A Study on Mechanical and Thermal Behavior of Coir Fiber Reinforced Epoxy Composites

A thesis submitted in partial fulfilment of the
requirements for the degree of

Master of Technology

in

Mechanical Engineering

[Specialisation: Production engineering]

by

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(Roll no: 212ME2287)

Department of Mechanical Engineering
National Institute of Technology
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Under the guidance
of

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Certificate

This is to certify that the thesis entitled ñ**A Study on Mechanical and Thermal Behavior of Coir fiber Reinforced Epoxy Composites**ò, submitted to the National Institute of Technology, Rourkela by **Mr. Binu Haridas**, Roll No: bearing Roll no. 212ME2287 in partial fulfilment of the requirements for the award of Master of Technology in the Department of Mechanical Engineering, National Institute of Technology, Rourkela, is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other university/institute for the award of any Degree or Diploma.

Place: Rourkela
Date:

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Binu Haridas

Abstract

The main focus of this study is to utilize the properties of natural fibers and make them compatible with polymer resins effectively. Coir fibres have been used as reinforcement in epoxy resin with various weight percentages of 5%, 10% and 15%. Surface treatment method like alkali treatment is done to improve the performance of coir fibre on epoxy resin. Cow dung powder is added as filler to the composite with a purpose of improving the insulation property of the composite. The mechanical properties like tensile strength, flexural strength, impact strength and the micro hardness showed an increment with respect to fibre loading as well as the alkali treatment. The maximum value is found with the composite having 15% treated coir fibre. Flexural strength showed maximum value at 10% treated fibre loading which decreases after 10% fibre loading. When fibre loading was increased, thermal conductivity reduces. By adding cow dung powder to the untreated fibre composite, thermal conductivity is further decreased. From Thermo Gravimetric Analysis (TGA) it is found that the surface treated fibre composites resist the thermal decomposition effectively up to 260^0C after that there is a considerable increase in the thermal stability. Differential Scanning Calorimetry (DSC) showed that the specific heat capacity increases with increase in fibre loading. Untreated fibre composites showed better specific heat capacity than the treated ones. Cow dung powder added to the untreated composite showed that maximum specific heat and specific heat capacity increases further to higher values as the quantity of cow dung powder is increased. Glass transition temperature (Tg) showed an increment with surface treatment as well as fibre loading of up to 10% and after that it decreases.

Keywords: alkali treatment, coir fibre, composite, glass transition temperature, specific heat capacity, thermal conductivity.

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CHAPTER 1
INTRODUCTION

1.1Motivation and background

Composite materials are being widely used in recent period for day to day applications and at the same time they possess a vital role in manufacturing of highly sophisticated machines and equipment also. Composite materials has many advantages over the conventional materials such as light weight, simple and cheap manufacturing process and also have comparable properties of their constituent materials [1]. So the main task for researchers are to improve the properties of composite materials according to the application and make them more durable, weightless and cost effective.

Composites consists of two phases one is called discrete phase called reinforcing material, which may be fiber, particulate or flakes and the other is a continuous phase which termed as matrix material which possess the major share of composite material. In a composite material components like matrix and fibers are bounded together but its main difference from an alloy is that its constituents will retain their own identity and properties [2]. If we define composite materials, it is a unique combination of fiber and matrix where function of the fiber is to withstand load and make the composite stiffer meanwhile matrix is a binder which holds the fiber in place [3].

Composite shows advantages like low weight, low density, low cost and good specific properties like tensile, flexural and impact strengths. It may possess applications in area where weight of the total equipment is a major problem, like rocket technology, aircraft industry, marine structures etc. By combining with some insulating material, composites can also utilized as thermal and electrical insulating material. Composites are used to prepare many mechanical components like brakes, drive shafts, flywheels, pressure vessels etc [4].

1.2 Classification of Composites

According to the reinforcing phases the composites are mainly classified into three types, i.e. fiber reinforced composites, flake reinforced composites and particle reinforced composites [5]. The schematic diagram of classification of composite according to the type of reinforcement used is shown in figure 1.1. Fiber reinforced composites consists of fiber and matrix, former provides strength while latter glues all the fiber together and transfers stress between the reinforcing fibers. The primary function of fiber is to carry the loads in the longitudinal direction. Glass fiber, polyester fibers, coir, jute etc. are some example of the fibers which are used as the reinforcing material. In Flake Reinforced Composites material flakes are used as reinforcing material. The flakes will be more or less oriented in a plane so such composites often have the behavior of biaxial oriented material. Flake composites have strong resistance against puncturing by sharp objects. They have high moduli and high aspect ratio compared to the particulate and fiber reinforced composites. Examples are mica, graphite, glass flakes, aluminum flakes etc. The flakes composites are discontinuously reinforced polymer composites which exhibits improved mechanical properties and possess relative easiness in fabrication and manufacturing [6]. Particles of various sizes are randomly distributes in particulate reinforced composites. Examples are aluminum particles, Cu particles etc.

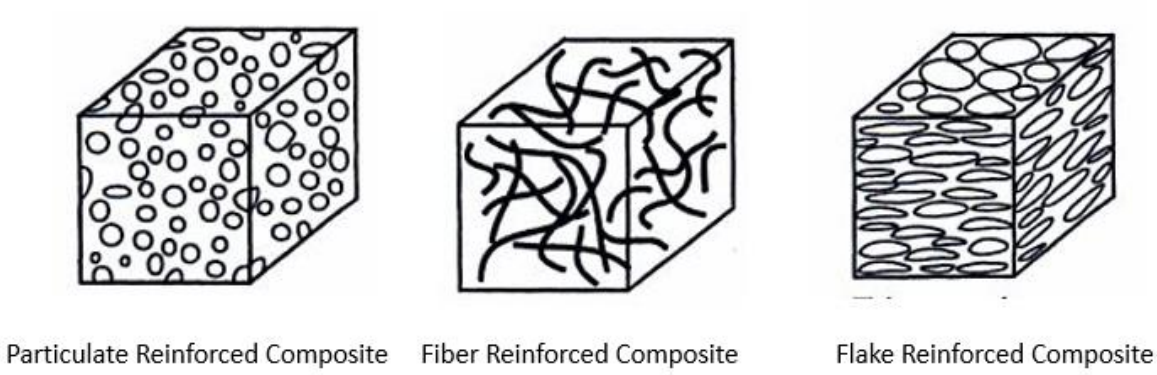

Figure.1.1: Schematic diagram of classification of composite according to the type of reinforcement used [5].

Fiber-reinforced polymer (FRP) composites are fabricated by combining polymer resin with strong reinforcing fibers. The components maintains its original properties and contribute their own individual properties to the new composite material so that the overall property will be enhanced. The polymer resins are typically viscous, and may be easily molded, but are comparatively weak to fibers. The resin component acts as a binder in between the reinforcing fibers and also acts as a medium to transfer stress. The FRP shows low specific gravity, low strength weight ratio and low modulus weight ratio makes them superior to metallic materials. Over a long period of time, the high-strength and light weight FRP composites materials have been used largely in defense and aerospace systems [7]. Recently, it has been applied for preparing luxury items like table, chairs and doors etc. as a substitution to metals and alloys. They are also used in automobile and aerospace sectors to reduce the weight of the components which results in substantial saving of the fuel and energy during transportation.

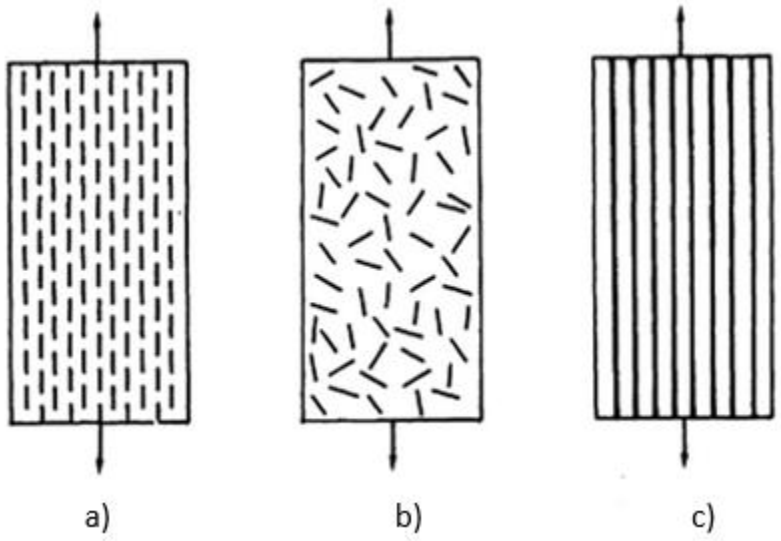

Figure.1.2: Types of FRPs a) discontinuous fibers (unidirectional) b) discontinuous fibers (random) c) continuous fibers (unidirectional) [8]

According to the type of matrix material used, composites can be categorized as Polymer Matrix Composites (PMC), Metal Matrix Composites (MMC), and Ceramic Matrix Composites (CMC). MMC consists of at least two components one is a metallic part which functions as matrix and other part may be ceramic or organic material. MMC have many advantageous over monolithic metals such that they possess higher specific strength, high specific modulus, low thermal

coefficient of expansion and excellent wear resistance. But the toughness of MMC is lower than metals [9]. CMC consists of fiber embedded in ceramic matrix. They are not widely being established in service like PMCs because the processing temperature of CMCs are very high. In PMC, the matrix is a polymer which may be thermoplastic or thermosets and is reinforced by fiber or fillers. Compared to MMC and CMC, PMC are widely used because of the relative easiness to produce them and also due to its light weight and low cost. They possess application in aircraft, space shuttle, rocket, rotor blades etc. There are several criteria, on which composite material can be classified, like on the basis of type of matrix material used, type of reinforcement used, type of fibers used. Figure 1.3 shows the classification of composite material on the basis of physical structure and geometry.

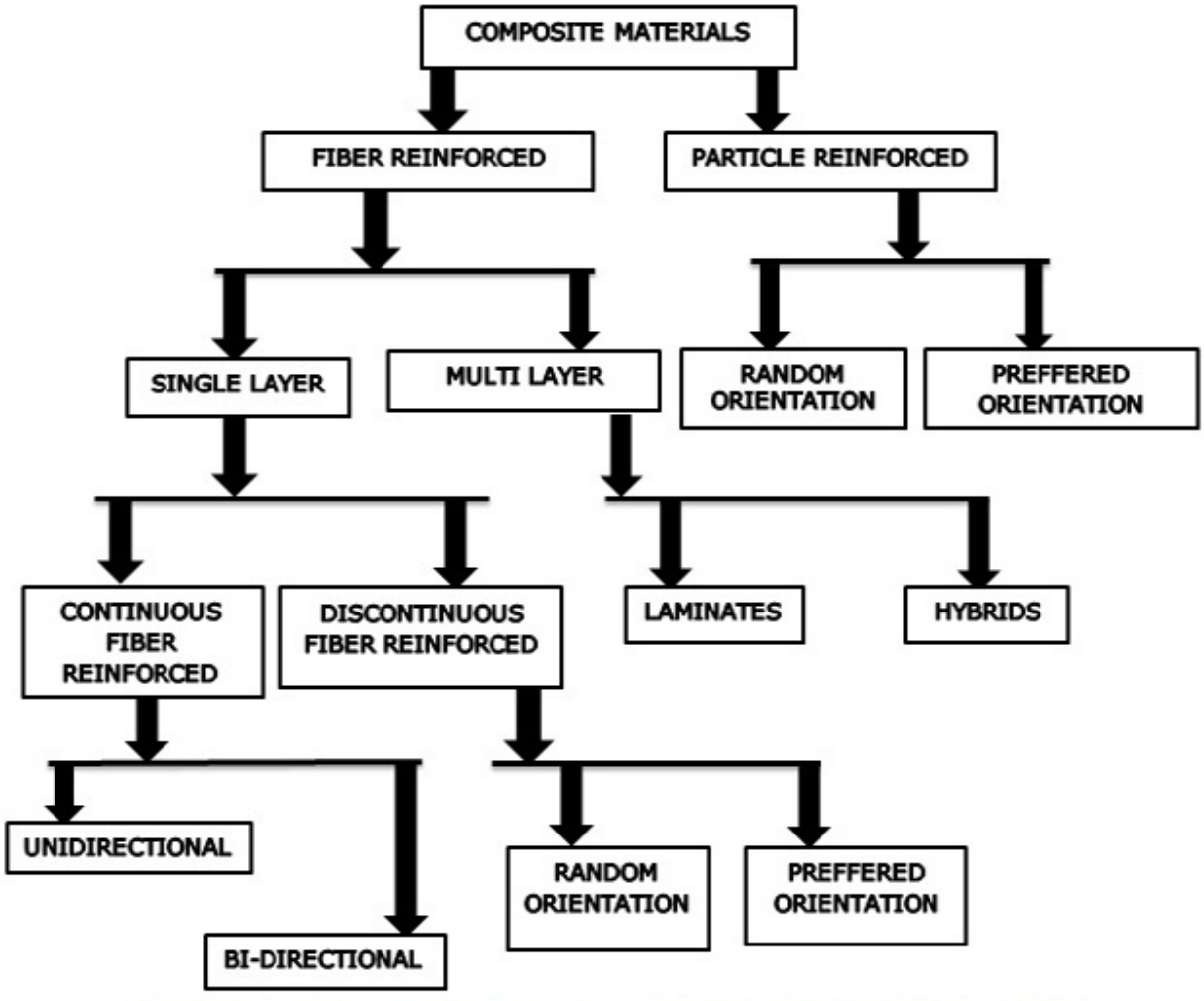

Figure.1.3: Classification of composites [3]

1.3 Types of Polymer Resins

In general, polymers are classified as thermoplastics and thermosets. Thermoplastics are linear polymers which acquires new shapes on the application of heat and pressure. Examples are nylons, polystyrene, polyethylene, PVC, polypropylene etc. Thermosets are cross-linked polymers, this crosslinks pulls each parallel chains and brings a strong bond. They can't be reshaped by heating because of this crosslinks [10]. Thermoset polymers are used at high temperatures and also have better creep property than thermoplastics. Examples are epoxy, polyester, phenolic, bakelite, polyurethanes etc.

Epoxy resins is one of the widely used thermosetting polymer. Commercially it is known as araldite or epon. It is formed by polycondensation reaction of epichlorohydrin and bisphenol-A. Epoxies are stiffer, stronger and shows effective thermal and electrical insulation properties, chemically resistant and low toxic also. They are available in abroad range of physical forms, from low viscous liquids to high viscous solids. . Epoxy resin composites are used largely in industry because of its high toughness, adhesiveness and chemical resistant nature.

1.4) Types of Fibers

In general, fibers are categorized into two groups i.e. natural and synthetic fibers. Glass fibers, carbon fibers, CNT are some examples of synthetic fibers. Synthetic fiber possess high elastic modulus, strength and resilience and they are hydrophobic in nature also. But, these days natural fibers receives a lot of attention due to its low cost, comparable strength to synthetic fibers, low density, non-toxicity and biodegradability. Depending upon the source of availability, natural fibers are divided by categories: seed hair, bast fibers, and leaf fibers. Some examples are cotton (seed hairs); ramie, jute, and flax (bast fibers); and sisal and abaca (leaf fibers). Among these fibers jute, ramie, coir, flax, sisal, hemp etc, are the most generally using fibers for fabrication of polymer matrix composites. Table 1.1 shows the physical properties of these natural fibers. Sometimes natural fibers in the form of wood-flakes have also been used for fabrication of composites. One of the main drawback of natural fibers are their hydrophilic behavior. So they have the tendency to absorb the moisture from atmosphere and it causes dimensional and property changes. The other major challenge in the application of natural fibers are their poor compatibility with polymer so that the stress transfer is not so acceptable. To improve the

compatibility with matrix natural fiber can be subjected to various surface modification treatment like alkali treatment, acetylation, cyanoethylation, bleaching etc.

Table .1.1: Physical properties of natural fibers [11]

Properties	Unit	Coir	Flax	Hemp	Jute	Ramie	Sisal
Density	g/m^3	1.25-1.5	1.4	1.48	1.45	1.5	1.26-1.33
Diameter	μm	100-450	100	25	60	40-50	100-300
Cellulose content	%	36-43	62-72	67-75	59-71	68-76	60-67
Hemicellulose Content	%	0.2	16-18	16-18	12-13	13-14	10-13.9
Lignin Content	%	41-45	2-2.5	2.8-3.3	11.8-12.9	0.6-0.7	8-12
Microfibrillar angle	deg	30-45	10	6.2	7-9	7.5-12	10-20
Tensile Strength	Mpa	105-175	800-1500	550-900	400-800	500-870	600-700
Young's Modulus	Gpa	4-6	60-80	70	10-30	44	38
Elongation at break	%	17-47	1.2-2.4	1.6	1.16-1.8	1.2	3.64-5.12
Moisture Absorption	%	10	7	8	12	12-17	11

1.5) Basic Structure of Natural Fibers

If we examine the structure of natural fiber, they are mainly consists of five components i.e. cellulose microfibriles, hemicellulose, lignin, pectin and waxes. Cellulose is a type of natural polymer which is formed by repeating units of D-anhydroglucose and the units are joined by β-1, 4-glycosidic linkages. Hemicellulose consists of a group of polysaccharides which combined to

form 5 and 6 –carbon ring sugars. Lignin is total insoluble component and hydrophobic in nature among this group and is basically a complex hydrocarbon polymer consists of both aliphatic and aromatic group. A group of heteropolysaccharides which are collectively called as pectin. Waxes are also the component of natural fiber that consists of various types of alcohol.

Basically natural fibers are multilayered structures consists of primary layer and secondary layers as shown like figure 1.4. Here primary layer which forms at the time of cell growth and which surrounds the secondary layers. Each layer consists of thick walls and are called primary wall and secondary walls. The middle layer of secondary wall is the thickest among secondary walls and that determines mechanical property of fiber. The main content of natural fiber is cellulose micro fibrils which are bonded by amorphous materials called hemicellulose. The angle between micro fibrils orientation in the structure and the axis of main fiber body is called microfibrilar angle. The microfibrilar angle is different for different natural fibers and that determines the mechanical strength of fibers. The interesting thing is that the natural fibers itself act as a composite material where amorphous materials like hemicellulose, pectin and wax acts as a matrix which bonds the microfibrilar cellulose. The hemicellulose molecules are making hydrogen bond to microfibrilar cellulose and functions as a binding material. Lignin acts as a coupling agent which helps to improve the stiffness of the cellulose/hemicellulose composite [12].

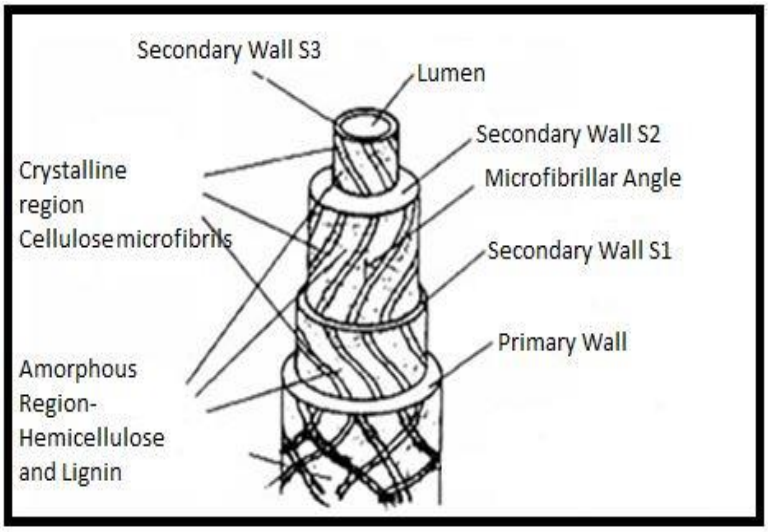

Figure.1.4: Structure of natural fiber [13]

1.6) Coir Fiber

Coir fiber is extensively for preparing ropes, yarns, mattresses, mats, sacking, brushes, caulking boats, insulation panels and floor tiles [14]. It is a lignocellulostic fiber which extracts from the seed of coconut palm. Coir has low tensile strength and young's modulus because of its low cellulose and high lignin contents. Coir has high microfibrilar angle due to which it possess low moduli. But the percentage of elongation of break and toughness of coir fiber is higher than other natural fibers. It also exhibits much better resistance to weather, fungal and bacterial because of its high lignin content [11]. The incorporation of coir as a component in polymer composites is unsatisfactory in some perspective compared to other natural fiber because of its low cellulose content (36–43%), high lignin content (41–45%) and high microfibrilar angle. Morphological investigations carried out by the researchers on coir fibers reveals that the external sheath of lignin obstructs the cellulose to make interfacial bond with the polymers. The removal of this peripheral layer of lignin generally brings about a superior and more stable interfacial bond. To attain this, there are several treatments that are widely established such as alkali treatment, bleaching and graft copolymerization etc, by which the surface properties of natural fibers can be enhanced. The coir industry is much developed in India, Srilanka and Brazil. The coir fiber polymer has many application in structural systems in housing, electrical panels, ducting etc. The other main feature of coir fibers are its low thermal and electrical conductivity. Thus, the coir composites can be used as low temperature insulating materials in household application and electronic packaging.

1.7) Thesis Outline

The remainder of this thesis is organized as follows:

Chapter 2: This includes the information of previous research work that gives support and backup to the present work that is being described here.

Chapter 3: Includes the detail description of materials required, processing techniques and theory behind the experiment for characterization of the composites under investigation.

Chapter 4: This chapter presents the results and discussion of the mechanical and thermal tests of the coir-epoxy and cow dung filled hybrid composites.

Chapter 5: This chapter presents the conclusions and recommendations for the corrections and modification to be implemented for future work.

CHAPTER 2
LITERATURE REVIEW

This chapter deals with the supporting knowledge that had developed in past for using enough data for the present work. A thorough review of the available literates was also done to understand the effect of various parameters that influence the mechanical and thermal properties of fiber reinforced polymer composites. The literature survey is done on the basis of following points:

2.1) About the Mechanical Properties of Natural Fiber Based Polymer Composite

The growing factors like environmental challenges, biodegradability, non-toxicity etc, leads the researchers to focus their studies on exploring the features of natural materials like natural fibers. A lot of research is going on to make use of natural fibers as a reinforcing material in the polymer matrix composites. There are a lot of challenges faced by the researchers to make the natural fiber suitable for their needs due to its hydrophilic nature, thermal and chemical instability. But now a days natural fibers can replace synthetic fibers to some extent by making them compatible with polymer matrixes by some surface modification techniques.

Rout et al. [15] studied the significance of surface treatment on the coir reinforced polyester composites. The coir fiber was subjected to alkali treatment, vinyl grafting, and bleaching before adding them with general purpose polyester resin. The mechanical charecteristics like tensile strength, bending and impact strength were increased because of surface treatment. Bleached fiber composite (at 65^0C) showed better flexural strength. NaOH treated fiber/polyester composite exhibited better tensile strength. Because of the chemical treatments of fibers the water absorption tendency of composite was reduced Biswas et al. [16] carried out a study on the significance of fiber length on the mechanical charecter of coir/epoxy composite. It was found that the hardness of the composite decreases by increasing length of fiber up to 20 mm and then after it increases. They also concluded that fiber length has a major influence on enhancing mechanical properties like tensile strength, flexural strength and impact strength. Romli et al. [17] done a factorial study upon tensile strength of coir reinforced epoxy composite. In their

study, the volume fraction, curing time and compression load during the solidification of composites were taken as parameters. From the results, they concluded that volume fraction influences the tensile strength of the composites. Authors also increased the percentage volume fraction of fiber and found that the tensile properties of composites increased to some extent. Curing time also showed some effects on the characteristics of composites meanwhile the influence of compression load on the properties of composites were not revealed properly.

Lu et al. [18] worked on bamboo/epoxy composites and the mechanical charecter of composites were compared. Samples with different volume fraction were prepared using treated fiber. Surface modification of fibers was done using NaOH and silane coupling agent (KH560). FTIR analysis was also performed to observe the chemical structure of the fibers. From the analysis they concluded that NaOH would partially dissolve the lignin and hemicellulose from the periphery of fiber and created some porosity on the surface of fiber. It would increase the interlocking capacity of fiber and eventually fiber would be adhered to matrix firmly. The silane treatment of the fibers leads to the formation of Si-O-Si and Si-O-C chemical bonds with the cellulose surfaces which results in enhanced mechanical properties of the composites. They concluded that the tensile strength of the composites was much higher in silane treated fibers than alkali treated.

Nam et al. [11] studied the significance of alkali treatment on interfacial bonding and mechanical properties of coir fiber filled poly (butylene succinate) biodegradable composites. Composites with fiber concentration of 10-30 % were prepared using 5 % NaOH treated fibers. On comparing with untreated fiber composites authors found a remarkable improvement in the interfacial shear strength (IFSS) and mechanical properties of treated coir fiber/ polybutylene succinate (PBS) composites. The treated composites with 25 % fiber content exhibits higher mechanical properties. Samal et al. [19] prepared bamboo as well as glass fiber filled polypropylene hybrid composites and examined their mechanical, thermal and morphological properties. They also added maleic anhydride grafted polypropylene (MAPP) to the composite in order to enhance the interfacial bonding between the fibers and matrix. It was reported that the hybrid composite shows improved mechanical properties like tensile, impact and flexural strength as compared with virgin polypropylene. SEM micrograph of the composites showed a

reduction in the interfacial gap between fiber and matrix. TGA showed the improved thermal stability of hybrid composite compared to the polymer.

Mishra and Biswas [20] fabricated jute fiber epoxy composites by hand lay-up method and studied the physical and mechanical properties of the prepared composites. They concluded that the presence of voids in the composites adversely affect its mechanical properties.

Mir et al. [21] performed surface treatment on coir fiber, after that a systematic investigation on the mechanical and physical properties of coir-polypropylene bio composites had conducted. For improving the compatibility with polypropylene matrix, the coir fiber was reacted with basic chromium sulfate and sodium bicarbonate salt in acidic solution. Composites with fiber percentage of 10, 15 and 20 were prepared. The study reveals that the chemically treated fiber based composite showed good mechanical charecters than untreated. The composite with 20% fiber weight concentration exhibited optimum mechanical property compared to other. During surface treatment, the OH groups of untreated coir cellulose which were hydrophilic in nature had been changed to hydrophobic –OH-Cr groups. Because of this, the water absorption amount of composite was also lowered. Reddy et al. [22] treated glass/bamboo hybrid fiber reinforced polyester composites with some chemicals such as sodium carbonates, sodium hydroxide, acetic acid, benzene, carbon tetrachloride, ammonium hydroxide, toluene and water to check the chemical resistivity of the composite. It was observed that the hybrid composites showed excellent resistance to chemicals and the tensile strength of alkali treated hybrid composite was also improved. The reason found that once the fiber subjected to alkali treatment, the amorphous hemicellulose can be removed to certain extent and eventually composite may show some crystalline behavior.

Sreenivasan et al. [23] compared the mechanical properties of untreated and surface treated Sansevieria cylindrica fibers (SCFs) /polyester composites. Surface treatments such as alkali, potassium permanganate, benzoyl peroxide and stearic acid were performed in order to modify the fiber surface. They concluded that the surface treated fiber showed improved mechanical property than the untreated fiber. Composites with potassium permanganate treated fiber exhibited better mechanical property due to better compatibility of fiber upon matrix. Monteiro et al. [24] conducted a study on the mechanical characteristics of coir fiber reinforced polyester composites. The coir fiber percentage was increased up to 80 % and found that up to 50% fiber loading, composites were become rigid, and after that composites behaves like agglomerates. A

systematic study on the influence of lignin as a compatibilizer on the physical property of coir fiber reinforced polypropylene composites were performed by Rozman et al. [25]. They made the conclusion that the coir fiber filled polypropylene composites with lignin as a compatibilizer was performed better flexural properties than control composites. Tensile properties were not at all improved where lignin was incorporated as a compatibilizer.

The use of coir fibre reinforced polypropylene composite for the panel of automotive interior applications was studied by Ayrilmis et al. [26]. This study proved that the coir fibre would be a vital component in the production of thermoplastic composites, especially for the effective replacement of comparatively highly expensive and dense glass fibres. When the coir fiber quantity increased up to 60 wt %, the flexural and tensile properties of the composites improved by 26% and 35%, respectively. Even if the further increase in fibre quantity caused to decreases the flexural and tensile properties because of the inadequate coverage of all the surfaces of the coir fibre in polymer matrix. Pothan et al. [27] studied the significance of fiber length and fiber quantity on short banana fiber filled polyester composite. The maximum tensile strength was obtained at a fiber length of 30 mm and impact strength was getting maximum at of 40 mm fiber length banana fiber polyester composite. As the fiber quantity increased up to 40%, the tensile strength increased by 20% and there was a 34% increase in impact strength also.

2.2) On the Thermal Physical Properties of Natural Fiber Based Polymer Composite

Ramanaiah et al [28] studied mechanical, thermo physical and fire features of polyester composites reinforced with sansevieria fibre. It was observed that at maximum fiber content, the tensile and mechanical properties were increasing 2.55 and 4.2 times to that of neat resin respectively. The thermal conductivity was measured by heat flow meter and found that the thermal conductivity was decreasing with the volume fraction of fiber. But they found that the thermal conductivity was increasing with the increase of temperature. Specific heat capacity of composite was also observed and found that that was also increasing with the temperature. Weidenfeller et al. [29] justified the interconnectivity significance of the filler particles in between the fiber and matrix upon thermal conductivity. They observed a remarkable improvement in the thermal conductivity of the polypropylene matrix from 0.27 up to 2.5W/m-K with the addition of 30 vol% talc. The interesting fact was that, while adding the same volume

quantity of copper particles caused a thermal conductivity raised to 1.25 W/m-K even if copper particles have a thermal conductivity almost 40 times that of talc particles. This is because of the strong interfacial bond between talc and fiber compared to copper and fiber.

Reddy et al [30] studied the thermal conductivity of characteristics of cow dung powder filled glass/polyester hybrid composite. It was found that as the volume fraction of cow dung powder increased, the thermal conductivity of the composite was decreased.Ramanaiah et al [31] studied on the mechanical and thermal properties of polyester composites reinforced with waste grass broom fiber. They varied the volume fraction of fibers in the composites from 0.163 to 0.358.It was observed that the thermal conductivity of the composite decreased gradually as the volume fraction of fiber increased. And a quite opposite result of increase of thermal conductivity was found when the temperature increased. Specific heat capacity had also measured and found a similar tendency of that thermal conductivity. Volume fraction and temperature had no influence on thermal diffusivity. Fernandez et al [32] made cork polyethylene composite and studied its characteristics. Its thermal and acoustic properties, impact strength, hardness, dimensional stability were tested. The obtained results showed that this natural-based composite exhibits improved characteristics such as low water absorption, impact resistance, fire resistance, and insulation properties than conventional materials.

Kalaprasad et al. [33] studied thermal conductivity and thermal diffusivity studies of sisal, glass and intimately mixed sisal/glass fiber reinforced low-density polyethylene composites. It was observed that sisal reinforced polyethylene composite and the low density polyethylene shows almost same variation of thermal conductivity with temperature. Here the rate of thermal conductivity increased in glass fiber .polyethylene composite was higher than sisal /polyethylene composite. The thermal conductivity of glass fiber showed higher because of the existence of Fe^{2+}metal ions content in E-glass fibre. Kumlutas and Tavman [34] conducted a numerical and experimental study on thermal conductivity of particle reinforced polymer composites, they observed that if tin particle was filled HDPE in a volume ratio of 8% and 16% they observed that the thermal conductivity raises from 0.554W/m/K to 0.681W/m/K and 1.168W/m/K respectively.

Idicula et al [35] carried out the experiment on the thermo physical characteristics of polyester composites reinforced with natural fibre. Thermal conductivity, thermal diffusivity, and specific heat of banana/sisal /polyester hybrid composer was evaluvated.They concluded that with the

incorporation of the banana/sisal fiber the effective thermal conductivity of the composite reduces. They also fabricated PALF/Glass reinforced hybrid polyester composite and found that the thermal conductivity was increased with addition of glass fibers. The sisal and banana fiber undergone chemical treatment such as NaOH and PSMA and obtained a much better conductivity compared to untreated fiber composites.

2.3) On the Thermal Stability of Natural Fiber Based Polymer Composite

Shekeil et al. [36] studied the mechanical, morphological and thermal characteristics of poly (vinyl chloride)/thermoplastic polyurethane poly-blend composites reinforced with kenaf fibers on the basis of increasing fiber content. The mechanical properties like tensile strength, flexural strength were improved with the increase in fiber content. For observing the thermal stability, thermo gravimetric analysis carried out. They concluded that the thermal degradation takes place in three stages. In the first stage, composites as well as the matrix had a similar stability. Matrix showed a slightly improved stability than the composites at the second stage. And at the final stage, composites showed a greater stability compared to the matrix. Rosa et al. [37] studied the significance of fiber surface treatments on mechanical and thermal characteristics of starch/ethylene vinyl alcohol copolymers reinforced coir composites. All experiments leads to an enhanced the thermal stability of the fibers and finally to the composites. The better stability attained to the composite which contain mercerized coir fiber. In addition to this, the mechanical properties like tensile and flexural strength also increases with the effect of mercerization. Azwa and Yousif [38] fabricated kenaf/epoxy composite and characterized it thermal decomposition property at high temperature. Weight loss and physical changes were also observed by furnace pyrolysis method. The results from the TGA exhibited that when kenaf fibres volume fraction increased into the epoxy, both thermal stability and charring of the composites increases. Even if, it was detected that after alkalization, there would be a decrease in these performances for the kenaf/epoxy composite. Kumar et al. [39] made composite with coconut sheath fiber and epoxy resin then compared the mechanical properties and thermal degradation phenomena with its treated category. They found a sound increase in mechanical property in treated coconut sheath fiber epoxy fiber than untreated category.TGA had also conducted and observed that the treated composite had showed better thermal stability and less char yield than untreated composites.

2.4) Objective of the present Work

From inspiration of the research work that had conducted already, the following points, which outlined below are the highlights of present study

- To functionalize the coir fiber with the treatment of NaOH and fabricate epoxy composite filled with both treated and untreated coir fiber by hand lay-up method.
- To study the mechanical charecteristics like tensile strength, flexural strength, impact strength and hardness of treated fiber composite, untreated fiber composites and cow dung powder filled untreated composites.
- To study the thermo physical properties like thermal conductivity, specific heat capacity of both the treated and untreated fiber reinforced composites.
- To estimate the thermal conductivity of cow dung powder filled coir/epoxy composite.
- To study the importance of fiber surface treatment on thermal stability of composites.
- To study the surface morphology of composites using optical microscope.

CHAPTER 3
MATERIALS AND METHODS

This chapter contains the details about materials and the experimental procedure that were considered for the fabrication of composite and the test procedure followed for testing the characterization of composites, respectively. The raw materials used for fabrication are

1. Coir fiber
2. Epoxy
3. Hardener

3.1) Materials

The coir fiber used for the preparation of composites are arranged from local resources. First of all the coir fibers are segregated finely and they cut into pieces of length about 12 mm. The Epoxy resin(LY 556) is taken as matrix binder is distributed by Ciba Geigy India Ltd. Commonly epoxy resin have poor mechanical and thermal properties. For getting the properties to be improved, the resin should undergo curing reaction in which the liner epoxy resin structure changes to form three-dimensional cross-linked thermoset structure. This curing reaction takes place by adding a curing agent called hardener in a ratio of 10:1 to epoxy resin. The following reaction is an exothermic reaction in which homopolymerisation of resin takes place. The curing agent or hardener is triethylenetetramine (HY-951) is also supplied from Ciba Geigy India Ltd.

3.2) Alkali treatment

In order to get improved mechanical and physical characters of the composites, coir fiber is subjected to alkali treatment process. In alkali treatment, fibers are firstly prewashed with huge amount of distilled water and dried at constant temperature of 50 ^{0}C. The alkalization process consisted of immersing coir fibers of certain weight in a 5% (w/v) NaOH aqueous solution for 3 h at 70^{0}C. After that, fiber is removed from alkali solution and is dipped in 5 % acetic acid

solution for neutralizing. Then it is washed with plenty of distilled water and is dried in an electric oven at a temperature of 110^0C for 2hr [37].

3.3) Composite fabrication

Fabrication of composite is done by conventional method called hand lay-up method. A mold of dimension $210 \times 210 \times 40$ mm^3 is used. Epoxy resin with its corresponding hardener in a ratio of 10:1 is thoroughly mixed. Mold releasing silicon spray is applied to mold releasing sheet and then the chopped fiber, mixed with the resin is gently poured on the sheet which is placed inside the mold. The purpose of releasing agent is to facilitate easy removal of the composite from the mold after curing. The mixture is allow to set inside the mold for a period of 24 hr under a pressure of 20kg over the cast. Then the specimen is cut into appropriate dimension for mechanical and thermal tests. In this fabrication procedure ,three classes of composites are made with different compositions are shown in the table no:3.1.Cow dung powder is added in one group of composite in a weight percentage of 5%, 10% and 15% for improving the thermal properties of composites.

Table.3.1: Designation of Composites

Composites	Epoxy (wt %)	Coir – untreated (wt %)	Coir -treated (wt %)	Cow dung powder (wt %)
C1	100	0	0	0
C2	95	5	0	0
C3	90	10	0	0
C4	85	15	0	0
C5	80	15	0	5
C6	75	15	0	10
C7	70	15	0	15
C8	95	0	5	0
C9	90	0	10	0
C10	85	0	15	0

3.4) Mechanical Property Tests

3.4.1) Tensile Strength

The tensile test of the composites were performed as per the ASTM D3039 standards. The test was done using a universal testing machine (Tinius Olsen H10KS).The specimen of required dimension 100 x 15 x 6 mm^3 dimension was cut from the composite cast. The test was conducted at a constant strain rate of 2 mm/min. The tensile test arrangement is shown in figure 3.1

Figure.3.1: Loading arrangement for tensile test

3.4.2) Flexural strength

The flexural strength of a composite is the maximum tensile stress that it can withstand during bending before reaching the breaking point. The flexural test of the composites were performed as per ASTM D790-03 test standards. The three point bend test was performed on the composites using same universal testing machine (Tinius Olsen H10KS) at a cross head speed of 1mm/min. The loading arrangement for the flexural test is shown in Figure 3.2. The test was repeated three

times for each composite type and the mean value was taken. The flexural strength is determined as

$$f=3PL/2bt^2 \quad (3.1)$$

Where, L is the span length of the sample (mm)

P is maximum load (N)

b the width of specimen (mm)

t the thickness of specimen (mm)

Figure.3.2: Loading arrangement for three point bending test

3.4.3) Micro-hardness

Leitz micro-hardness tester was used to measure the micro-hardness of composite specimens. Figure 3.3 shows the experimental set up for the micro-hardness test. A diamond intender with an apical angle of 136° was intended over the surface of the specimen under a load of 2.94 N.

After the removal of load the two diagonals D1 and D2 of the indentation were measured. The hardness value was calculated using the Equation (3.3)

$$Hv=0.1889F/L^2 \quad (3.2)$$

$$L= (D_1 +D_2)/2 \quad (3.3)$$

where, F is the applied load (N), L is the diagonal of square impression (mm), D_1 is the horizontal length (mm) and $D_2$is the vertical length (mm).

Figure.3.3: Experimental set up for Micro-hardness test

3.4.4) Impact Test

Impact tests were performed to understand the toughness of material. During the test, specimens were subjected to a large amount of force for a very short interval of time. For any material, the higher amount of impact strength indicates that it can absorb a large amount of energy before failure. As the impact energy increases the toughness of material increases and its plasticity will be also large. The pictorial view of impact tester is shown in figure 3.4. The specimen was clamped into the tester and the pendulum was released from a height to strike the specimen. The corresponding values of impact energy of different specimens were getting directly from the dial indicator. The size of the specimen for the impact test was 64 x 12.7 x 3.2 mm^3.

Figure.3.4: Pictorial view of Impact tester.

3.5) Optical Microscope

The optical microscope, often considered as the light microscope, is a type of microscope which uses light and magnify images of small samples with the help of lenses. A diagram of typical arrangement of optical microscope is shown in figure 3.5. Generally, they are classified as simple microscope and compound microscope. A simple microscope is a microscope that provides angular magnification with the help of single or a group of lenses. Simple microscopes are not capable of high magnification. A compound microscop**e** is a microscope which has two types of lenses. One close to the object to gather the light from object called objective lenses and other close to eye called eye piece. The compound microscope gives better magnification than simple microscope. Here the microscope of model used for magnifying the image of composite material.

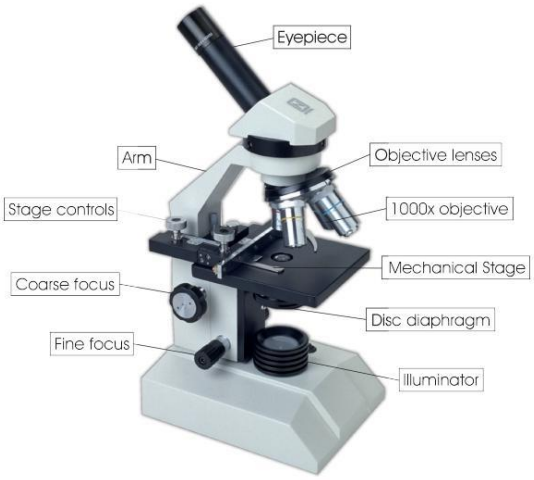

Figure.3.5: Schematic diagram of an optical microscope

3.6) Thermal Property Testing

3.6.1) Thermal Conductivity Testing

The thermal conductivity of composites were measured using Unitherm™ Model 2022 guarded heat flow meter. The heat flow meter measures the thermal conductivity according to ASTM E1530 standard. A schematic diagram showing the heat flow occurs in a heat flow meter is shown in figure 3.6. A sample of the material was prepared in the shape of a round disk of 50 mm diameter and 5 mm thickness .Then it was held between two plates which were regulated at a different temperature and a compressive load was applied. The lower surface would be portion of a calibrated heat flux transducer. When the experiment started heat flows from the upper surface through the sample to the lower surface, an axial temperature gradient was established in the stack. The temperature difference across the sample along with the output from the heat flux transducer was noted and thermal conductivity of the sample could be determined if the thickness was known. A guard furnace surrounds the test stack to reduce the effect of heat transfer through the edges of the sample that would cause an error in the measurement.

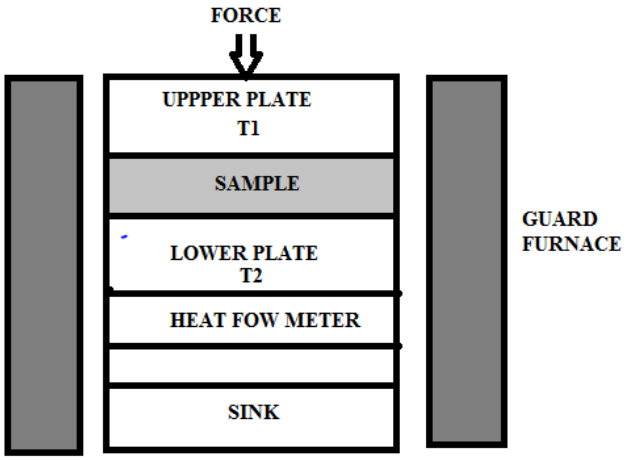

Figure.3.6: Schematic arrangement of guarded heat flow meter

Equations 3.5-3.7 were used to determine the thermal conductivity [31]:

Heat flow by conduction in one dimension=K (T1-T2)/x (3.4)

Where Q is the heat flux (W)

K is the thermal conductivity of the body (W/m-K)

A is the cross sectional area (m2)

T1-T2 is the difference in temperature across the body (K)

x is the thickness of the sample (m)

Thermal Resistance (m^2-K/W) of sample is calculated by,

$$R = (T1 - T2) / (Q / A) \quad (3.5)$$

$$K = x / R \quad (3.6)$$

3.6.2) Thermo gravimetric Analysis

The thermal stability of the material as a function of temperature was measured using a thermo gravimetric analyzer. In this test, the material was exposed to nitrogen atmosphere and the sample was heated slowly at the rate of 10 °C/min. This results in thermal degradation of the material and the corresponding weight loss was recorded. Figure 3.7 shows the schematic arrangement of TGA setup. The final experimental result was generated in the form of graph with mass percentage in ordinate and temperature in abscissa. TGA curve can gives the information regarding the phase transition like vaporization, sublimation, decomposition etc. In the case of natural fiber polymer composite the thermal stability is closely depend upon the temperature. TGA helps in determining the thermal stability of PMC, which is responsible for the factors like thermal expansion, thermal contraction and rate of moisture absorption [38].

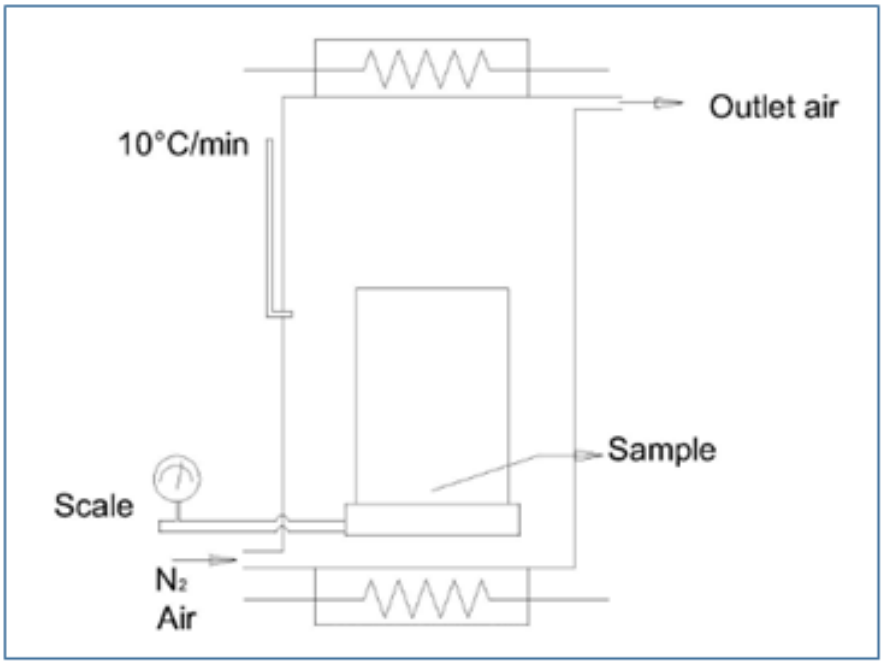

Figure.3.7: Schematic arrangement of TGA set up.

3.6.3) Differential Scanning Calorimeter

DSC was used to study the thermal transition of a polymer while heating. The test was performed using METTLER TOLEDO DSC822^{e}. The equipment had a simple arrangement for two pans, out of which one pan was kept empty (reference pan) and other pan (sample pan) contained the test specimen, as shown in figure 3.8. In this test the heat absorbed by the two pans were compared. In order to maintain same temperature in both the pans, the heater has to deliver extra heat into the non-empty pan. DSC experiment measures this extra amount of heat delivered by the heater to the samples. The extra amount of heat delivered by the sample pan heater to maintain the temperature equivalent to the reference pan was absorbed by the specimen and this absorbed heat is the heat capacity of the material. This data was used to calculate the specific heat capacity of the material. The glass transition temperature of the coir composites was also determined using DSC.

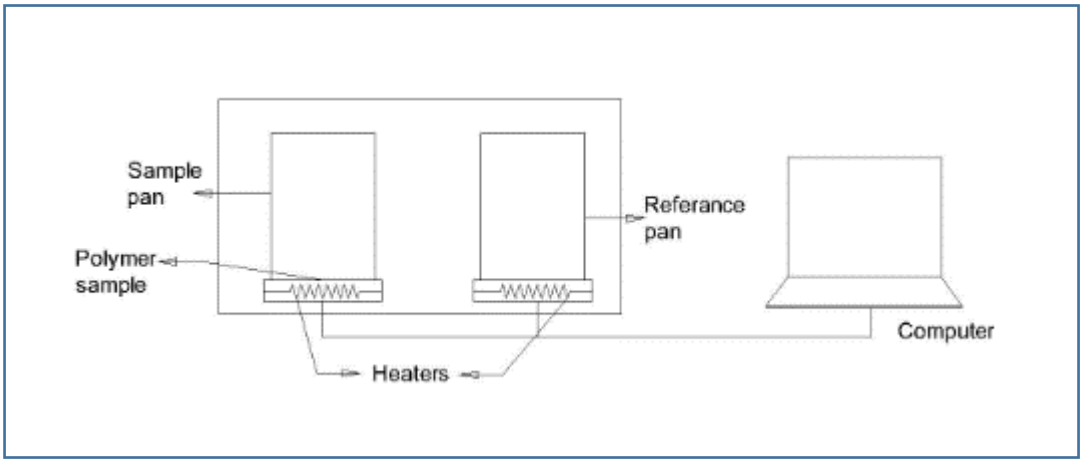

Figure.3.8: Schematic arrangement of DSC

CHAPTER 4
RESULTS AND DISCUSSIONS

This chapter contains the variation of mechanical and thermal behavior of coir epoxy composites with respect to some factors like weight percentage of fiber, surface treatment of fiber and the addition of cow dung power as an additive.

4.1) Mechanical Characteristics of Composites

4.1.1) Effect of fiber and filler concentration on hardness of composites

Vickers Micro hardness test had conducted for the composites of name given as C1, C2, C3, C4, C8, C9, C10. Figure4.1 depicts that as the fiber weight percentage increases, the hardness value of the both treated and untreated composites increases. This may be attributed to the fact that the incorporation of fibers into the resin has lowered the mobility of the polymer chain in the rigid composites [40]. The treated fiber composites exhibits better hardness compared to the untreated ones. This may be due to the better dispersion of the coir fiber into the epoxy matrix as well as the strong interfacial bonding between the fiber and the matrix.

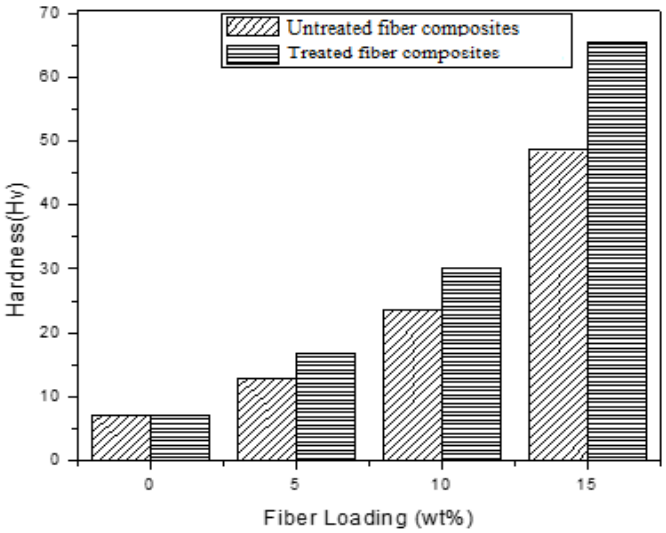

Figure.4.1: Variation of Hardness of composite with respect to fiber loading

The cow dung powder was added to the untreated 15% fiber loaded composite in a weight percentage of 5, 10 and 15%. The measured hardness values is plotted in the graph, as shown in figure 4.2. A slight increment in hardness value of 5 wt% cow dung powder composite is observed. When the filler loading increases further to higher values of 10 and 15%, the hardness of the composites seemed to decrease.

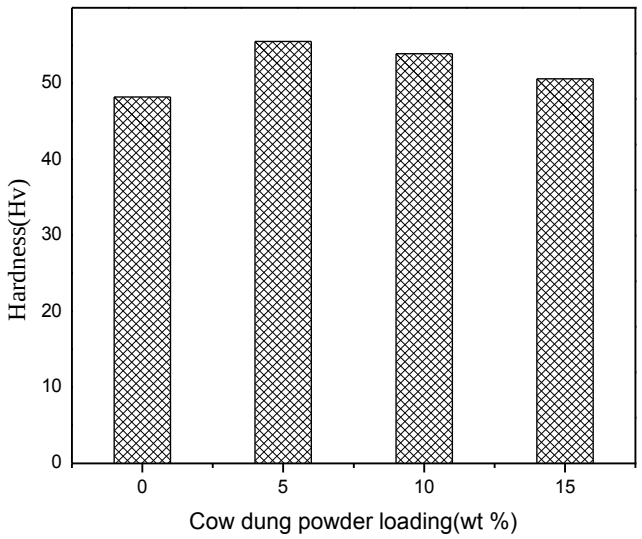

Figure.4.2: Effect of Cow dung powder on hardness of the composite

4.1.2) Effect of fiber and filler concentration on tensile strength of the composites

Figure 4.3 shows the effect of fiber loading on both treated and untreated coir fiber reinforced composites. It can be clearly observed that the tensile strength of the composites increases with the increase in fiber loading. The stress strain behavior of any fiber reinforced composites depends on many factors such as the effectiveness of the bonding between the matrix and fibers, strength of matrix and fiber and volume fraction of fibers [41]. When the load is applied to the composites, fibers acts as a load carrier, and matrix transfers the stress to the fibers uniformly and effectively, thus resulting in good mechanical properties of composites. At higher fiber content the composite exhibit better tensile properties due to presence of sufficient fibers which withstand load. The result also shows that the treated composites exhibit higher tensile strength than untreated composites. The alkali treatment of fibers lead to the removal of noncellulosic

filler constituents and increased roughness of surface which helps in better bonding of the coir fibers with the epoxy resin.

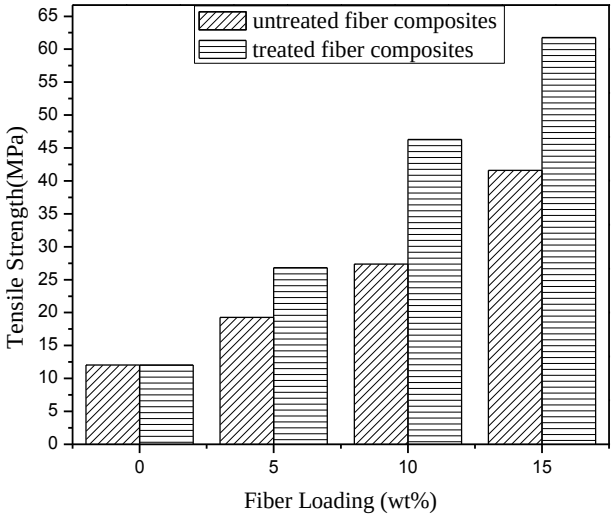

Figure.4.3: Variation on Tensile Strength of composite with respect to fiber loading

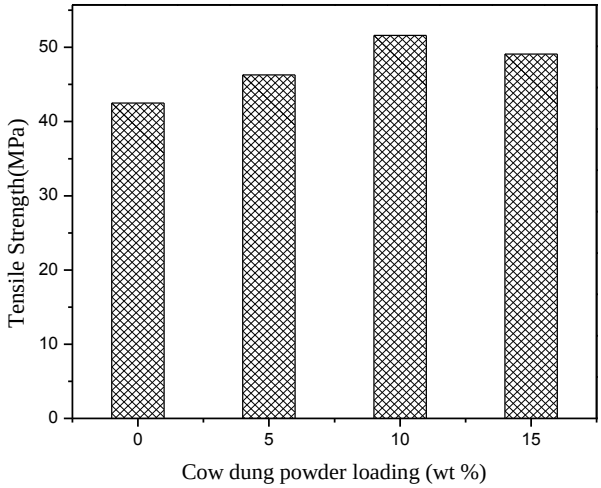

Figure.4.4: Effect of Cow dung powder on Tensile Strength of Composite

Cow dung powder with 5, 10 and 15 wt% was added to 15 wt% untreated fiber composites and the tensile strength was measured. From figure4.4, it is observed that the tensile strength of the composite increases with the addition of cow dung powder up to 10% weight. When the loading is further increased up to 15 wt% , the tensile strength of the hybrid composite tends to decrease.

This is because the total reinforcement percentage of the composites increases which in turn reduces the interaction between the reinforcement and matrix.

4.1.3) Effect of fiber and filler concentration on flexural strength of composites

Result of alkali treatment on the flexural properties of coir/epoxy composites with different fiber loading (from 0 to 15 wt%) is plotted in Fig. 4.5. Initially the flexural properties are increasing with the increase in fiber loading from 0 to 10 wt%, however at 15% fiber loading there is a decreases in flexural strength. The reduction in mean flexural strength of 15 wt% coir fiber reinforced composites may be due to the deficiency of epoxy resin which lead to the improper wetting of the coir fibers. The treated fiber composites exhibited higher flexural strength in compared to untreated one. This shows that the improved interfacial adhesion between the fiber and matrix results in higher flexural strength of the treated composites.

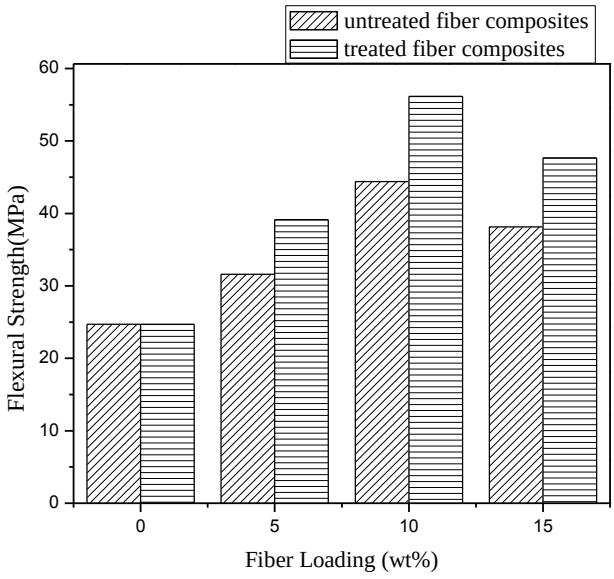

Figure.4.5: Variation on flexural strength of composites with respect to fiber loading

The effect of cow dung powder on the flexural strength of untreated coir-epoxy can be interpreted by figure 4.6 .From figure, it could be observed that there is a gradual decrease in flexural strength of the hybrid composite with respect to the filler loading. For untreated coir-epoxy composite specimen flexural strength is 38.15 MPa, whereas for 5, 10 and 15 wt% of filler

content in the composites flexural strength is 36.96 Mpa, 36.03 MPa and 34.11 MPa respectively and indicating poor performance of composite due to filler-matrix interaction.

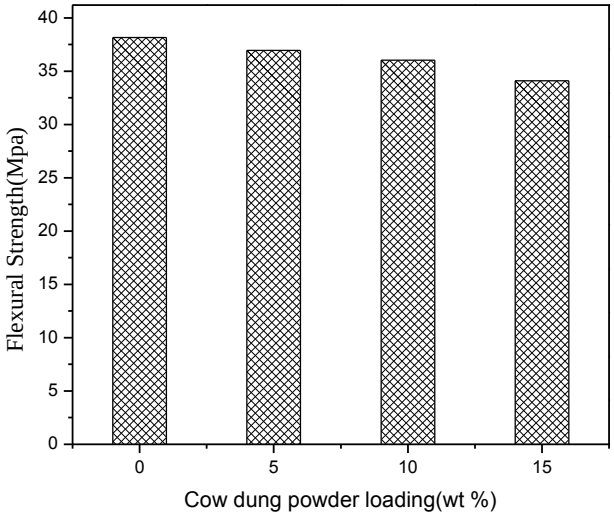

Figure.4.6: Effect of Cow dung powder on Flexural Strength of Composite

4.1.4) Effect of fiber and filler concentration on impact strength of composites

The effect of fiber content on the impact strength is shown in figure 4.7. It is observed from the figure that addition of fiber in the matrix leads to improved impact strength of the composites. The impact strength increases with the increase in the fiber loading of the composites. The main reasons of fiber fracture while impact loading is fiber fracture,fiber debonding and fiber pull out.The energy dissipation in fiber pullout is much greater than the fiber fracture.So this is the main reason for impact fracture in FRP.So as the fiber loading increases, impact strength increases because more energy can be dissipated .In this case, fiber loading with 15% concentration shows higher impact strength. [44]. In case of composites with higher fiber content the chance of fiber pull-out is more. As the fiber content in composites increases, more energy will be required for the weakning of the fiber matrix bonding or in other words more energy will be absorbed by the fibers. The imact strength with the alkali treatment composites also. The improvement in the impact strength of alkali treated composites may be due to presence of low moisutee in fibers due to which strong interfacial adhesion between fiber and matrix is possible.

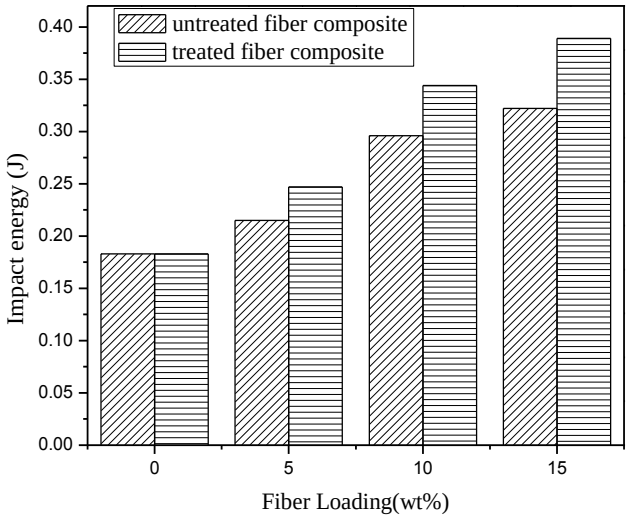

Figure.4.7: **V**ariation of impact strength of composites with respect to fiber loading

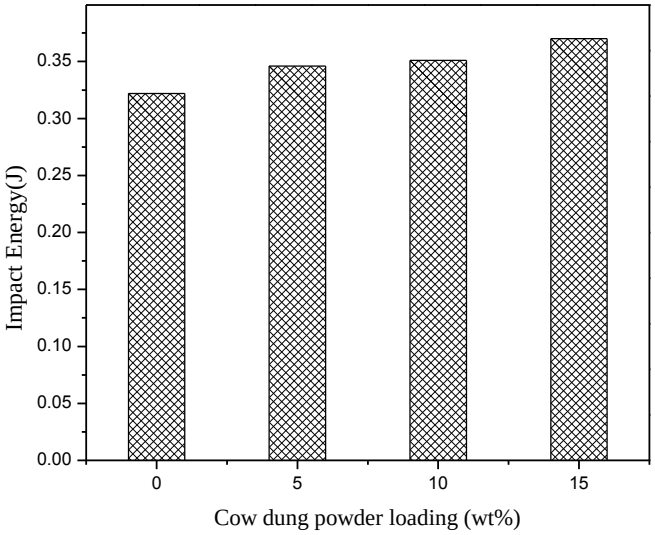

Figure.4.8: Effect of cow dung powder on impact strength of composite

The effect of cow dung powder weight percentage on impact strength of composite is shown in Figure 4.8. From the figure 4.8, improvement in the impact strength of the composites is observed with the addition of filler. Similar observation has been reported by the researchers in case of oil palm wood flour filled glass epoxy composites [45]. Authors explained that the

improvement of the impact strength of the composites is due to cushioning effect provided by the natural fillers.

4.2) Optical microscopic images

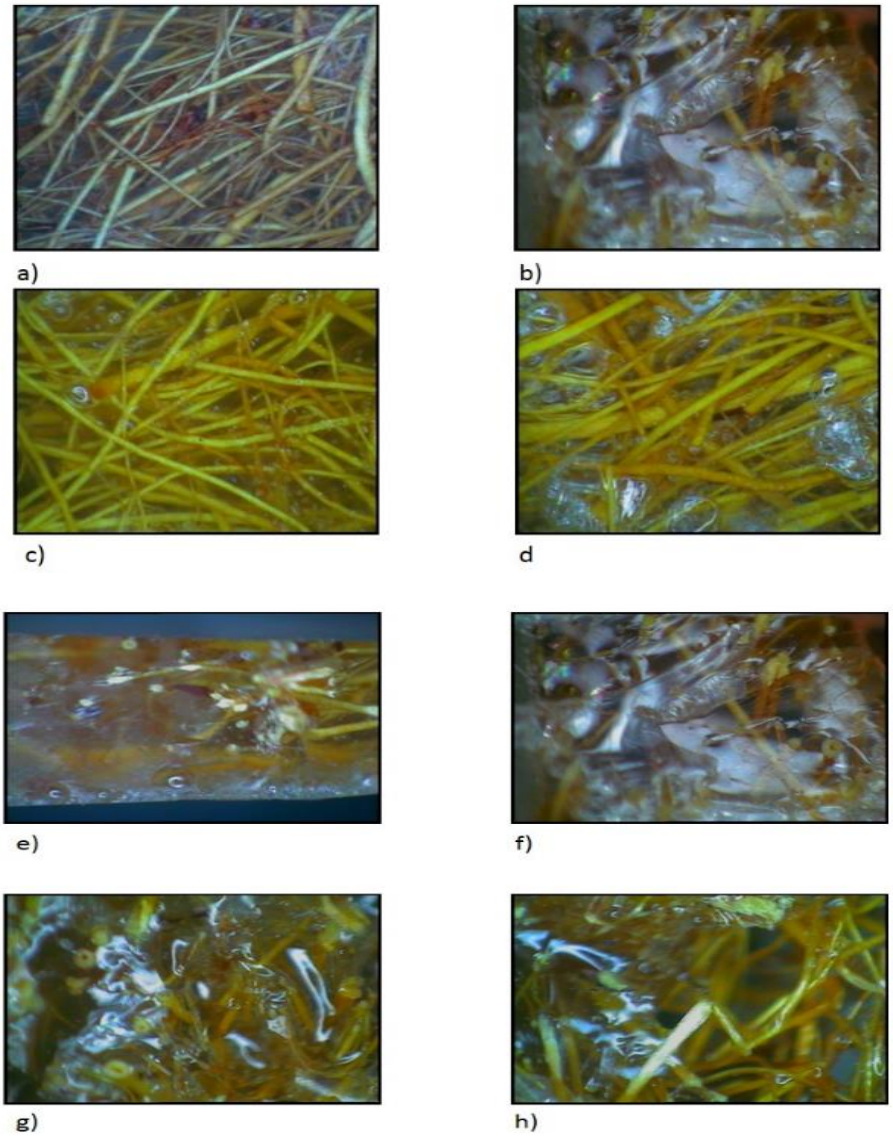

Figure.4.9: Optical Microscopic images of composites.

The images shown above are the optical microscopic images of various samples. In figure 4.9,sample (a) & (b) are the images surface view of untreated fiber composites of fiber concentration 5% and 15% respectively(C2 and C4).The images shown in (c)&(d) are the treated fiber composite of same fiber concentration (C8 and C10)mentioned above. Images (e) & (f) are the end surface view of C2 and C4 after tensile testing .And the images (g) & (h) are the end

view of sample C8 and C10 after tensile testing. The images (a) and (c) are the composite of same concentration (5%) of untreated fiber and treated fiber respectively. We can observe that there is a color difference between these two the treated fiber is seems as somewhat yellowish compare to pale light brown coloured untreated fiber. This colour change is due to The colour change of fibre of (a) and (b) pale brown to yellow was observed due to removal of lignin.

4.3) Thermal Characteristics of Composites

4.3.1) Effect of fiber concentration and the addition of cow dung powder on Transverse Thermal Conductivity of composite.

The resultant variation of the thermal conductivity of composite with respect to fiber loading is shown in the figure 4.10. From the figure it is observed that the thermal conductivity of the composites decreases with the increases in fiber loading. On comparing with pure epoxy matrix, it has been found that the thermal conductivity of composites decreased by 19.08%, 31.90% and 42.45% for the composites with 5, 10 and 15 wt% fiber loading, respectively. From the above observation it can be concluded that the thermal insulating behaviour of the composites increases with increase in fiber loading. The natural fiber coir has a hollow portion which contains air. The air has a low thermal conductivity of 0.026 W/m-K at 25 °C and thus offer an excellent heat insulating effect. The percentage of air increases with the increasing fiber loading of the composites and results in the reduction of thermal conductivity of the composites [46].

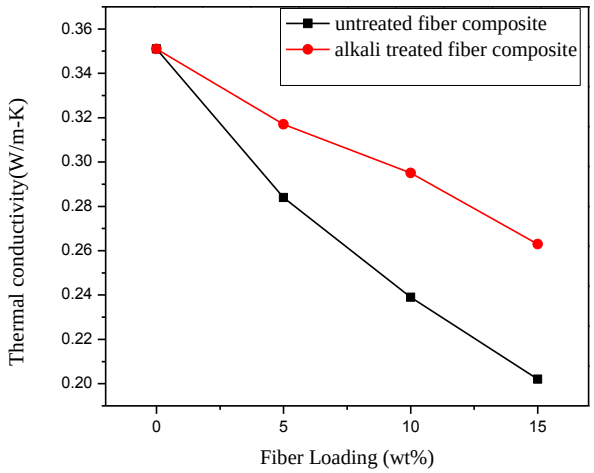

Figure.4.10: Significance of fiber loading on thermal conductivity of composite

The thermal conductivity of alkali treated composites with different fiber loading were also determined. It is observed that, there is a slight increase in thermal conductivity of treated composite samples compared to the corresponding untreated one. The alkali treatment of the fibers practically removes all the noncellulose components except waxes. The dissolution of lignin by NaOH led to formation of small pores on the surface of the fibers, thus improving the area of contact between the matrix and fiber [47]. Thus resulting in increased thermal conductivity of the treated coir fiber composites. From the thermal insulation point of view untreated coir fiber composites are more efficient compared to the treated composites. Figure 4.3 shows, composites with 15% untreated fiber loading (C4) has the lowest thermal conductivity.

To further reduce the thermal conductivity of the coir fiber composites cow dung powder with 5, 10 and 15 wt% was added to 15 wt% untreated composites. The thermal conductivity of these samples are plotted in figure 4.11. It is observed that the addition of cow dung powder results in reduction of thermal conductivity of the untreated composites. Similar observation has been reported by the authors [30] in case of cow dung powder filled glass–polyester hybrid composites. The thermal conductivity values of the untreated coir fiber composites having 0-15 wt% of cow dung powder decreases from 0.202 - 0.168 W/m-K. The thermal conductivity of the pure epoxy matrix is reduced by 52.13% o on adding 15 wt% cow dung powder to the untreated composites i.e. C7 sample.

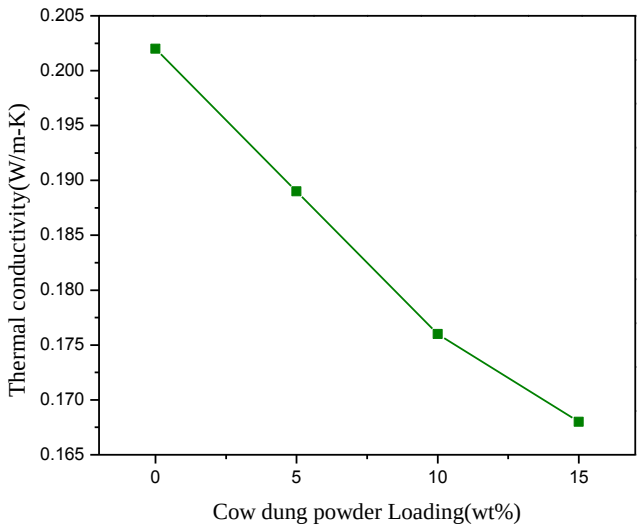

Figure.4.11: Variation of thermal conductivity of composite with respect to the addition of cow dung powder

4.3.2) Thermo gravimetric Analysis

In the TGA the thermal degradation phenomena of treated and untreated coir epoxy composite had been studied. From figure 4.12, it can be observed that at lower temperature weight loss occurs more in the case of untreated fiber composite compared to treated fiber composites. The untreated coir fiber has higher moisture content due to the presence of hemicellulose and lignin. Thus, the relative weight loss is higher in untreated fiber composites. In untreated composites, most of the moisture is present in between the interface region of fiber and matrix.

During the test, when untreated fibers were subjected to heating, the evaporation of large amount of moisture present would take place and due to this weight loss occurs more in case of untreated composites. However in alkali treated fiber reinforced composites, the hemicellulose content was less and the moisture absorbed was also low [11]. At higher temperature the weight percentage of untreated composite was found to be larger than the treated composite. This was because of the presence of lignin in the untreated fiber, which were responsible for the formation of char. Thus, the optimum removal of lignin content is required to attain balance between positive property of formation of chars and the negative impact of low temperature degradation [48].

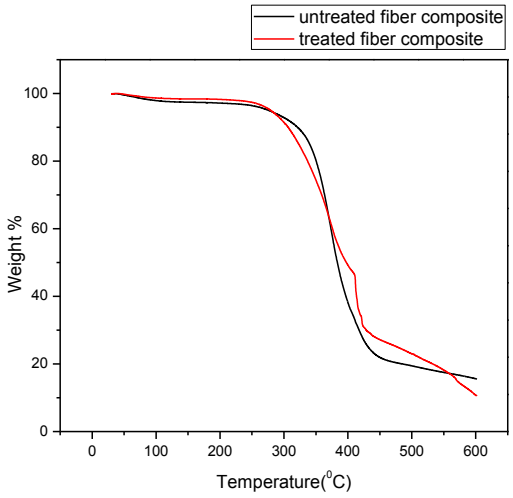

Fig.4.12: Comparison on thermal stability of alkali treated and untreated fiber filled composites

4.3.3) Effect of fiber concentration and the addition of cow dung powder on Specific Heat Capacity of composite

Specific heat capacity of a material is the quantity of heat required to increase the temperature of unit mass of the substance by 1 K. For higher specific heat materials, more energy is needed to raise their temperature. The specific heat capacity of composites is measured by DSC method. The specific heat capacity of the polymers can be increased by adding fibers. Thus, fiber reinforced composited can be used for insulation purposes.

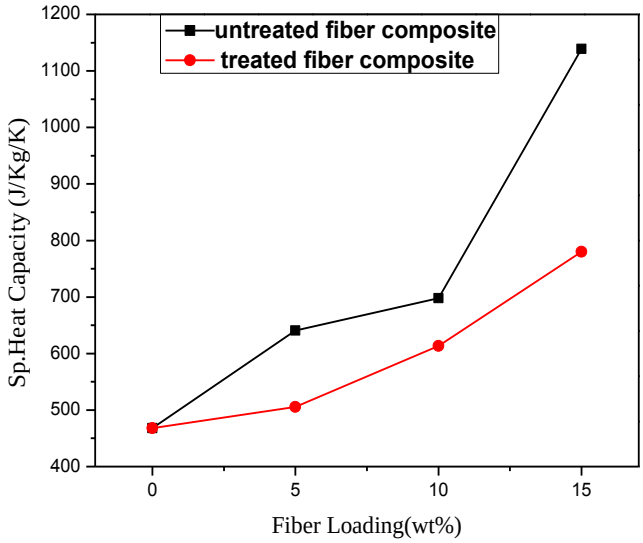

Figure.4.13: Variation of specific heat capacity of composite with respect to fiber concentration

The specific heat capacity of the treated and untreated fiber composites at different fiber loading are represented in figure 4.13. It is observed that the untreated fiber composites exhibits better specific heat capacity than the treated composites. The treated fibers contains less moisture as majority of the hemicellulose is removed on treatment. The specific heat capacity of water is much higher than that of the polymers. The specific heat capacity of water is 4180 J/Kg/K. More the moisture or water content in a material more is the specific heat capacity of that material. As untreated composites contains more moisture they exhibit higher specific heat capacity compared to the treated composites. The untreated fiber composite with 15% fiber content (C4) showed higher specific heat capacity, as observed from the figure 4.6. Further improvement in the specific heat capacity of the composites is achieved by adding cow dung powder into C4. From

figure 4.14, it is observed that the increase in cow dung powder concentration results in increased specific heat capacity of the untreated composites. The composites with 15 wt% cow dung powder exhibits higher specific heat capacity.

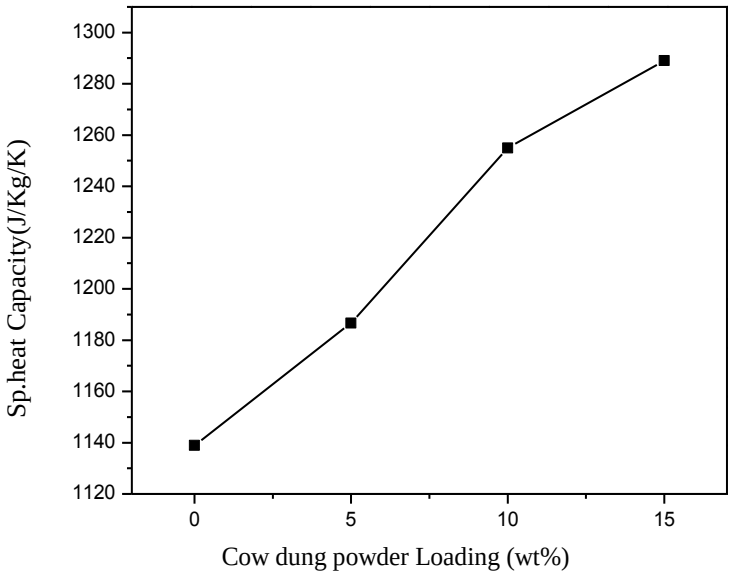

Figure.4.14: Effect of cow dung on Specific Heat Capacity of composite

4.3.4) Effect of fiber concentration on Glass Transition temperature of composite

The glass transition temperature (Tg) is a particular temperature below which the polymer behaves as hard and brittle material like glass, and if temperature exceeds Tg, polymer behaves like rubbery material or viscous fluid. The glass transition is a transition that occurs to amorphous polymers, whose chains are not organized as ordered crystals. When the temperature is above Tg, the polymer chains can move around effortlessly. On applying the transverse force to bend polymer samples, the molecules show the tendency to move into new positions to relieve the stress that is applied on them. But, if force is applied to bend sample of a polymer which is kept below its *T*g, the polymer chains cannot be able to move into new locations to relieve the stress that applied on that**.**

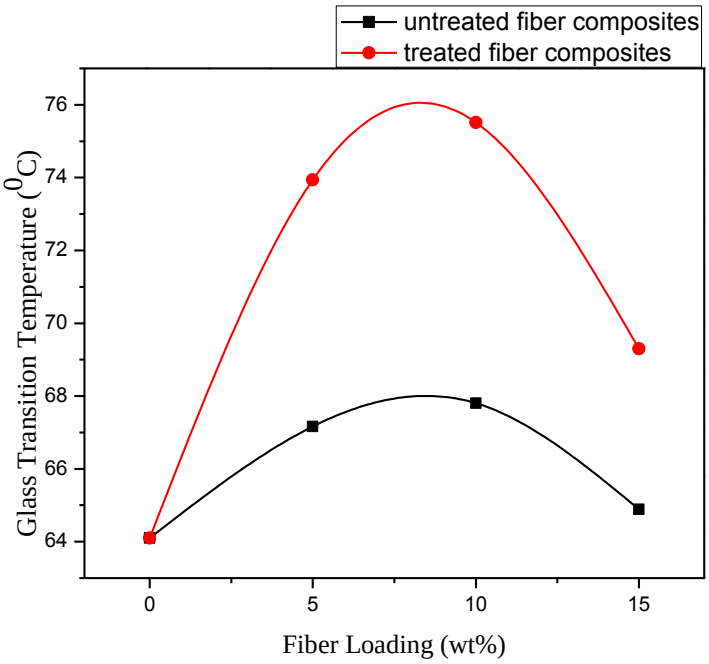

Figure.4.15: Effect of fiber concentration on Glass Transition Temperature of Composite.

The glass transition temperature of coir epoxy composite was determined using differential scanning calorimeter. Figure 4.8 shows the glass transition temperature of both treated and untreated coir-epoxy composites with varying fiber loading. It is observed that that Tg of composites increases with increase of fiber quantity. Higher Tg temperature is observed in case of composites with 10 wt% fiber loading. When fiber is added to the matrix, it would obstruct the mobility of the polymer and thereby more energy required to break the immobility of polymer. So the Tg is increasing initially. And when the fiber content exceeds a certain limit (here more than 10%) a decreasing tendency of Tg is observed. The quantity or amount of moisture will increase when large amount of natural fibers are added to the composites. The higher moisture content in the composites might disrupt the bond between fiber and matrix and with this effect polymer chain segment mobility could be increased [49]. The glass transition curve with respect to fiber loading of both treated and untreated composites shows similar trend. However, the glass transition temperature of treated coir composites is much higher compared to untreated composites. Due to surface treatment of fiber, reduction in fiber moisture and strong interfacial bonding between fiber and matrix takes place which in turn improve the glass transition temperature of treated composites. The untreated composite with 5 wt% of filler

loading exhibits maximum glass temperature of 67.5 ˚C, as observed from figure 4.16. But the glass transition temperature of composites decreases with further addition of cow dung powder in the composites.

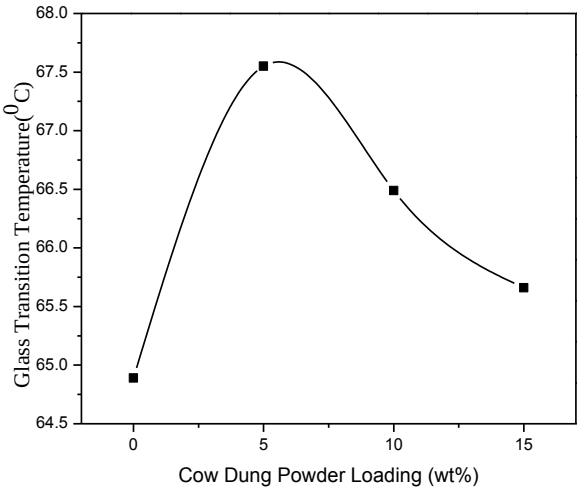

Figure.4.16: Effect of cow dung on Glass Transition Temperature of composite

CHAPTER 5
CONCLUSION

A detailed study has been conducted on the thermal and mechanical behavior of coir/epoxy composite on the basis of different weight concentration of fiber and filler. Alkali treatment of the coir fiber has also been done. The study led to the conclusions mentioned below.

1. Epoxy resin reinforced with alkali treated fiber and untreated fiber has been fabricated by hand lay-up method. Coir/Cow dung powder/Epoxy hybrid composite had also fabricated with same technique.
2. In tensile testing, as the fiber concentration increases, tensile strength of composite increases. It is also found that alkali treated fiber loaded composites shows excellent tensile strength compared to untreated one. As a result, the maximum tensile strength obtained in case of 15 wt.% fiber loaded composite and it showed almost 48% higher value compared to respective untreated one. When cow dung powder was added to the composite of untreated fibers, the hybrid composites with 10 wt% of cow dung powder exhibits higher tensile strength.
3. In flexural testing similar behavior were also obtained. Flexural strength increases with fiber concentration and here maximum value obtained is at 10% fiber concentration. When the concentration of fiber increases further, flexural strength decreases.
4. Micro hardness also exhibits the similar character as that of tensile and flexural strength. It increases with fiber loading and surface treatment. Maximum hardness obtained on 15%fiber loaded treated composite.
5. In the testing of impact strength, it was observed that the impact strength increased with increase of fiber loading. Impact strength of the coir-epoxy composite is enhanced by alkali treatment. When cow dung powder was added to untreated version, the impact strength were increased further.
6. Thermal conductivity was tested with heat flow meter and it was observed that conductivity decreases with the increase of fiber concentration. When surface treated coir

fiber composites were compared with untreated fiber composites, lower thermal conductivity was shown by untreated coir fibers.

7. As the cow dung powder added to composites thermal conductivity decreased further to lower values. The highest thermal insulation property was shown by hybrid composite containing 15 wt% untreated coir and 15 wt% cow dung powder.
8. Specific heat capacity of the composites were tested with DSC and it was observed that as fiber loading was increased, specific heat capacity of the composite also increased. Untreated fiber composites showed higher specific heat capacity compared to treated fiber composites because untreated fiber contain more water. The effect of cow dung powder also enhanced the value of specific heat capacity.
9. Rate of decomposition of treated and untreated fibers were carried out by TGA .In low temperatures decomposition rate or weight loss is higher for untreated fiber composites When the temperature crossed 550^0C residue content in untreated fiber composite was higher compared to untreated one because of the presence of lignin in untreated fiber, which was responsible for the formation of char.
10. Glass transition temperature (Tg) was also tested by DSC .It was found that Tg increases with increasing fiber concentration up to 10% fiber loading and there after Tg decreases.

5.1) Scope for future work

There is a wide scope for future to scholars to explore the current research field. The present work can be further continued to study other aspects of composites like,

- Use of other natural fibres and their behavior on the basis of same parameters used here,
- Study of composite properties on the basis of different fabrication techniques other than hand lay-up method like spray up method, compression molding method, filament winding method etc. can be done.
- Evaluation and optimization of tribological, electrical, physical properties etc. and the experimental results can be analyzed.

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