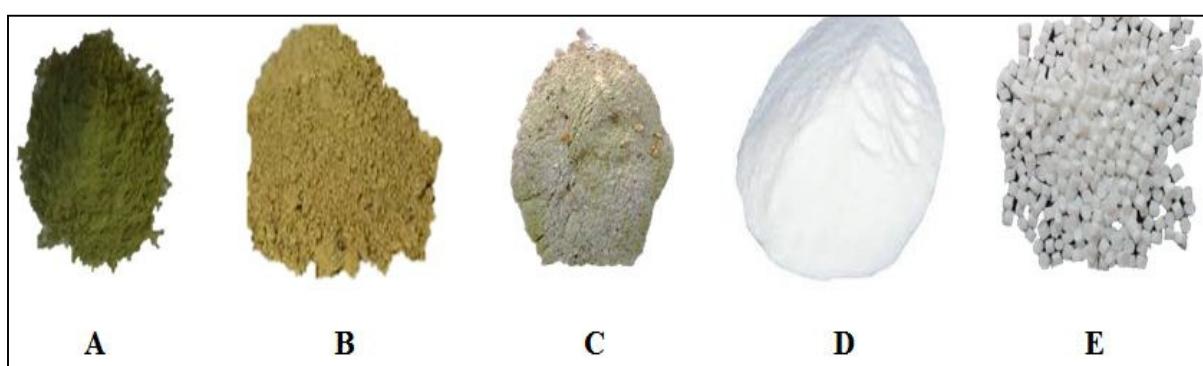
Arecanut shell powders (Figure.1.C) are prepared from the fine dried shells of arecanut. 10kg of well dried arecanut shells is obtained from the thirumurugan arecanut products, Thalaivasal, Salem District, Tamilnadu, India. After that the shells of the areca nuts are allowed to dry at room temperature in an open space for three weeks duration to eliminate the complete moisture content present in its shells. Then the well dried arecanut shells are taken into the flour mill hopper and grinded by the flour mill grinder with different grid size blades to change the shells into desirable grain sizes powder form with the processing time of four hours. In order to reduce the grain size of the arecanut shells powder the grinding process is repeated until it is converted to fine grain size particles. Finally the desired grain size arecanut shellpowders are made with the flour mill grinder.

#### 2.1.5. Nano Carbon powder

Carbon is a versaile material used as refractory, engineering ceramics material, abrasive and in various other applications where chemical inertness coupled with its high hardness and abrasiveness is of primary importance. The micron size particles of Carbon powder are purchased from M/s Star Scientific Traders, Erode, Tamilnadu, India. Then the micron size particles of the Carbon powders are changed into nano size particles by using ball milling process at Sona College of Technology, Salem, Salem District, Tamilnadu, India. The particle size confirmation test is carried out at K.S.Rangasamy College of Technology, Tiruchengode, Namakkal District, Tamilnadu, India. The Nano Carbon powder is shown in Figure.1.D.

#### 2.1.6. Polylacticacid [PLA]

Polylacticacid [PLA] (Figure.1.E) is a thermoplastic “addition polymer” made from the combination of propylene monomers. It is used in a variety of applications which includes packaging for consumer products, plastic parts for various industries including the automotive industry, special devices like living hinges, and textiles. Today it is one of the most commonly produced plastics in the world. PLA is used in both household and industrial applications. Its unique properties and ability to adapt to various fabrication techniques make it stand out as an invaluable material for a wide range of uses. Another invaluable characteristic is PLA’s ability to function as both a plastic material and as a fiber. PLA’s unique ability to be manufactured through different methods and capability to be used in different applications makes it to challenge many of the old alternative materials, notably in the packaging, fiber, and injection moulding industries. Its growth has been sustained over the years and it remains a major player in the plastic industry worldwide.



**Figure.1** (a) Water hyacinth stem powder (b) Areca nut shell powder (c) Hen feather powder (d) Nano Carbon powder (e) PLA Particles

## 2.2. Preparation of composite specimens

The composite materials used for the present investigation is fabricated by using hydraulic injection moulding machine. In this investigation three samples were prepared by changing the natural fiber powders (water hyacinth stems, Hen feather shell & arecanut shell). Sample "A" contains PLA of WEIGHT % grams, 0 – 6% grams of nano Carbon powder and 0-6% grams of water hyacinth powder, sample "B" contains PLA of WEIGHT % grams, 0 – 6% grams of nano Carbon powder and 0-6% grams of arecanut shell powder and sample "C" contains PLA of WEIGHT % grams, 0 – 6% grams of nano Carbon powder and 0-6% grams of Hen feather powders respectively. The composite specimen consists of the scattered particles of nano Carbon powder and natural fiber powders as reinforcement and the PLA as matrix material. Initially well mixed sample "A" composition is taken and feed into the hydraulic injection moulding machine's (**Figure.2.a**) input cylinder and this composition is heated above the melting temperature of the PLA using the electric heater. After ten minutes the liquid state sample "A" compositions were compressed inside the input cylinder by the hydraulically operated piston. Then the liquid state sample "A" compositions are allowed to squeeze out from the input cylinder via nozzle with high pressure and temperature into the prefabricated die. Then the die is allowed for slow cooling with the atmospheric air to get the specimen output in desired dimensions. After the composite materials getcured completely, the composite material is taken out from the die and rough edges are neatly cut and removed. Then the specimen is machined as per the ASTM standard using Vertical CNC Machine (**Figure.2.b**) by as per the required dimensions. Similarly this process is repeated for remaining sample "B" and "C". The different test specimen's sizes as per ASTM standards are shown in table.1.



**Figure 2** (a) Hydraulic Injection Moulding Machine (b) Vertical CNC Machine

**Table.1.** Different test specimens sizes as per ASTM standards

S1.No.	Name of the test	Specimen standards	Specimen size (Length , width & thickness (mm)
1.	Tensile test	ASTM D638	115×19×9
2.	Compression test	ASTM D3410	155×12×9
3.	Flexural test	ASTM D790	150×12.7×10

### 3.1. Tensile test

The tensile test is carried out as per ASTM D638 standard using Universal Testing Machine (**Figure 3.a**). The different tensile properties like tensile strength, breaking load, yield stress, yield load, elastic modulus, and percentage of elongation, percentage of area reduction, linear strain & lateral strain were obtained from the tensile test. The sample tensile test specimens namely A, B & C after tensile test are shown in Figure.4.



**Figure 3** (a) Universal Testing Machine (b) specimen fixed in UTM cross head between flat jaws



**Figure 4** Tensile test specimens after test

#### 3.2.1. Tensile Strength

Tensile strength execution was assessed for the main system (WH + NC + PLA) was arranged and their charts are shown in the Figure 5. As a component of fiber scattering. Tensile strength for perfect mixed composite was estimated as 25.06 MPa and tensile strength was expanded further while expanding fiber wt. % from 0 to 4.0 wt. %. It was seen that at 4.0 wt. % fiber loading execution was upgraded to 32.35 Mpa and it was expanded to 29.09 % when contrasted and 0 wt. % fiber loading. Tensile strength execution for second system (i.e. AC + PLA + NC) ideal from the pure mixed hybrid NCFRPCs was 40.01 MPa, and when 1 wt. % fiber it was 42.63 MPa and after that strength was intensified up to 4 wt. %. It was seen that at 4.0 wt.% fiber loading execution was enhanced was 65.23 Mpa and it was expanded to 63.03%, when contrasted and 0% fiber loading. PLA Nano-carbon directly inferable from noteworthy limit among the fiber and matrix and furthermore great blending of PLA polymer and NC with fiber mixes, and furthermore diminish in agglomerations, anyway strength was diminished at 5 wt. % fiber. The explanation

behind the abatement in strength was because of poor interface between the AC + PLA + NC and matrix, and expanded viscosity of adjusted matrix is hard to stream because of that plausibility of air entrapment, subsequently voids will frame. Tensile strength execution for third system (i.e. HF + PLA + NC) appropriate from the pure mixed hybrid NCFRPCs was 22.77 MPa, and when 1 wt. % fiber it was 23.85 MPa and after that strength was intensified up to 4 wt. %. It was seen that at 4.0 wt. % fiber loading execution was upgraded and it was expanded to 49.97%, when contrasted and 0% fiber loading. PLA Nano-carbon straightly inferable from huge limit among the fiber and matrix and furthermore great blending of PLA polymer and NC with fiber mixes, and furthermore diminish in agglomerations, anyway strength was diminished at 5 wt. % fiber. The purpose behind the abatement in strength was because of poor interface between the HF + PLA + NC and matrix, and expanded viscosity of altered matrix is hard to stream because of that plausibility of air entrapment, thusly voids will appear.

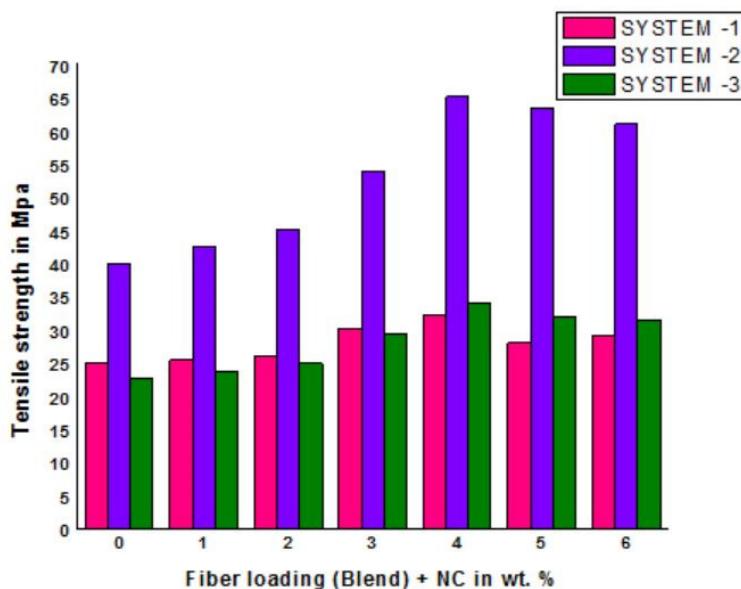
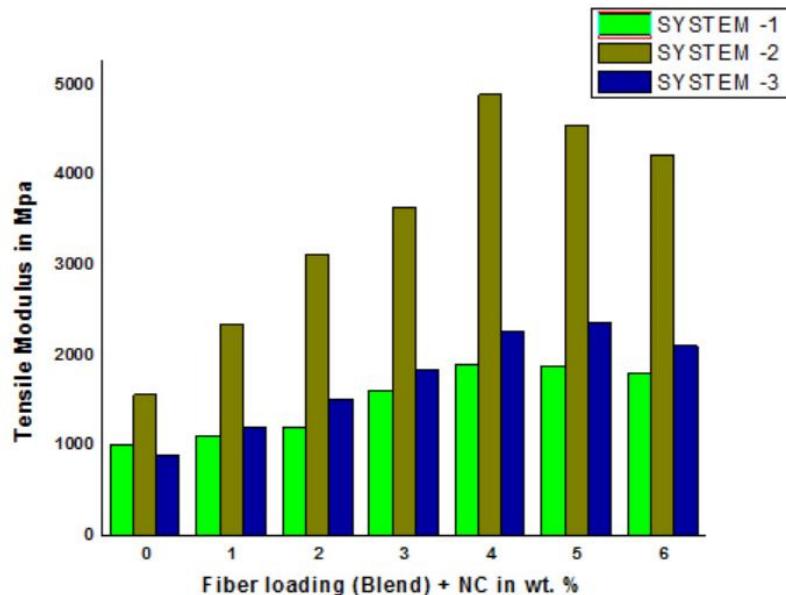


Figure 5 Tensile strength (Mpa) vs Fiber loading (Blend) + NC in (wt. %)

### 3.2.2. Tensile Modulus

Tensile modulus (TM) for system-1, 2 and 3 is structured as an element of PLA Nanocarbon ratios uncovered in the Figure 6 and their qualities classified in Table. In system - 1, TM for 0 wt. % PLA Nanocarbon dispersion is 1101.23 MPa, and moreover, TM is straightly improving from the 0 wt. % fiber to 4.0 wt. % PLA Nanocarbon. At 4.0 wt. % fiber loading, TM was distinguished as 1907.49 MPa and TM was improved up to 73.21% for 4.0 wt. % when related with 0 wt. % PLA Nanocarbon ratio. By and by, consequently 4.0 wt. % TM was diminishing. Tensile modulus (TM) of system-2 is assessed with the variety of PLA Nanocarbon ratios uncovered in the Fig. 7.4 and their qualities arranged in Table 7.4 TM for 0 wt. %, PLA scattering is 1563.45 MPa, and furthermore the TM was enhancing from 1 wt. % to 4 wt. % PLA Nanocarbon. At 4 wt. % PLA Nanocarbon, TM was seen as 4896.36 MPa and TM was expanded up to 213.17% for 4 wt. % when related with 0 wt. % PLA Nanocarbon. By and by, along these lines after 4 wt. % PLA TM was decreasing. Tensile modulus (TM) of system-3 is assessed with the variety of PLA Nanocarbon ratios revealed in the Fig. 6 and their qualities arranged in Table. TM for 0 wt. %, PLA scattering is 897.638 MPa, and furthermore the TM was enhancing from 0 wt. % to 5 wt. % PLA Nanocarbon. At 5 wt. % PLA Nanocarbon, TM was seen as 2372.062MPa

and TM was expanded up to 164.25 % for 5 wt. % when related with 0 wt. % PLA Nanocarbon. In any case, therefore after 5 wt. % PLA TM was diminishing.



**Figure 6** Tensile Modules (MPa) Vs Fiber loading (Blend) + NC in (wt. %)

### 3.2. Compression test

The compression test is carried out as per ASTM D638 standard using Universal Testing Machine (**Figure.2.a**). The different compressive properties like ultimate compressive strength, ultimate compressive force, and percentage of area increase, compressive linear strain, compressive lateral strain and compressive elastic modulus are obtained from the compression test. The sample compression test specimens before and after compression test are shown in 7.

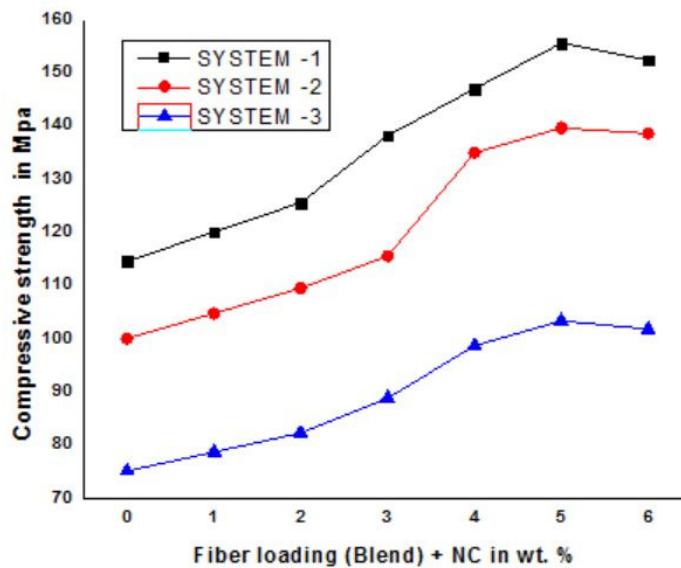


**Figure 7** Compression test specimens after test

Compression strength (CS) of system-1 was seen as an expansion of PLA Nano-carbon ratios uncovered in the Figure 8 and their qualities classified in Table 7.7. At 0 wt. % PLA Nano-carbon scattering CS was 114.56MPa and furthermore, CS was straightly expanding ideal from the 0 wt. % fiber to 5 wt. % PLA Nano-carbon ratio. At 5 wt. % PLA Nano-carbon ratios, CS was seen as 155.65MPa and CS was climbing up to 35.86% for 5 wt. % when related with 0wt. % PLA Nano-carbon ratios. Past 5 wt. % PLA Nano-carbon the estimation of CS is declining.

Compression strength (CS) of system-2 was estimated with the variety of PLA Nano-carbon ratios is spoken to in the Fig. 7.7 and their qualities classified in Table 7.7. CS for 0 wt. % PLA

Nano-carbon was 100.05MPa, and furthermore CS was continuously rising ideal from the 0wt. % PLA to 5 wt. % PLA loadings. At 5 wt. % PLA loading, CS was experiential as 139.64MPa and CS was expanded up to 39.57% for 5 wt. % when related with 0wt. % fiber loading. Be that as it may, after 5 wt. % CS is declining for further expansion of fiber. Compression strength (CS) of system-3 was estimated with the variety of PLA Nano-carbon ratios is spoken to in the Fig. 7.7 and their qualities arranged in Table 7.7. CS for 0 wt. % PLA Nano-carbon was 75.11MPa, and furthermore CS was logically rising appropriate from the 0wt. % PLA to 5 wt. % PLA loadings. At 5 wt. % PLA loading, CS was experiential as 103.35MPa and CS was expanded up to 37.59% for 5 wt. % when related with 0wt. % fiber loading. In any case, after 5 wt. % CS is declining for further expansion of fiber.

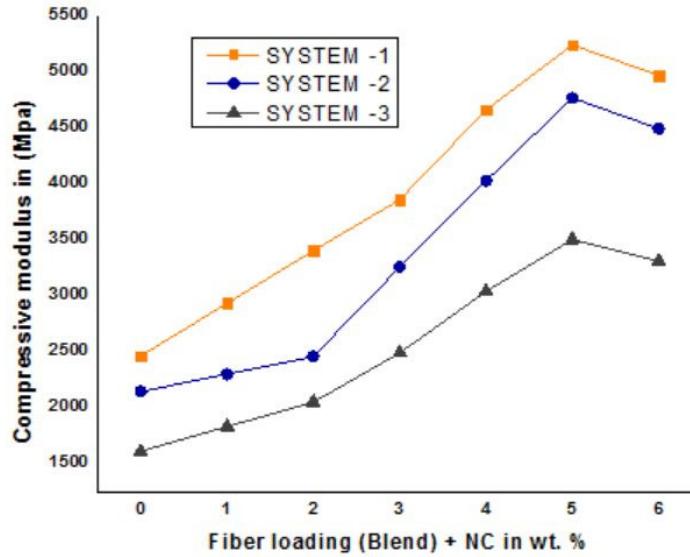


**Figure 8** compressive strength (Mpa) vs Fiber loading (Blend) + NC in (wt. %)

Compression Modulus (CM) of system-1 is estimated as an expansion of PLA doped are displayed in Fig. 9 and their qualities classified in Table. CM for 0 wt. % PLA circulation was 2463.08MPa, and furthermore, CM was directly aggregate from the 0 wt. % fiber to 5 wt. % PLA Nanocarbon ratios bit by bit. At 5 wt. % fiber loading CM was identified as 5236.44MPa and CM was enhanced up to 112.59% for 5 wt. % when related with 0 wt. % PLA Nanocarbon ratios. In any case, past 5 wt. % PLA Nanocarbon loading CM is declining.

Compression Modulus (CM) of system-2 is seen with the variety of PLA Nano-carbon ratios is discussed in the Figure 9. And their qualities organized in Table. CM for 0wt. % fiber scattering was 2145.02MPa and CM was dynamically enhancing from 0 wt. % to 5 wt. % Nano-carbon increases. At 5 wt. % fiber loading CM was trial as 4764MPa and CM was expanded up to 122.09% for 5 wt. % while contrast with 0wt. % fiber loading. Past 5 wt. % of PLA Nano-carbon the estimation of CM is reducing. These outcomes indicate that PLA Polymer-PLA Polymer/PLA composites have demonstrated higher strength with lower PLA ratios.

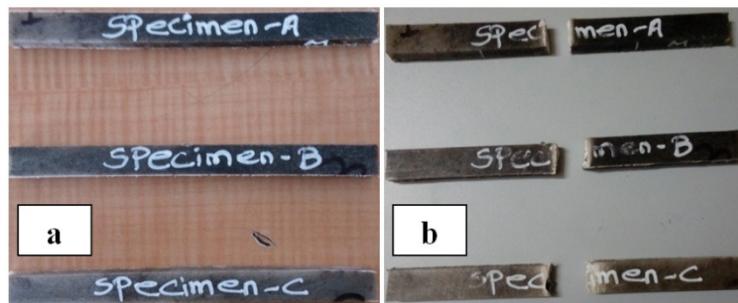
Compression Modulus (CM) of system-3 is seen with the variety of PLA Nano-carbon ratios is spoken to in the Figure 9. And their qualities arranged in Table. CM for 0wt. % fiber scattering was 1612.835MPa and CM was logically enhancing from 0wt. % to 5 wt. % Nano-carbon augmentations. At 5 wt. % fiber loading CM was test as 3500.154MPa and CM was expanded up to 117.01% for 5 wt. % while contrast with 0wt. % fiber loading. Past 5 wt. % of PLA Nano-carbon the estimation of CM is decreasing. These outcomes determine that PLA Polymer-PLA Polymer/PLA composites have indicated higher strength with lower PLA ratio.



**Figure 7.8** compressive modulus (Mpa) vs Fiber loading (Blend) + NC in (wt. %)

### 3.3. Flexural test

The flexural test is carried out as per ASTM D790 standard using Universal Testing Machine (**Figure.2.a**). The different flexural properties like flexural strength, maximum flexural load and flexural modulus were obtained from the compression test. The sample flexural test specimens before and after compression test are shown in Figure.10.

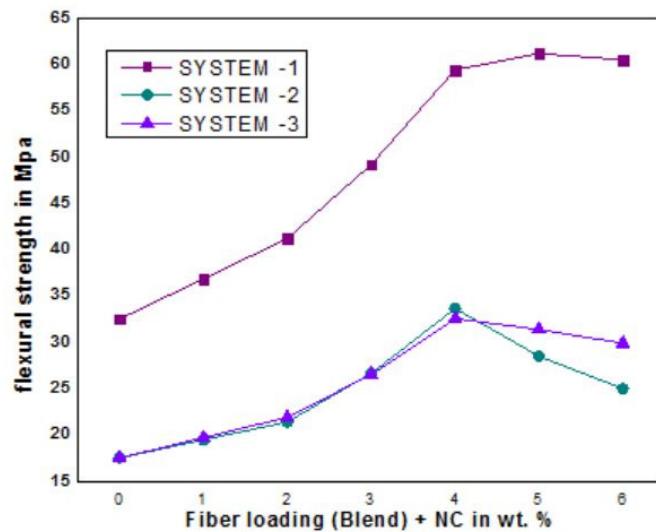


**Figure 10** Flexural test specimens after test

Flexural strength (FS) for system-1 are planned as an expansion of PLA ratios appeared in the Fig. 11. And their qualities organized in Table. FS for 0 wt. % PLA dissemination was 32.56MPa, and further FS was straightly developing from the 0 wt. % PLA to 5 wt. % PLA Nanocarbon ratios. At 5 wt. % PLA loading FS was seen as 61.23MPa and FS was expanded up to 88.05 % for 5 wt. % when related with 0 wt. % PLA. Nonetheless, after 5 wt. % FS was dropping. Flexural strength (FS) for system-2 is estimated as an expansion of PLA ratios appeared in the Fig.11. And their qualities organized in the Table. FS for 0 wt. % PLA scattering was 17.56MPa, and furthermore FS was straightly accumulating appropriate from the 0 wt. % to 4 wt. % PLA Nano carbon. At 4 wt. % fiber loading FS was identified as 33.69MPa and FS was enhanced up to 91.85% for 4 wt. % when identified with 0 wt. % PLA ratio. Further expansion of PLA Nano carbon diminishes the estimation of FS.

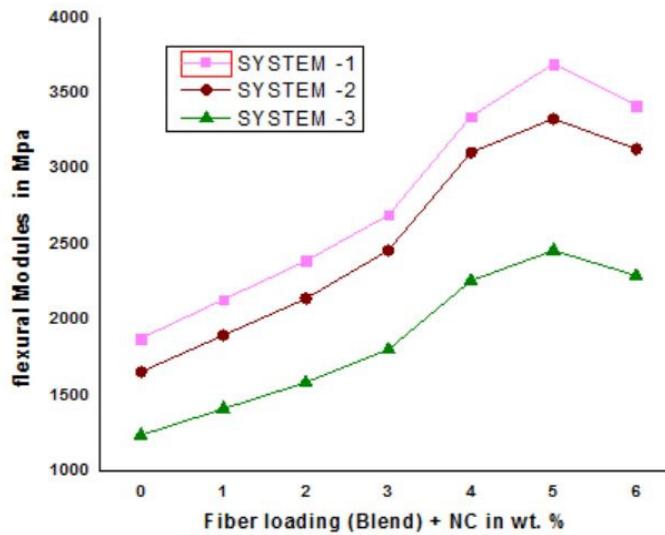
Flexural strength (FS) for system-3 is estimated as an expansion of PLA ratios appeared in the Fig.11. And their qualities organized in the Table 11. FS for 0 wt. % PLA scattering was

17.52MPa, and furthermore FS was straightly accumulating appropriate from the 0 wt. % to 4 wt. % PLA Nano carbon. At 4 wt. % fiber loading FS was identified as 32.59MPa and FS was enhanced up to 86.01% for 4 wt. % when identified with 0 wt. % PLA ratio. Further expansion of PLA Nano carbon diminishes the estimation of FS.



**Figure 11.** Flexural strength (MPa) Vs Fiber loading (Blend) + NC in (wt. %)

Flexural modulus (FM) of system-1 is seen as an expansion of PLA ratio appeared in Figure 12. And their qualities arranged in Table. FM for 0 wt. % PLA Nano carbon scattering is 1874.23MPa, and furthermore, FM was directly advancing ideal from 0wt. % PLA to 5 wt. % PLA loading. At 5 wt. % PLA loading FM was estimated as 3688.42MPa and FM was enhanced up to 96.79% for 5 wt. % in correlation with 0wt. % PLA Nano carbon loading. The estimation of FM was decreased with the expansion of PLA Nano carbon past 5 wt. %. Flexural modulus (FM) for system-2 is structured as expansion of PLA Nano-carbon uncovered in the Figure 12. And their extents are classified in the Table. FM for 0 wt. % PLA scattering was 1652.02MPa, and furthermore FM was straightly going high from the 0wt. % PLA to 5 wt. % PLA Nano carbon loading. At 5 wt. % PLA loading FM was recognized as 3325.88MPa and FM was intensified up to 101.32% for 5 wt. % when related with 0wt. % PLA Nano carbon. Flexural modulus (FM) for system-3 is planned as expansion of PLA Nano carbon unveiled in the Figure 12. And their extents are classified in the Table. FM for 0 wt. % PLA scattering was 1234.188MPa, and furthermore FM was directly going high from the 0wt. % PLA to 5 wt. % PLA Nano carbon loading. At 5 wt. % PLA loading FM was distinguished as 2455.005 MPa and FM was intensified up to 98.91% for 5 wt. % when related with 0wt. % PLA Nano carbon.



**Figure 12** Flexural Modulus (mpa) vs Fiber loading in wt. %

In any case, past 5 wt. % PLA Nano carbon the estimation of flexural modulus is reducing. Another probability is that in light of the manner in which that the PLA has a significantly more unquestionable modulus than the PLA Polymer-PLA Polymer blends, extend obsession may have existed at the interfaces of the PLA Nano-carbon and PLA Polymer-PLA Polymer mix. In this manner, under twisting loadings, splits begin at those frail concentrations and root the example to crash and burn at for the most part low strains. It makes the feeling that the assortment of modulus with the dimension of peeling of PLA is pretty much nothing and the modulus is estimated on a very basic level by the weight some portion of PLA rather than by its shedding. Elective likelihood is, this may in light of the manner in which that the thickness of the climate temperature dried PLA Polymer would not be adequately low to allow scattering of the monomer into the planar structure of the PLA Nano-carbon particles. Thusly, agglomeration may be realized in the midst of the curing system of composites. Similar recognitions be seen by past researchers

#### 4. CONCLUSION

The best specimen is manufactured with compresses injection moulding. This process made under vaccum results in material with single and dual fibre composites.

- Tensile strength is linearly enhancing from the 0 wt. % fiber to 4 wt. % PLA nanofiller. In system -2 at 4 wt. % fiber loading, TS was detected as 65.23 MPa and Ts was enhanced up to 63.03 % for 4 wt. % when related with 0 wt. % PLA nanofiller ratio. Where System-2 is better compared to system 1 and 3.
  - Tensile modules for system-2 of 0 wt. % PLA dispersion is 1563.45 MPa, and also the TM was improving from 0 wt. % to 4 wt. % PLA nanofiller. At 4 wt. % PLA nanofiller, TM was noticed as 4896.36 MPa and TM was increased up to 213.17 % for 4 wt. % when related with 0 wt. % PLA nanofiller. Nevertheless, subsequently after 4 wt. %PLA TM was reducing. Where System-2 is better compared to system 1 and 3.
- Compression Modules for system-1 of 0 wt. % fiber dispersion was 2463.08 MPa and CM was progressively improving from 0 wt. % to 5 wt. % with Nanocarbon additions. At 5 wt. % fiber loading CM was experimental as 5236.44 MPa and CM was

increased up to 112.59% for 5 wt. % when compared to 0 wt. % fiber loading. Where System-1 is better compared to system 2 and 3.

- Compression strength for system-1 of 0 wt. % PLA Nanocarbon was 114.56 MPa, and also CS was progressively rising right from the 0 wt. % PLA to 5 wt. % PLA loadings. At 5 wt. % PLA loading, CS was exponential as 155.65 MPa and CS was increased up to 35.86 % for 5 wt. % when related with 0 wt. % fiber loading. However, after 5 wt. % CS is declining for further addition of fiber. Where System-1 is better compared to system 2 and 3.
- Flexural Strength was linearly accumulating right from the 0 wt. % to 5 wt. % PLA Nanocarbon. In system-1 at 5 wt. % fiber loading FS was detected as 61.23 MPa and FS was improved up to 88.05 % for 5 wt. % when related to 0wt. % PLA ratio. Where System-1 is better compared to system 2 and 3.
- Flexural modulus (FM) for system-1 is designed as addition of PLA Nanocarbon disclosed and their magnitudes are tabulated. FM for 0 wt. % PLA scattering was 1874.23 MPa, and also FM was linearly going high from the 0 wt. % PLA to 5 wt. % PLA Nanocarbon loading. At 5 wt. % PLA loading FM was detected as 3688.42 MPa and FM was amplified up to 96.79 % for 5 wt. Where System-1 is better compared to system 2 and 3.

#### Nomenclature

TS - Tensile strength  
TM - Tensile modules  
CM- Compression Modules  
CS - Compression strength  
FS - Flexural Strength  
FM - Flexural modulus  
PLA – Polylactic acid

## REFERENCES

- [1] Saheb, D. Nabi, and Jyoti P. Jog. "Natural fiber polymer composites: a review." *Advances in polymer technology* 18.4 (1999): 351-363.
- [2] Landel, Robert F., and Lawrence E. Nielsen. *Mechanical properties of polymers and composites*. CRC press, 1993.
- [3] Agarwal, Bhagwan D., Lawrence J. Broutman, and K. Chandrashekara. *Analysis and performance of fiber composites*. John Wiley & Sons, 2017.
- [4] Joseph, P. V., Kuruvilla Joseph, and Sabu Thomas. "Effect of processing variables on the mechanical properties of sisal-fiber-reinforced polypropylene composites." *Composites science and Technology* 59.11 (1999): 1625-1640.
- [5] Nair, K. C., S. M. Diwan, and Sabu Thomas. "Tensile properties of short sisal fiber reinforced polystyrene composites." *Journal of applied polymer science* 60.9 (1996): 1483-1497.
- [6] Sathishkumar, T. P., P. Navaneethakrishnan, and 0110S Shankar. "Tensile and flexural properties of snake grass natural fiber reinforced isophthalic polyester composites." *Composites Science and Technology* 72.10 (2012): 1183-1190.
- [7] Sathishkumar, T. P., et al. "Mechanical properties of randomly oriented snake grass fiber with banana and coir fiber-reinforced hybrid composites." *Journal of Composite Materials* 47.18 (2013): 2181-2191.
- [8] Sathishkumar, T. P., J. Naveen, and S. Satheeshkumar. "Hybrid fiber reinforced polymer composites—a review." *Journal of Reinforced Plastics and Composites* 33.5 (2014): 454-471.

- [9] Oksman, Kristiina, Mikael Skrifvars, and J-F. Selin. "Natural fibres as reinforcement in polylactic acid (PLA) composites." *Composites science and technology* 63.9 (2003): 13171324.
- [10] Li, Yunlong, et al. "Enhancement of fracture properties of polymer composites reinforced by carbon nanotubes: A molecular dynamics study." *Carbon* 129 (2018): 504-509.
- [11] Savastru, D., et al. "Study of thermo-mechanical characteristics of polymer composite materials with embedded optical fibre." *Composite Structures* 183 (2018): 682-687.
- [12] Suryanegara, Lisman, et al. "Mechanical Properties of Composites Based on Poly (Lactic Acid) and Soda-Treated Sugarcane Bagasse Pulp." *Sustainable Future for Human Security*. Springer, Singapore, 2018. 277-285.
- [13] Quintero, Sebastian, et al. "The Response of Manicaria saccifera Natural Fabric Reinforced PLA Composites to Impact by Fragment Simulating Projectiles." *Advances in Natural Fibre Composites*. Springer, Cham, 2018. 89-98.
- [14] Manimaran, P., et al. "Study on characterization of Furcraea foetida new natural fiber as composite reinforcement for lightweight applications." *Carbohydrate polymers* 181 (2018):650-658.
- [15] Milan, S., T. Christopher, and JT Winowlin Jappes. "Investigation on mechanical properties and chemical treatment of litterous fibre reinforced polymer composites." *International Journal of Computer Aided Engineering and Technology* 10.1-2 (2018): 102-110.
- [16] Arulkumar, M., K. Rajeshwaran, and G. Sathish. "Experimental Investigation of Static Mechanical Properties of Epoxy Based Glass, Carbon & Sisal Woven Fabric Hybrid Composites." *Mechanics, Materials Science & Engineering MMSE Journal. Open Access* 9 (2017).
- [17] Maya, M. G.,et al. "Mechanical Properties of Short Sisal Fibre Reinforced Phenol Formaldehyde Eco-Friendly Composites." *Polymers from Renewable Resources* 8.1 (2017):27.
- [18] Jayaseelan, Chinnapalanichamy, et al. "Comparative Investigation of Mechanical Properties of Epoxy Composites Reinforced with Short Fibers, Macro Particles, and Micro Particles." *BioResources* 12.2 (2017): 2864-2871.
- [19] Pulikkalparambil, Harikrishnan, et al. "Physical and thermo-mechanical properties of bionano reinforced poly (butylene adipate-co-terephthalate), hemp/CNF/Ag-NPs composites." (2017).
- [20] Milan, S., T. Christopher, and JT Winowlin Jappes. "Investigation on mechanical properties and chemical treatment of litterous fibre reinforced polymer composites." *International Journal of Computer Aided Engineering and Technology* 10.1-2 (2018): 102-110.
- [21] Xie, Qi, et al. "A new biodegradable sisal fiber-starch packing composite with nest structure." *Carbohydrate Polymers* (2018).
- [22] Sanjay, M. R., et al. "Characterization and properties of natural fiber polymer composites: A comprehensive review." *Journal of Cleaner Production* 172 (2018): 566-581.
- [23] Thiruvasagam, C., S. Prabagaran, and P. Suresh. "Investigation of mechanical behaviour of natural composites (snake grass and elephant grass) with poly lactic acid." *International Journal of Engineering & Technology* 7.1.1 (2018): 158-166.
- [24] Irullappasamy, Sankar, and D. Ravindran. "Combined effect of nano clay and fibre surface treatment on mechanical behaviours of Palmyra fruit fibre/MMT clay reinforced polyester hybrid composite." *International Journal of Computer Aided Engineering and Technology* 10.1-2 (2018): 26-34.
- [25] Wu, Yingji, et al. "Water-resistant hemp fiber-reinforced composites: In-situ surface protection by polyethylene film." *Industrial Crops and Products* 112 (2018): 210-216.
- [26] Saurabh S.G. Gunasekaran, L. Devaraj Stephen, M. Soundarajan, Comparative Removal of Chromium Toxic Metal from Water using Vermiculite Blended Chitosan Coated Carbon Biopolymer Composites. *International Journal of Civil Engineering and Technology*, 9(2), 2018, pp. 76-86Saini, Sandeep Kumar, Sandeep Pandey, and Mohd. Zeeshan A Review on Various Techniques Used for Self-Healing in Fiber Reinforced Polymer Composites. *International Journal of Mechanical Engineering and Technology*, 8(7), 2017, pp. 1383–1395.