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# EVALUATION OF THERMAL AND CHEMICAL PROPERTIES ON NANO CARBON WITH FIBER REINFORCED POLYMER MATRIX COMPOSITES

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## ABSTRACT

*A composite is a combination of two materials in which one of the material, called as reinforcing phase, is in the form of Arecanut fibers, sheets, or particles, and is embedded in the other material called as matrix phase. In general, the current research is focused in blended NCFRPCs which have Three facets one of which is development and another one is an assessment. The one side of the Tri facets is researched by many and now the time has come to investigate the second facet of the composites. In this work, characterization of thermal and chemical resistance is reported. Thermal tests are the tests that are made on water hyacinth filled blend (i.e. system-1) and ArecaNut filled blend reinforced of carbon fiber (i.e. system-2) Hen feather (i.e. system-3) NCFRPCs at different fiber variations viz., 0, 1, 2, 3, 4, 5 and 6 wt. % are presented. Results and discussions are presented based on the type of test and their experimental results and graphs are shown. In all the cases Seven specimens are tested for the sake of accurate results and mean values are computed for drawing graphs. Specifications of the machines are presented.*

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

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# 1. INTRODUCTION

A composite is combination of two materials in which one of the materials, called the reinforcing phase, is in the form of Arecanut fibers, sheets, or particles, and is embedded in the other materials called the matrix phase. The reinforcing material and the matrix material can be metal, ceramic, or polymer. Composites typically have an Arecanut fiber or particle phase that is stiffer and stronger than the continuous matrix phase and serve as the principal load carrying members. The matrix acts as a load transfer medium between Arecanut fibers, and in less ideal cases where the loads are complex, the matrix may even have to bear loads transverse to the Arecanut fiber axis. The matrix is more ductile than the Arecanut fibers and thus acts as a source of composite toughness. The matrix also serves to protect the Arecanut fibers from environmental damage before, during and after composite processing. When designed properly, the new combined material exhibits better strength than each material individually. Composites are used not only for their structural properties, but also for electrical, thermal, tribological, and environmental applications. [1]stated that “Composites are multifunctional material systems that provide characteristics not obtainable from any discrete material. They are cohesive structures made by physically combining two or more compatible materials, different in composition and characteristics and sometimes in form”. [2] very clearly stresses that the composites should not be considered only as a combination of two materials. In the broader significance; the combination has its own distinctive properties. In terms of strength to resistance to heat or some other desirable quality, it is better than either of the components alone or radically different from either of them. [3]defines as “The composites are compound materials which differ from alloys by the fact that the individual components retain their characteristics but are so incorporated into the composite as to take advantage only of their attributes and not of their short comings”, in order to obtain improved materials. [4] explains composite materials as heterogeneous materials consisting of two or more solid phases, which are in intimate contact with each other on a microscopic scale. They can be also considered as homogeneous materials on a microscopic scale in the sense that any portion of it will have the same physical property.

# 2. THERMALPROPERTIES

## 2.1. Thermo gravimetric Analysis (TGA)

Thermo gravimetric examination is a testing technique in which changes in weight of the examples are recorded as the example is dynamically heated. The example weight is ceaselessly checked as the temperature is expanded at a steady rate and parts of a PLA Polymer that volatilize or deteriorates at various temperatures are quantitatively measured.

Contraption comprises of a diagnostic equalization supporting a platinum cauldron for an example with the pot maintained in an electric heater and methods for plotting the rate weight changes as a function of temperature.

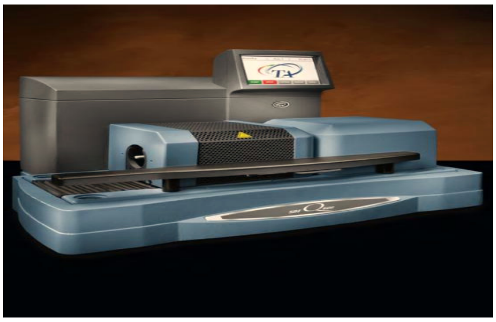

**Figure 2.1** A Photograph showing the -/TGA SDT Q600 thermal analysis testing machine

Specifications SDT Q600 -/TGA (TA Instruments) is shown in Table 2.1. TGA is exceptionally helpful in portraying PLA Polymers containing distinctive levels of added substances by measuring the level of weight reduction. TGA can likewise be utilized to distinguish the fixing blended compounds as per the relative strong qualities of individual components. Another method for describing PLA Polymers using TGA is by concentrating on the degradation profiles of different PLA Polymers.

## 2.2. Chemical Resistance

ASTM D 543-87 testing technique is utilized to evaluate the chemical resistance of the composite. In this technique, there is an arrangement for reporting changes in weight, measurements, appearance and quality properties. Standard reagents are indicated to set up results on a similar premise. There is an arrangement for different introduction times and presentation to reagents at lifted temperatures. In this present work, led concoction resistance tests is made on PLA polymer-WH/AC/HF fiber dirt mixed NCFRPCs, on sensibly selecting three acids, three salts and four solvents given below.

**Acids**: Hydrochloric acid (HCl) (10%), Acetic acid ($CH_3COOH$) (5%), Nitric acid ($HNO_3$) (40%).

**Alkalis**: Sodium hydroxide (NaOH) (10%), Sodium Carbonate ($Na_2CO_3$)(20%), Ammonium Hydroxide ($NH_4OH$) (10%).

**Solvents**: Benzene, Tolune, Carbon tetrachloride ($CCl_4$) and Distilled water ($H_2O$).

Five specimens are weighed with the help of electrical balance and soaked in the separate chemical substances for one day. They are then detached instantly, wash away with purified water and dehydrated out by tensile them with a clean paper obviously with all sides, at ambient temperature. The specimens are then weighed again and the percentage loss/gain is investigated by the subsequent calculation.

# 3. MATERIALS

In this present investigation water hyacinth stem powders (Eichhorniacrassipes), 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 powder sand, areca nut shell powders are obtained from Erode District, Tamil Nadu, and India. PLA is obtained from kovaiseenu & Company Ltd.,Coimbatore, India. Carbon powder is obtained from M/s Star Scientific Traders, Erode, Tamilnadu, India.

## 3.1. 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.

## 3.2. WATER HYACINTH STEMS POWDERS

Water hyacinth stem powders (Figure.1.A) are prepared from the stems of water hyacinthplant. 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.

## 3.3. 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.

## 3.4. 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.

## 3.5. 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 themicron 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.

## 3.6. 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.

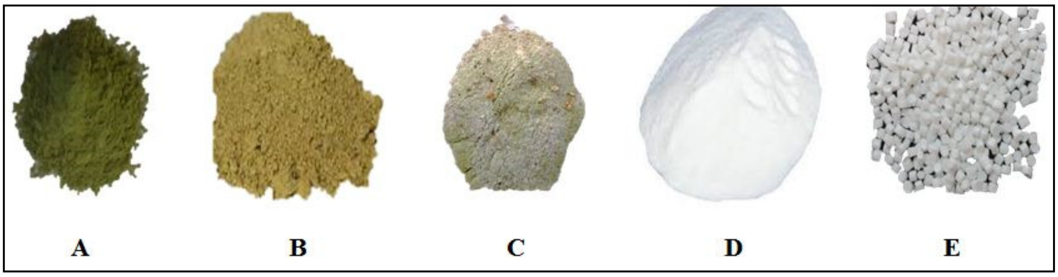

**Figure.1** (a) Water hyacinth stem powder (b) Areca nut shell powder (c) Hen feather powder (d) Nano Carbon powder (e) PLA Particles

## 4. 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 get cured 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.

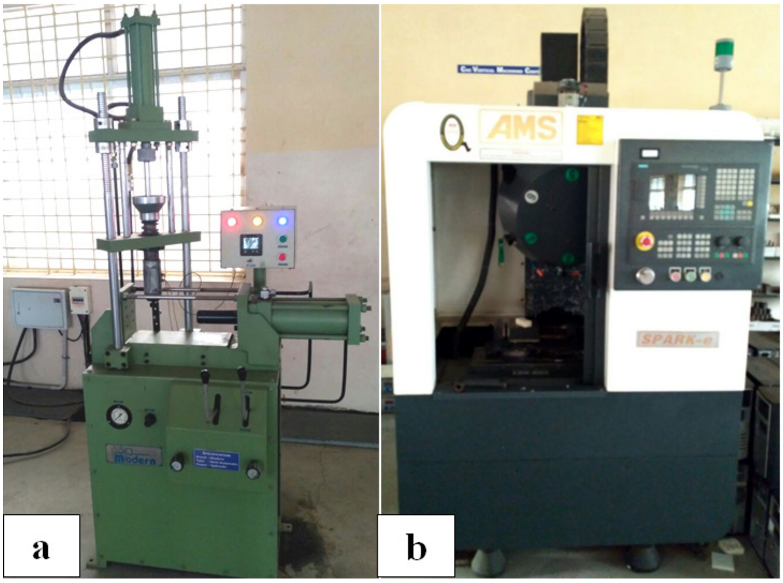

**Figure 2** (a) Hydraulic Injection Moulding Machine (b) Vertical CNC Machine

## 5. RESULT AND DISCUSSION

### 5.1. THERMOGRAVIMETRIC ANALYSIS (TGA):

The analysis specifies that in the clean fiber there is a precise silicate units in air and there is no progress in the range of 40-150ºC for 4 wt. % fiber and it also depicts that the smoothening starts reducing  at 324ºC, and at this heat 15% weight loss was detected. For 5 wt. % fiber loading curve was categorize that 14% weight loss of composite was detected at 350ºC and yet it is rather bit advanced thermal steadiness, when compared with 4 wt. % fiber. In Figure 3 [a] there was a small variation of weight loss among the considered fiber loadings.

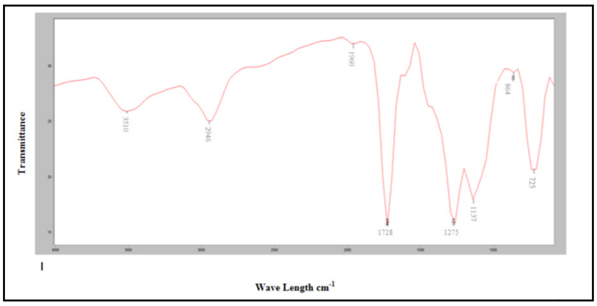

**Figure 3** [a] TGA result validation Analysis System -1

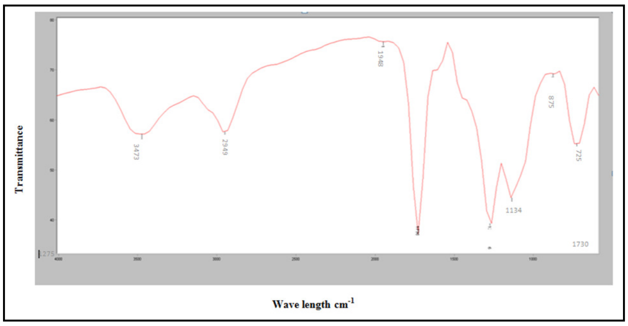

**Figure 3** [b] TGA result validation Analysis System -2

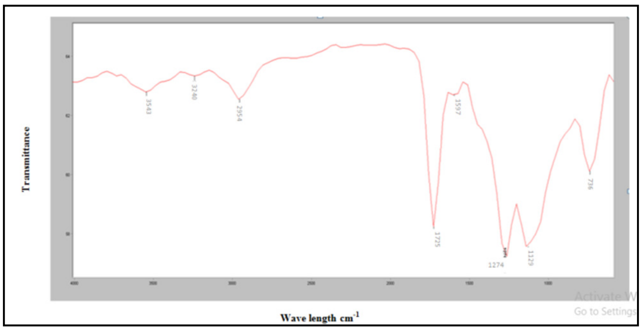

**Figure 3** [c] TGA result validation Analysis System -3

That was due to the presence of moisture in the sample or due to the low volume fraction of metallic substance in the fiber weight fraction. Thermogram for PLA polymer and fiber blended NCFRPCs for three speckled fiber loadings viz. 4, 5 and 6 wt. %. $T_g$ of PLA Polymer-PLA Polymer/fiber mixed composites are empirical for dissimilar PLA fiber fillings viz. for 4, 5 and 6 wt. % PLA nanofiller contents at 436, 430 and 431°C steadily are shown in figure 3[a]. It was theoretical that a very small change in glass transition temperature was marked at 5 and 6 wt. % fiber loadings.

Figure 3[b], [c] demonstrates the fraction mass loss with deference to temperatures of dissimilar prototypes of 2, 3, and 4 wt. % fiber remote PLA Polymer- PLA Polymer mixed nano-composites for system-2 and system-3 . For 2 wt. % PLA nanofiller sample, heat stability was not up to the mark, as it is underway right after 112°C, the mass- loss was additional nonstop up to 90% till it reaches 320°C, the cause for mass loss is the wetness in the fiber or insufficient miscibility of the PLA Polymers capacity. For 3 wt. % PLA nanofiller doping, no mass-loss was originate up to 200°C and then disintegration underway from then to 330°C.For 3 wt. % PLA filled specimen resistance to mass-loss was meaningfully better, since enhanced flowability of mixture, as well as fewer dampness in the PLA particles. Contrary, for 4 wt. % PLA doped specimen, there was no mass loss was detected till 332°C. For overall, sample 4 wt. % was good thermal stability amongst all the specimens. The cause for the vanishing of mass-loss for 4 wt. % PLA nanofiller was due to the fewer dampness quantity in the specimen. Furthermore, at 4wt. % PLA nanofiller has not lost their weight till to 332°C [5]. The aim for this enhanced firmness is due to the presence of mineral ingredients in PLA Polymer matrix, it improves the heat resistance ability of the PLA Polymer-PLA Polymer/fiber composites. The mass-loss as a function of temperature graphs indicates that the deposit left beyond 450°C is in line with the inorganic substance presence.

### *2.5.2. CHEMICAL RESISTANCE*

Chemical resistance was measured for foreordained three acids (i.e. hydrochloric acid, acidic acid, nitric acid), three antacids (i.e. sodium hydroxide, sodium carbonate, ammonium hydroxide), and four solvents (i.e. benzene, toluene, carbon tetrachloride, refined water).

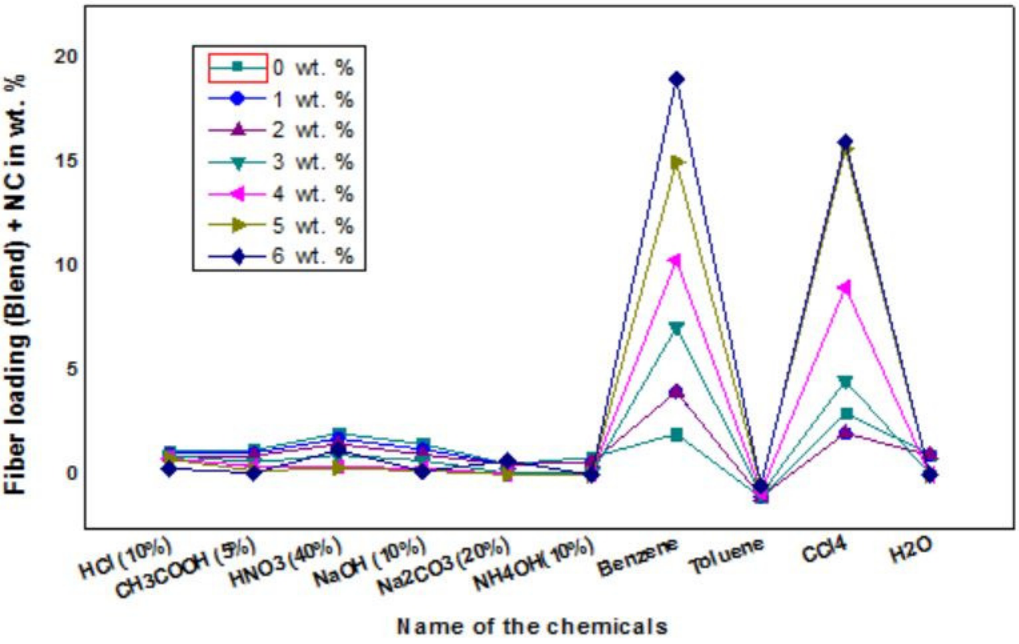

**Figure 4.1** Fiber loading (Blend) + NC in wt. % Vs Name of chemical contents –System -1

Tables 4.1 and 4.2, 4.3 shows the chemical resistance experimental results of % weight gain and weight loss of PLA polymer WH/AC/HF fibers blended Nano composites as a function of fiber at % wt. The specimens were immersed in the specific chemical for one day. Increase in weight is experimental in most of the samples excluding toluene. The cause is the occurrence of toluene atoms on the cross-linked PLA Polymer/PLA Polymer blend. Increase in weight indicates that blend Nano composites were distended with gel creation somewhat than melting in chemical reagents. Further, it is noted that blended PLA Polymer-PLA Polymer mixtures absorbed very less water when compared with other chemicals. Thus, blended Nano composites are the good candidates for the chemical storage tanks.

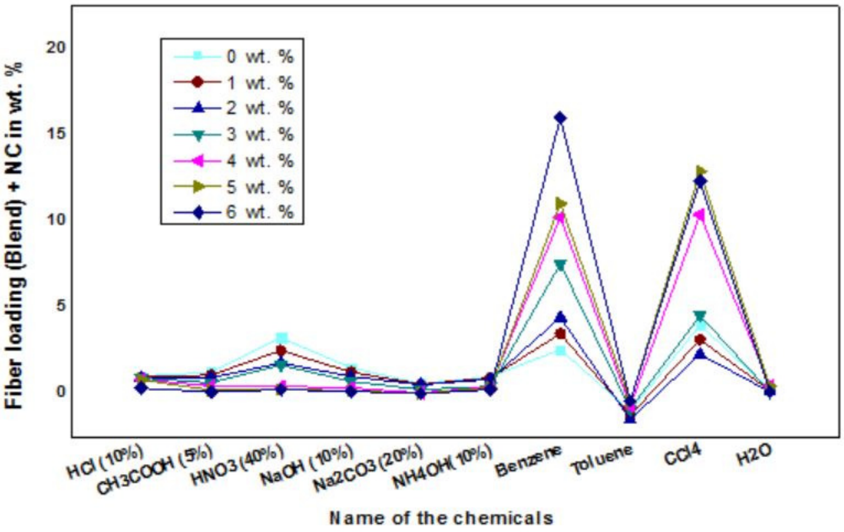

**Figure 4.2** Fiber loading (Blend) + NC in wt. %Vs Name of chemical contents –System -2

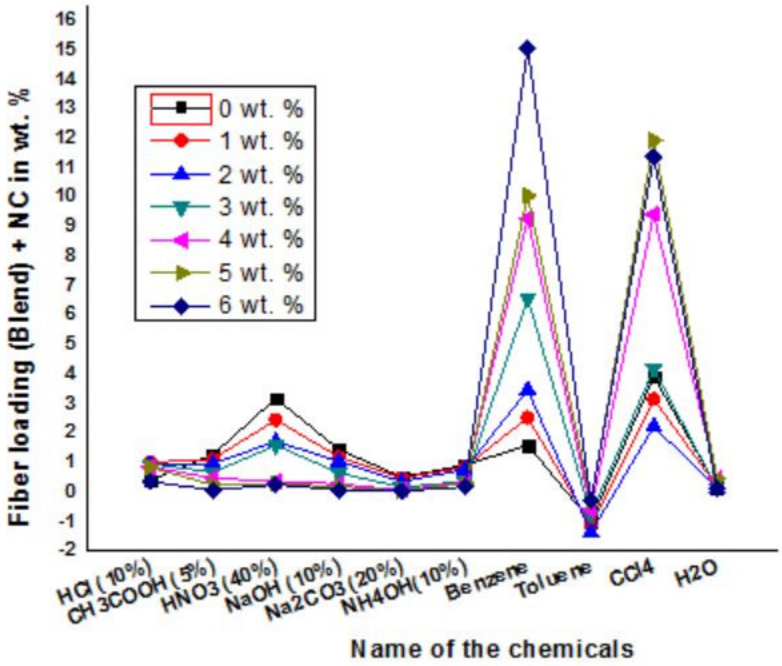

**Figure 4.3** Fiber loading (Blend) + NC in wt. % Vs Name of chemical contents –System -3

## 3. CONCLUSION

In the Thermal study, the research demanded two PLA Polymers such as PLA polymer and the fiber resins which are used as matrices and catalyst, promoter, accelerator as curing agents. These matrices are selected because it is being used mostly in high performance and cost effective applications. Nano carbon WH/AC/HF System1, System 2, System 3 fiber is selected as reinforcing agent along with modified WH/AC/HF fiber as Nano filler. In the present research synthesized two different systems namely (a) fiber filled blend and (b) fiber filled blend reinforced with 6 wt. % Nano carbon WH/AC/HF fiber NCFRPCs as a function of fiber respectively. It is observed that properties are improved better for system-2 when compared with the system-1 and system-3.

1. These results clearly designate that improved interface and bonding of PLA polymer with fiber blended NCFRPCs lead to improved warm stability graphs for PLA Polymer-PLA Polymer blended NCFRPCs with 3 diverse weight ratios 2, 3, and 4 wt. % fiber filled specimens for system-2 , system 3 were revealed in figure 3 [b] . Tg of blended NCFRPCs was experimental for different PLA nanofiller ratios viz. for 2, 3 and 4 wt. % at 435, 438, 432°C respectively. Figure 3 [c]as refer to 3°C increase in $T_g$was detected for 3 wt. % fiber sample when related to 2 wt. % fiber sample. Reduction in the value of $T_G$ was noticed for 4 wt. % PLA nanofiller sample when related with the 2 and 3 wt. % PLA nanofiller specimens.
2. Normal NCFRPC fibers analyzed had been discovered density and also higher quantity of cellulose up content to 70.35% and density was discovered 10.04 %.

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