STUDY OF THE MECHANICAL AND ELECTRICAL PROPERTIES OF SAWDUST REINFORCED POLYMER COMPOSITES

by

SANGITA SHARMA
Roll No. 040314006
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DHAKA
DEPARTMENT OF PHYSICS

CERTIFICATION OF THESIS

The thesis titled "STUDY OF THE MECHANICAL AND ELECTRICAL PROPERTIES OF SAWDUST REINFORCED POLYMER COMPOSITES" submitted by **SANGITA SHARMA**, Roll No: 040314006F, Registration No: 0403571, Session: April/2003, has been accepted as satisfactory in partial fulfillment of the requirement for the degree of **MASTER OF PHILOSOPHY (M.Phil.)** in Physics on 29 June, 2008.

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DR. MD. ABU HASHAN BHUIYAN (Supervisor)
Professor
Department of Physics, BUET, Dhaka

2. ______________________________ Member

DR. M. A. GAFUR (Co-Supervisor)
Senior Engineer
Heat Treatment Section, PP & PDC, BCSIR
Dhaka-1205

3. ______________________________ Member

DR. MD. FEROZ ALAM KHAN
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Department of Physics, BUET, Dhaka

4. Jiban Podder ______________________________ Member

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Department of Physics, BUET, Dhaka

5. ______________________________ Member (External)

DR. A. B. M. OBAIDUL ISLAM
Professor
Department of Physics
University of Dhaka, Dhaka

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It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

Sangita Sharma
(Sangita Sharma)
Roll No- 040314006
Session- April 2003

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Abstract

A simple hot press molding technique was used to produce Polyvinyl Chloride (PVC)-sawdust composites. The various physical, mechanical, thermal and electrical properties were investigated on composites prepared from PVC and different size sawdust. Bulk density has been investigated and was found to decrease with sawdust addition.

The flexural strength of fabricated product slightly increase with the increase of sawdust addition where as flexural strain increases with the increase of sawdust addition Tangent modulus decreases with the increase of sawdust content. The tensile strength increases and tensile strain decreases with the increase of sawdust addition. Thus Young's modulus has been calculated and is found to increase with the increase of sawdust addition.

The thermal behavior of PVC- sawdust composites was analyzed by Thermogravimetry, Differential thermal Analysis and Differential thermogravimetry. Degradation have been investigated for sawdust, PVC, composite. The degradation behavior of the composite is intermediate to those of PVC,and sawdust.

The current –voltage (I-V) characteristics of PVC –sawdust composites having different weight (%) sawdust have been investigated at different temperatures The I-V curves show ohmic nature in the low temperature and become non- ohmic at elevated temperatures. Resistivity have been calculated and is found to decreases with the increase of sawdust (wt%)content.

CHAPTER-1

INTRODUCTION

1.1 Introduction

Composite materials can be defined as substances consisting of two or more physically distant and mechanically separable materials. Over last few decades, composite materials, plastics and ceramics have been the dominant emerging materials. The volume and number of application of composite materials have grown steadily by penetrating and conquering new markets relentlessly. Modern composite materials constitute a significant proportion of the engineered materials, market ranging from everyday products to sophisticated high tech application. While composite have already proven there worth as weight saving material, the currently challenge is to make them cost effective. The effects to produce economically attractive composite compounds have resulted in several innovative manufacturing techniques current being used in the composites industry. The composite technology of a polymeric matrix reinforced with man made fibers such as glass, Kevlar, carbon, etc, has come of age especially with the advance in aerospace applications since 1950s

Materials property combinations and ranges have been, and are being, extended by the development of composite materials. . Composite materials represent nothing but a giant step in the ever-constant endeavor of optimization in materials property. Strictly speaking, the idea of the composite is not a new or recent one. Nature is full of example wherein the idea of composite is used.. Wood is fibrous composite; cellulose fiber in lignin matrix. The cellulose fibers have high tensile strength but are very flexible. While the lignin matrix joins the fiber furnishes the stiffness [3]. Besides naturally occurring composites, there are many other engineering materials that are composites in a very natural way. Among the modern structural materials, the history of fiber-reinforced composites is only three decades old. However, in this period of time, there is a tremendous advancement in the science and technology of the new classes of materials. The low density, high strength, high stiffness to weight ratio, excellent durability, and design flexibility of fiber reinforced polymers are primary reasons for their use in many structural components in the air craft, automotive, marine and other industries [4]

Natural fibers are a promising reinforcement to use in thermoplastic composites due to their low density biodegradable, less expensive and excellent mechanical properties as alternatives to synthetic fibers e.g. glass, carbon etc. Further more the natural fibers such as sisal, jute hemp, sawdust and flax etc. are relatively cheap and obtained from agricultural renewable resources in many developing countries in the world.

Composite fabricated using these natural fibers have the potential over the synthetic fiber composites and are currently being explored in sectors like automobiles and buildings. The lightweight natural fiber reinforced polymers have a weight saving potential, lessening the dependency of automobiles on fossil fuel resources. The natural fibers however, exhibit large variation in quality, are thermally less stable and are sensitive to moisture absorption.

For manufacturing of reinforced composite materials, factors such as fiber content, fiber diameter, fiber length, void content matrix properties, fiber-matrix bonding, fiber orientation and fiber properties are very important as they determine the final properties of the natural fiber reinforced composite compounds. [6]

1.2 Review of the Earlier Research Work

The history of human civilization and social development is strongly intertwined with the pervasive role of materials - namely, the substances that are accessible to mankind and can be processed to exhibit the desired properties for making things. The complexity of biomaterials available today is a result of the continual demand to improve the quality of biomaterials needed for technological advancement. Biomaterial researchers around the world work to develop both new biomaterials and also improve existing ones. The new era of science and technology know how in research development is a foundation for every other procedure.

Sombatsompop and Caochanchanchaikul [7] worked out research on PVC sawdust composite with different silence coupling agent. Unique explanation are given to describe changes in the mixing torque and tensile and impact properties of PVC wood sawdust composites affected by various types and concentrations of silence coupling agents. Concentration of .5-1.0 and 1.5% coupling agent are recommended for the optimization of the tensile and impact properties of the composite, respectively. Changes in the tensile and impact properties of the composites, with low sawdust content were more sensitive to the addition of silence coupling agents than those with high sawdust content. The effect of sawdust content they found that the composites with a higher sawdust content exhibit a lower tensile strength than those with a lower sawdust content. Composite with higher sawdust content were likely to contain greater moisture content because the wood sawdust was hyperlink and the water molecules on the fiber surface could promote or accelerate the self condensation reaction of the coupling agent and increasing the wood sawdust content automatically increased the interfacial defects in the PVC matrix.

Sombatsompop et al. [8] carried out research on maleic anhydride grafted PP and impact modifiers on mechanical properties of PP/wood sawdust composites. The concentration of wood sawdust was also varied. The experimental results revealed their increasing the wood fiber into the PP matrix reduced the overall strength and toughness of the composites. It was observed that the higher the impact concentration, the greater the improvement in toughness of the PP/ wood composites, and there fore an impact modifier with high co monomer content and high melt flow rate is recommended. They suggested that the wood fiber content was increased, the overall strength and toughness of the composites decreased. The toughness of the PP/wood composites could be regained by adding an impact modifier content enhanced the toughness of the composites.

Las Penas [9] worked on the composite materials comprise a matrix of thermoplastic PP or mixtures with polymers, additives, stabilizers, anti- oxidants, dyes, etc. charge or reinforcement of vegetables fibers. The fiber may coir, sisal, jute, hemp, ramie, flax, cotton, kapok, and kenaf, alone in mixtures with or without pretreatment to enhance compatibility with the matrix, and as fibers of .5-12 micro m. or ground into a granulate material. The composite may contain 30-70% fibers and may be processed by extrusion, calentering lamination, optionally coated with another woven of non woven materials and finally molded in cold molds to obtain final forms. The materials have mechanical properties which are improved with respect to conventional similar material and are indeed for use as internal lining motor vehicles, essentially, in the construction industry as insulation or decorative materials, in the packing industry.

Bledzki and Faruk[10] worked on four type of wood fiber (hard, soft, long, wood chips) were used to prepare wood fiber reinforced PP composites. The effect of coupling agent and fiber length and geometry on the performance of wood fiber PP composites has been investigated. Wood chips pp composites showed better tensile properties comparative with other wood fiber pp composites with addition of 5% MAH-PP. Hard wood fiber pp composites showed better impact values compared to other. Long wood fiber and wood chips PP composites showed lower hygroscopic comparative to hard and soft wood fiber pp composites.

Thermoplastic- natural fiber composites containing polymeric interfacial blending agents. A natural fiber-thermoplastic composite comprises porous natural cellulose fibers, a thermoplastic material, a porosity aid, and an interfacial blending agent which is a polymeric substance. A process of preparing such composite includes the steps of mixing the natural fibers and the thermoplastic material in a blender with a porosity aid and an interfacial blending agent to from a mixture; adding the mixture to a heated extruder, compressing the mixture with an extruder screw having a plurality of flight sections, at least one of the flight sections serving as a compression flight sections which compresses the mixture by having its flight spaced closer together than other adjacent flight sections, and at least one other vent flight sections which allows gaseous reaction products to be removed from the extruder through a vent in the extruder by having its flight spaded farther a part than the compression section, the vent flight section being positioned after the compression flight section extruding the mixture Through an extrusion die as a composite and shaping the composite in a vacuum calibration device to a desired profile. The process further includes the step of co-extruding a second thermoplastic on to the natural fiber-thermoplastic composite for some applications (e.g., windows, doors and siding).showed lower hygroscopic comparative to hard and soft wood fiber PP composites [11]

Yang et al. [12] studied sisal/PVC composites with respect to the effects of fiber and matrix modification, Processing parameters on the mechanical and water resistance properties. Their main objective is to obtain the best processing parameters and interface modification to make novel sisal/PVC Composites. To make good use of Sisal fiber and PVC, it is important to improve the interface. So that better mechanical properties of the composite can be obtained. But unfortunately, their results show that thermal treatment, acetylating and coupling agent improve neither the interface nor the mechanical properties. On the contrary, the untreated sisal-fiber-reinforced PVC composite posses better mechanical properties. These results have been explained by the small fiber-volume fraction (18.5%) of their composite and the melting processes method that leads to the poor immersion of fiber in the PVC matrix. Also, both treated and untreated sisal/PVC composites have quite good moisture resistance.

Manikandan et al. [13] studied the tensile properties of short sisal-fiber-reinforced polystyrene composites. Untreated and benzoylated Sisal fibers were used to produce the Composite and the influences of fiber length, fiber content, fiber orientation and fiber benzoylation were investigated Variation in fiber length produces no considerable change in the modulus of the composites but gives maximum tensile strength (25M Pa) at a fiber length of about 10mm.

Bledzki et al. [14] worked out research on wood PP composites of different composition have been prepared using malice anhydride-polypropylene(MAH-PP) co-polymer of different percentage. Tensile, flexural, fracture toughness and impact test of the prepared were carried out. From the result it is observed that the hard wood fiber PP composites by using mileated PP shows comparatively better performance to soft wood fiber PP composites.

Kabir et al. [15] worked on PP-Bagasse composites. They found that the density decreases with the increases of fiber addition. The tensile strength of composite product decreases with the increases of fiber addition They found that the fiber burns out above 180^0c,so polymerization process could not proceed.

Jang et al. [16] studied the mechanical properties of several hybrid composites containing both continuous fibers and whiskers .Adding a small amount of inclusion in the epoxy resin can result in an improvement in the energy absorbing ability of a fiber composite. A uniform dispersion of the particulate whisker phase is essential to the achievement of balanced mechanical properties. Razzak and Bhuiyan reported the structural [17] and electrical [18] properties of PP Bijoypur white clay (BWC) composites. Due to inclusion of BWC the PP structure was modified.

Mayama et al. [19] worked on the composite sheets are prepared by laying mixtures of reinforcing fibers with a three dimensional structure, hydrophilic polymer (A) particles with average diameter 5 – 2000 µm and moisture-absorbing particles (B) with ratio of average diameter of B particles to average diameter of A particles 1-3.3-1 in a mold on a planer surface and heating the mixture at or above the m.p. of A to give porous composite with the core containing A and B and have the surface partially or wholly containing A and B. The sheets are useful as shoe insole and dew inhibitor. Thus 100 hundred parts Sunfine SH (HDPE) and 0.3 part polyglycerol isostearate were mixed to give a hydrophilic polymer which was mixed with three parts PCS and fed to a mold containing a fiber structure composing polyester fibers and polyamide mono filaments. The mold was heated at 140-150^0C to give a composite sheets showing moisture absorption 0.01 g/g H_2O absorption 0.86 g/g porosity 46.7% dimensional change after water absorption 0.16% tensile strength 35 Kg/cm^2 and impact strength 13 Kg-cm/cm^2.

Rowel et al. [20] results suggest that agro-based fibers are a viable alternative to inorganic mineral-based reinforcing fibers in commodity fiber thermoplastic composite materials as long as the right processing conditions are used and for application. These renewable fibers have low densities and high specific properties and their non-abrasive nature Permits a high volume of filling in the composite. Kenaf fibers, for example, have excellent specific properties and have potential to be outstanding reinforcing fillers in plastics. Several types of natural fibers, e.g., Kenaf, Corncob, Oat hulls, rice hulls, Peanut hulls and soybean hull residue, were blended with Fortilene 1602 PP and then injection molded, with the fiber wt. fractions varying to 60% A compatibilizer or a coupling agent, e.g., Epolene G 3002 a maleic anhydride-grafted Polypropylene, was used to improve the non-polar matrix and the polar lignocellulosic fibers. The specific tensile and flexural moduli of a 50%, by wt. (39% by vol) of Kenaf-PP composites compare favorably with a 40% by wt. of glass fiber (19% by vol.)-PP injection molded composites. Further more, Preliminary results suggest that natural fiber-PP composites can be reground and recycled.

Monteiro et al. [21] studied on the structural characteristics and mechanical properties of coir fiber and polyester composites. Random oriented coir fiber-polyester composites were low-strength materials, but could be designed to have a set of flexural strength building elements. The lack of an efficient reinforcement by coir fibers the composite was attributed to their low modulus of elasticity in comparison with that of the bare polyester resin. With the fabrication route used, two different products were obtained, namely: rigid composites, for fiber loading less than 50% wt, and agglomerates, when the fiber loading was higher than 50% wt.

1.3 Objective of the Present Study

As mentioned in the introduction, composites with natural fiber reinforcement play important role in the development of science and technology. From the review of literature it is seen that lot of efforts have been put on the study of natural fiber reinforced composites for their modified mechanical, electrical, thermal, etc. properties. The use of sawdust and their effects on the composite properties are not well studied. The use of sawdust, derived from the renewable source, as reinforcing fibers in thermoplastics composites may provide positive benefits with respect to ultimate disposability and raw material utilization.

This work was aimed at preparing and characterizing sawdust reinforced PVC composites. The composite of different compositions of sawdust and PVC were prepared by hot press molding method. Density and water absorption of the different composites were measured. The tensile and flexural strengths of the sawdust reinforced composite were also investigated. Investigation of mechanical properties allowed to the understanding the effect of sawdust on this property.

DTA and TG were employed for the thermal analyses of the composites. DC electrical measurements were performed at different applied voltages and different temperatures on PVC-sawdust composites of different compositions to understand the effect of sawdust on the electrical properties. These studies indicate the relation between structure and property, which help finding applications of these composites in science and technology.

1.4 Summery of the Thesis

To make this research work reader friendly this dissertation has been configured into six chapters.

In the first chapter, a general introduction is presented where an idea about the natural fiber, composite, fabricated composite are summarized. Some earlier and recent works of a number of literatures are reviewed to understand the scientific importance of those studies needs for the present investigation and the objectives of the study.

In chapter two, the details about polymer, classification about fibers are described. Classifications of composite materials are briefly described. Deformation, stress, strain and thermal analysis are focused at the end of this chapter.

The experimental procedures are briefly explained in chapter three along with description of the sample preparation, raw materials .The instrument, measurement principles are discussed briefly. Testing method is explained lastly in this chapter.

In chapter four, results and discussion are thoroughly explained. Bulk density, thermal analysis and mechanical properties (tensile and flexural) are discussed and current voltage characteristics are discussed at the end of this chapter.

Finally the conclusions of the work done and suggestions for future research on these composites are included in chapter five.

CHAPTER-2
LITERATURE SURVEY

2.1 Polymer
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- 2.1.2 Natural and synthetic of polymer
- 2.1.3 Organic and Inorganic polymer
- 2.1.4 Brief description of some polymer

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- 2.4.11 Stress Strain Relationship Hooke's law
- 2.4.12 Elastic modulus

2.1 Polymer

A molecule has a group of atoms, which have strong bonds among themselves but relatively weak bonds to adjacent molecules. Examples of small molecules are water(H_20),Methanol(CH_30H),carbon dioxide and so on polymers contain thousands to million of atoms in a molecule which is large, they are also called macromolecules, polymers are prepared by joining a large number of small molecules called monomers. Polymers can be thought of as big buildings and monomers as the bricks that go into them. Monomers are generally simple organic molecules containing a double bond or a minimum of two active functional groups. Polymers are structurally much more complex man metals or ceramics. They are cheap and easily possible. On the other hand, polymers have lower strength and modulus and lower temperature use limits prolonged exposure to ultraviolet light and some solvent can cause the degradation of polymer properties.

Because of predominantly covalent bonding, polymers are generally poor conductor of heat and electricity. Polymers however are generally more resistant to chemical man other metals.

2.1.1. General classification of polymers

Polymers are classified on many points of view. According to-

1) Source
2) Nature of the backbone chain of polymers.
3) Characteristic towards that.
4) Ultimate nature.
5) Chemical structare
6) Method of synthesis
7) Composition
8) Polarity

Polymers are mainly two types such as-

1) Thermoplastic Polymer
2) Thermosetting Polymer.

Thermoplastic Polymer-These polymers soften on heating and can be converted into any shape that they can retain on cooling. The process of heating, reshaping and retaining the same on cooling can be repeated several times such polymers, that soften on heating and stiffen on cooling are termed thermoplastics polymers example polyethylene, P.V.C, Nylon etc.

Thermoplastics have one or two dimensional molecular structure and they tend to soften at an elevated temperature and show exaggerated melting point. Another advantage is that the process of sifting at elevated temperature can be reversed to regain its properties during cooling, facilitating application of mould the compounds.

This type of polymer consists of linear molecular chains which are not cross- linked. Instead, the attractive forces between the chains are the weaker secondary bonding forces, I, e, Vander wall's forces. Thus they are not as rigid as the thermo sets, and exhibit upon heating.

The advantages of thermoplastic systems over thermo sets are that there are no chemical reaction involved which often result in the time required for heating, shaping and cooling the structure.

Thermoplastic resins are sold as molding compounds. Fiber reinforcement adapt for these resins. Since the fiber are randomly dispersed, the reinforcement will generally be almost isotropic. However, when subjected to molding processes, they can be aligned directionally.

Briefly some important characteristics of thermoplastics are given below-

*Short melting time

*Processing is easy

* Recyclable

* High fracture toughness

* Poor chemical resistance

* High shrinkage.

As our composite plate is made by using PVC resin as matrix therefore we have only discussed about PVC resin below ....

PVC is one of the least stable of commercially available polymers. The polymer first well known during World War I I as a substitute for natural rubber for wire insulation and for water proof sheeting. After the war it retained some of these applications uses in the areas of flexible sheeting, hose piping and small moldings. In many instances poor formulation gave the material a bad reputation which took some years to eradicate. Over the years many of the additives came under scrutiny concerning their toxicity but the discovery that the monomer had a number of undesirable toxic characteristics caused considerable alarm and revision of manufacturing procedures in the 1970s. More recently there have been worries concerning the use of plasticizers in applications requiring contact with food. In addition there has been concern about the nature of the decomposition products of fire and of compositing. Finally, as a long established material it was considered to be down market or indeed obsolescent Not surprisingly, it has been subject to increasing substitution by newer polymers. In the massive form poly vinyl chloride is a colorless rigid material with limited heat stability and with a tendency to adhere to metallic surface when heated. For these, and other, reasons it is necessary to compound the polymer with other ingredients to make useful plastics materials. By such means it is possible to produce a wide range of products, including rigid piping and soft elastic cellular materials.

Polyvinyl chloride has a good resistance to hydrocarbons but some plasticizers particularly the less polar ones such as dilutees separate, are extracted by materials such as iso- octane. The polymer is also resistant to most aqueous order transition temperature. Polyvinyl Chloride compounds are reasonably good electrical insulator over a wide range of frequencies but above the second order transition temperature their value as an insulator is limited to low frequency applications.

Thermosetting polymer- These polymers undergo some chemical change on heating and convert themselves into an in fusible mass. They are like the yolk of the egg, which on heating sets into a mass and once set, can not be reshaped such polymer, that become and infusible and is soluble mass on heat are called thermosetting polymers. Ex-phenols, polyester, epoxies resin.

This group of polymers is characterized by three- dimensional networks. Such non-linearity occurs when these are more then two reactive sites per monomer and cross-linking takes place between linear chains. Indeed, this type of polymer is initially cured or hardened by the application of heat, hence the term thermo set.

Thermo sets are the most popular of the fiber composite matrices. Aerospace components, auto mobile parts, defense systems etc use a great deal of this type of fiber composites. Again, in terms of molecular structure different configuration of polymers is as follows-

Linear polymer-This type of polymer consists of a long chain of atom with attached side groups. Ex-polyethylene, polyvinyl chloride.

Branched polymer-Polymer branching can occur with linear, cross-linked or another type of polymer.

Cross-linked polymer-In these case molecules of on chain are burned with those of matter, cross linking of molecular chain result in three dimensional networks. Cross linking make sliding of molecules past one another difficult. Thus making the polymers strong and rigid.

Ladder polymer-If we have two linear polymers linked in a regular manner, we get a ladder polymer not unexpectedly. Ladder polymer are more rigid that linear polymers.

2.1.2. Natural and Synthetic polymer-Depending on their origin, polymers can be grouped as natural or synthetic. Those isolated from natural materials are called natural polymers. Typical, Tropical examples are cotton, silk, wool and rubber, cellulose rayon and so on are infect chemical modification of natural polymer.

Polymers synthesis sized from low molecular weight compound are called synthetic polymer. Ex-polyethylene, PVC, Nylon.

2.1.3. Organic and Inorganic polymer-A polymer whose backbone chain is essentially made of carbon atom is termed an organic polymer. The atoms attached to the side valences of the backbone carbon atom are however, usually those of hydrogen, oxygen, nitrogen etc. The majority of synthetic polymers are organic and they are very extensively studied.

2.1.4 Brief Description of some polymers [22]

Polyethylene-

Monomer –Ethylene ($H_2C=CH_2$)

Polymerization- LDPE- Free radical Initiated chain polymerization

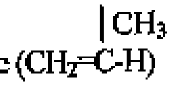
HDPE: Ziegler-Natta or metal oxide catalyzed chain polymerization.

Major uses (LDPE)-Film and sheet (95%) house wares and toys(16%),wire and cable coating(5%)

(HDPE)-Bottles (40%), house wares containers, toys (35%), fittings 10%, film and sheet (5%).

Polypropylene

Monomer: Propylene



$(CH_2=\overset{CH_3}{C}-H)$

Polymerization-Ziegler-Natta catalyzed chain polymerization.

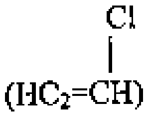
Monomer -Vinyl chloride (HC_2= C-H) Polymerization-Free radical initiated chain

Polymerization-Ziegler-Natta catalyzed chain polymerization.

Uses-fibre products (30%), house-wares (15%), automotive parts (15%)

Poly Vinyl Chloride

Monomer- Vinyl Chloride



$(HC_2=\overset{Cl}{C}H)$

Use-pipe and fittings (35%), film and sheet (15%) flooring materials (10%), wire and cable insulation (15%), auto motive parts (5%) and adhesive and coating

Poly (Vinylidene Chloride)

Monomer - Vinylidene Chloride ($CH_2=CCl_2$)

Polymerization-Free radical initiated chain polymerization.

Use-Film and sheeting for food

packing. Poly styrene

Monomer-styrene ($C_6H_5CH=CH_2$)

Polymerization-Free radical initiated chain polymerization.

Use- Packing and containers (35%), house wears, toys and

recreational equipment (25%), appliance parts (10%) disposable

food containers (10%)

2.2. Fibers

Fibers may be found in almost any part of the plant – stems, leaves, roots, fruits, and even seeds. Physical properties of fiber, such as, breaking strength, extensibility, flexibility and moisture absorption etc. all depend on a number of factors of which the length or size of the fiber molecules, the mode of alignment amongst them and the nature and intensity of inter chain cohesive forces are important. In pure celluloses fiber the lateral cohesive forces including hydrogen bonds have maximum intensity in the crystalline regions, where the chain molecules are arranged in a more organized manner. The crystalline portions contribute in the strength and rigidity of fibers, while amorphous portions, which allow the better freedom of movement of the chain molecule account for extensibility, flexibility and moisture affinity

Like tensile strength, the other properties of fibers, such as extensibility and flexibility are also influenced to a great extent by the cross-linkages in the amorphous regions usually, the low inter chain cohesion in the amorphous regions permits a better freedom of movement to the chain molecules as a result of which these regions in part the above useful qualities to the fiber.

2.2.1. Structure and occurrence of fibers

Although put to so many different uses, and perhaps differing in texture, strength, chemical composition, and place of origin, with few exceptions fibers are alike in that they are sclerenchyma cells and serves as the part of the plant leaves. For the most they are long cell with thick walls, correspondingly small cavities, and usually pointed ends. The walls often contain lignin as well as cellulose. Fibers may occur singly or in small groups, but more likely to form sheets of tissue with the individual cells overlapping and inter locking.

Among the more important may be mentioned the *Palmaceae, Musaceae, Liliaceae, Amaryllidaceae, Urticaceae, Malvaceae, Linaceae, Bombacaceae, Leguminosae, Moraceae, Tiliaceae,* and *Bromeliaceae.*

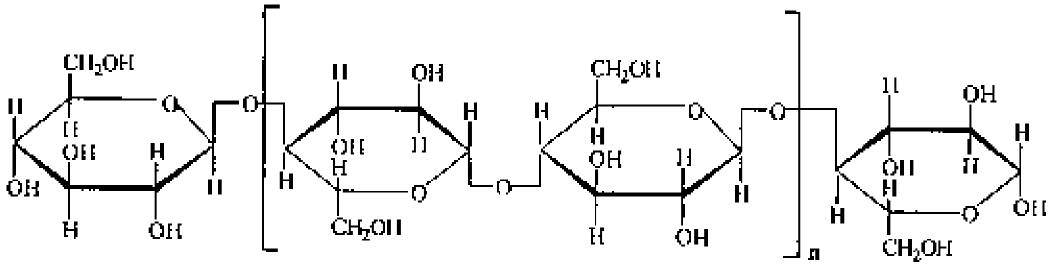
Main organic components of the natural fibers are Cellulose, Hemicellose, Lignin, and related products. Now we describe about them:

Cellulose

Cellulose pertains to the class of carbohydrates. It contains 44.4 percent of carbon, 6.2 percent of hydrogen and 49.4 percent of oxygen·

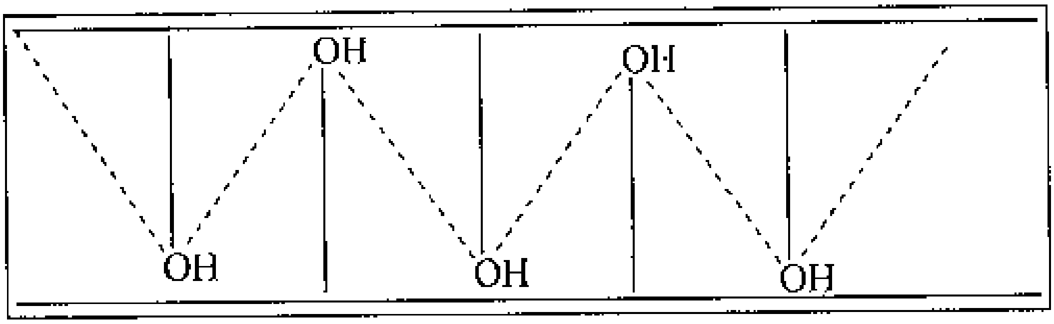
Cellulose is the principal constituent of all plant life. It is a linear polymer of anhydroglucose units linked in 1 and 4 position by a β-glycoside links. The empirical formula of cellulose $(C_6H_{10}O_5)$ n corresponds to a polyanhydride of glucose. The two terminal glucose residues of a cellulose molecule contain two different end groups; one contains a reducing hemiacetal group in the position C_1, and is therefore, known as the reducing end group, where as the other contains an extra secondary hydroxyl group in the position C_4 and is known as the non-reducing end group. The structure of cellulose is written as follows:

The structure of cellulose :



Cellobiose residue = repeating unit of cellulose

There are one primary and two secondary alcoholic hydroxyl groups in each basic anhydrous-D-glucose unit $(C_6H_{10}O_5)$ n, which are arranged in positions 2, 3 and 6 respectively, on the basic unit. The reactivity of the hydroxyl groups varies in different reactions. In many reactions (mainly esterification) the primary hydroxyl groups have a greater reactivity. The two secondary hydroxyls, at the second and third carbon atoms, differ somewhat in their reactivity. The primary hydroxyls of cellulose elementary units are responsible for the storability and dye ability of cellulose materials. Cellulose is highly stereo specific. The high hydroxyl content of cellulose might suggest high water solubility. This is because of stiffness of the chains and hydrogen bonding between



Hydroxyl groups of adjacent chain as shown in the following figure. Hydrogen bonding in adjacent chains: Besides hydrogen bonding, another type of linkages called "Semiacetal linkages" is present between the adjacent chain molecules of cellulose.
From X-ray diffraction diagram, it has been concluded that cellulose has two regions: crystalline and amorphous. In the amorphous region the polymer chains end to be folded, and consequently, they will have rather different properties the crystalline region. It is in disordered regions that the most of the chemical reactions take place with cellulose. Again, polymeric fibers are never completely crystalline. This interconnection of crystalline and amorphous regions enhances the strength of the polymer.
As early as 1920, Herzog and Janeke [23] recognized that cellulose from such widely different sources as cotton, ramie, wood, jute and flax gave identical X-ray diagram and concluded that these fibers had identical crystalline structures.

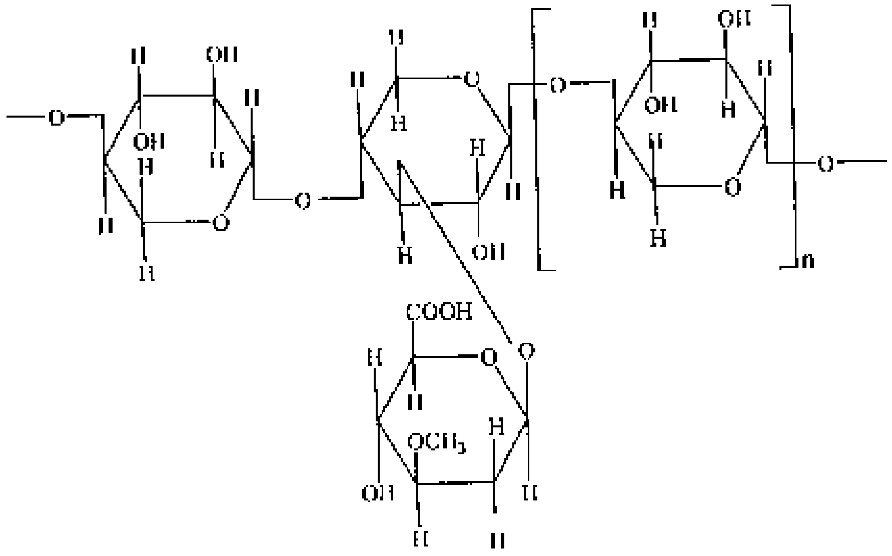
Hemi cellulose

Hemi cellulose is a group of cell wall polysaccharides. The isolated hemi cellulose is amorphous substance. The cellulose and lignin of plant cell walls closely interpenetrated by a mixture of polysaccharides called hemi cellulose. It is soluble in dilute alkali and they are readily hydrolyzed to pentose and hexose's with some uronic acids.

Sarker and others [22] showed xylose linked with methyluronic acid formed the basic building units of hemi cellulose in jute. It appeared that six xylose units were linked with 1-methyl glucuronic acid units.

The hemi cellulose is relatively short chain compounds and, therefore, occupies longitu- dinally the same space as the anhydroglucose unit in cellulose chain. The short chain polysaccharides would, therefore, pack rigidly into the oriented cellulose structure between which some cross bridging or looping may also occur.

The structure of hemicellulose :



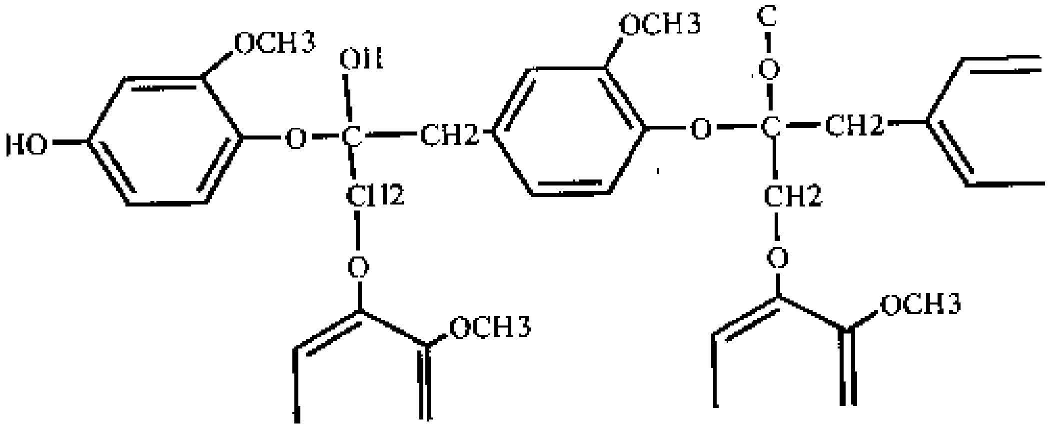
Lignin

Most plant tissues contain, in addition to carbohydrate and extractives, an amorphous polymeric gummy material is called lignin. The nature of lignin and its relationship to cellulose and other constituents of fiber are still uncertain. Unlike cellulose and hemi cellulose, lignin gives a series of color reactions that indicate the presence of compounds for which these reactions are typical. Isolated lignin is generally an amorphous material having average high molecular weight.

Lignin is an insoluble, resin like substance of phenolic character. It is built up to a large extent, of phenyl propane building stones, often having a hydroxyl group in the Para position and methoxyl group/groups in Meta position/positions to the side chain.

Besides, there may be carbon to carbon or carbon to oxygen bonds joining the aromatic ring to the portions of structure. The lignin molecule, thus being polyfunctional due to the presence of alcoholic and phenolic hydroxyl groups, may exist in combination with two or more neighboring chain molecules, cellulose or hemicellulose, serving the function of a cross-linking agent. Postulated monomer in lignin as shown below.

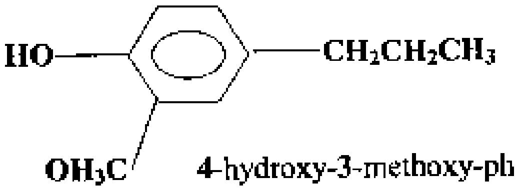
Over all structure of lignin:



Association of cellulose,hemicelluloses and lignin

There is no conclusive proof with regard to the chemical union of hemi cellulose with cellulose in the fiber. The opinion is that hemi cellulose, except xylem, can't inter into cellulose crystallites due to spacing difficulty. The cellulosans, mainly xylem, associated with the true cellulose in the cellulosic structure, are relatively short chain compounds, and occupy longitudinally the same space as the glucose units in the cellulosic chains. Xylem and cellulose are laid as a mixed crystallite structure probably with incrusting cement consisting of lignin and hemi cellulose.

Structural unit of lignin:



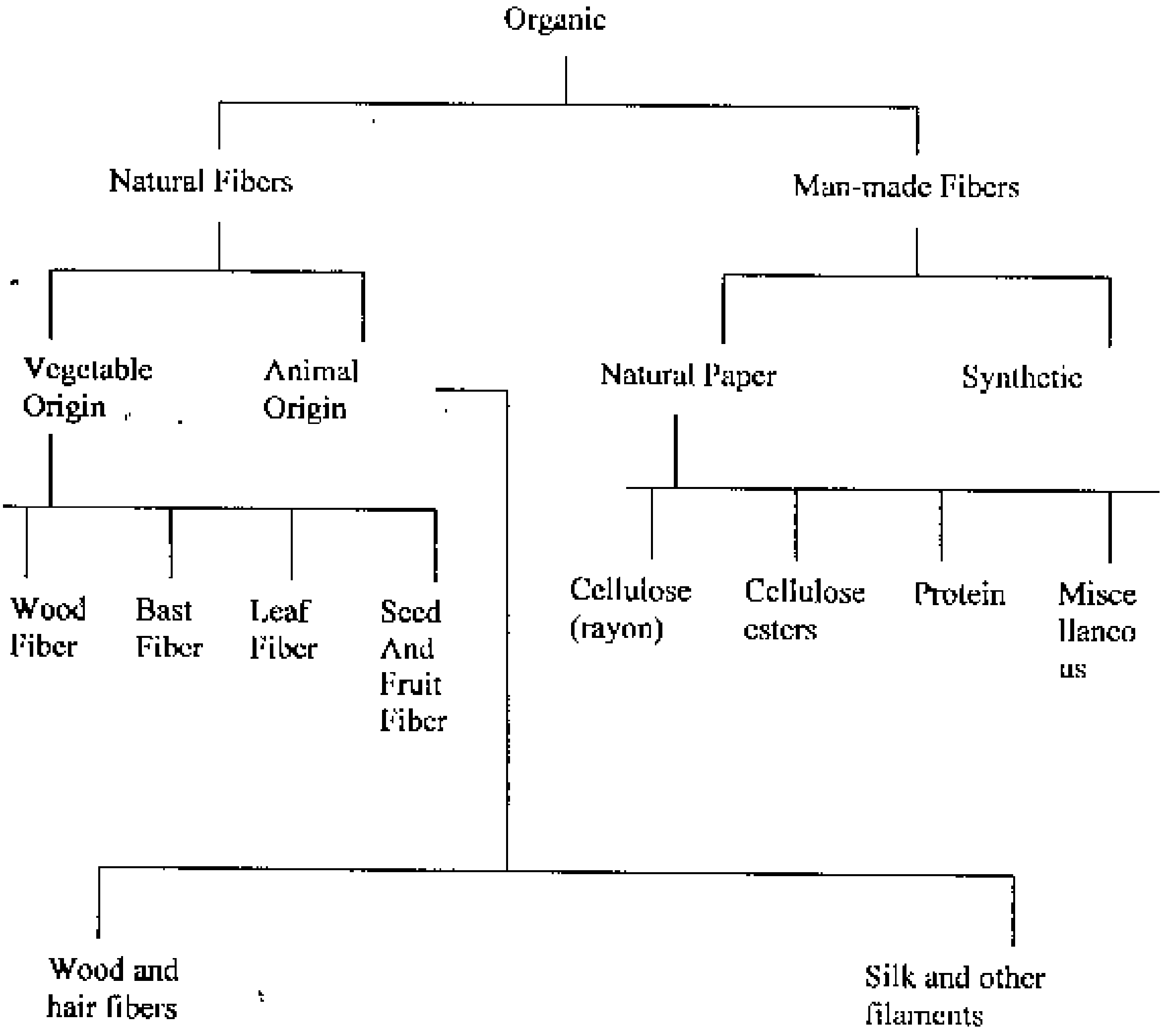
4-hydroxy-3-methoxy-phenyl propane

Regarding the possibility of cellulose-lignin combination, the view is that the lignin can't enter the cellulose crystallite due to the same spacing difficulties, but a small amount of lignin is intimately associated at the cell wall boundaries of cellulose. Chemical union exists between lignin and hemi cellulose and it is the ester type linkage between the alcoholic hydroxyl group of lignin and the carboxyl group of polyuronic acid of hemi cellulose, and the ether type linkage between phenolic hydroxyl group of lignin and hydroxyl group of hemi cellulose.

2.2.2. Economic classification of fibers

Organic fibers are divided into two main groups, natural fibers are man-made fibers.

Fibers & classification chart [24] is given below.



Vegetable fibers are particularly interesting for reinforcement of concrete. The vegetable world is full of examples where cells on groups of cell are designed for strength and stiffness. A sparing use of resources has resulted in optimization of the cell function. Cellulose is a natural polymer with high strength and stiffness per weight, and it is the building material of long fiber cells. These cells can be found in the stem, the leaves, or the seeds of plants. Here, under a few successful result of evolution are described.

(a) Bast fibers (flax, hemp, jute, kenaf, ramie (china glass))

In general the bast consists of a wood core surrounded by a stem. With in the stem there are a number of fiber bundles, each containing individual fiber cells or filaments. The filaments are made of cellulose and hemi-cellulose, bonded together by a matrix, which can be lignin or pectin. The pectin surrounds the bundle, thus holding them on to the stem. The pectin is removed during the reefing process. This enable separation of the bundle from the rest of the stem.

After fiber bundles are impregnated with a resin during the processing of a composite, the weakest part in the material is the lignin between the individual cells. Especially in the case of flex, a much stronger composite is obtained if the bundle are pre-treated in a way that the cells are separated, by removing the lignin between the cells.

Flex delivers strong and stiff fibers and it can be grown intemperate climates. The fibers

Can be spun to fine yarn for textile other baste fiber are grown in warmer climates. The

Most common is jute, which is cheap and has a reasonable strength and resistance to rot.

Jute is mainly used for packing. (Sacks and balsa) As far as composite applications are

Concerned, flax and hemp are two fibers that have replaced glass in a number of

Components, especially in the German automotive industries.

(b)Leaf fibers (sisal, abaca, banana, pulque, palm)

In general the leaf fibers are coarse than the bast fibers. Applications are ropes and coarse textiles; with in the total production of leaf fibers, sisal is the most important. It is obtained from the agaves plant. The stiffness is relatively high and it is often applied as binder twines.

As far as composites are concerned, sisal is often applied with flax in hybrid mats to provide good permeability when the mat has to be impregnated with a resin. In some interior application sisal is preferred because its low level of small compared to fiber like flax. Especially manufacturing process at increased temperatures fibers like flax can cause smell.

©Seed fibers (cotton, choir, kapok)

Cotton is the most common seed fiber and is used for textile all over the world. Other seed fibers are applied in less demanding application such as stuffing of upholstery. Coir is an exception to this. Coir is the fiber of the coconut husk; it is a trick and coarse but durable fiber. Applications are ropes, marring, mat making and brushing.

With the rise of composite materials they're in a renewed interest for natural fiber. These moderate mechanical properties restrain the fibers from using them in high tech applications, but for many reasons they can complete with glass fibers. Advantages and disadvantages determine the choice.

It is possible to classify fibers in six groups based on their utilization, as follows:

(d)Textile Fibers

The most important use of fibers at the present time is in connection with the textile industry, which is concerned with the manufacture of fabrics, netting, and cordage. In making fabrics and netting, flexible fibers are twisted together into thread or yarn and then woven, spun, knitted, or otherwise utilized. Fabrics inclnde cloth for wearing apparel, domestic use, awnings, sails, etc., and also coarser materials such as gunny and burlap. The fabric fibers are all of commercial importance. Netting fibers, which are used for lace, hammocks, and forms of net, include many of the commercial fabric fibers and a host of native fibers as well. Both commercial and native fibers used for cordage. For this purpose the individual fibers are twisted together rather than woven. Twine, binder twine, fish lines, rope, hawsers, and cables are among the many kind of cordage.

(e) Brush Fibers

These are tough and stiff fibers, or even twigs and small stems, which are utilized in the manufacture of brushes and brooms.

(f) Plaiting and Rough Weaving Fibers

Plaits are flat, pliable, fibrous strands which are interlaced to make straw hats, sandals, basket, chair seats and the like. More elastic strands are roughly woven together of meetings and thatched roofs of houses, while supple twigs or woody fibers are used for basket, chairs, and other forms of wickerwork.

(g)Filling Fibers

These fibers are used in upholstery and for stuffing mattresses, cushions, etc.; for cuking the seams vessels and in casks and barrels and stiffening in plaster; and as packing materials.

(h) Natural Fibers

These are usually tree bastes which are extracted from the bark in layers or sheets and pounded in to rough substitutes for cloth or lace.

(i)Paper Making Fibers

Paper making fibers include wood fibers, textile fiber utilized in either the raw or manufactured state, or many other kinds. It is obvious that any one plant cannot be restricted absolutely to any single group in this economic classification, since the same fiber may be used for different purposes and since the plant may yield more than one kind of fiber.

(j) Textile fibers andtheir classification

Textile fibers are those fibers, which have sufficient length, strength and cohesiveness to permit them to be made into a continuous length suitable for fabric construction.

Textile fibers are classified according to the source and chemical combination as follows:

A. Natural fibers

1. Animal
    - (a) Hair fibers-sheep's wool, mohair, camel's hair, alpaca, vicuna, Llama.
    - (b) Cocoon fibers-silk.
2. Vegetable
    - (a) Seed hairs-cotton, kapok, and milkweed.
    - (b) Bast fibers-flax, hemp, jute, cotton tree fiber, ramie.
    - (c) Leaf fibers -abaca (*Manila hemp*), pineapple fiber.
3. Mineral
    - (a) Asbestos.

B. Synthetic fibers:

1. Regenerated cellulose-Rayon.
    - (a) Viscuse.
    - (b) Cuprammonium.
    - (c) Fortisan.
        - (i) Regular.
        - (ii) Fortisan-36.
2. Cellulose esters
    - (a) Acetate.
    - (b) Arnel.
3. Protein fibers
    - (a) Animal-Casein.
    - (b) Vegetable, corn-vicara.
4. Glass
5. Metals-gold, silver, aluminum.

6. Nylon.
    (a) Type-66
    (b) Type-6
7. Polyester fibre.
    (a) Dacron.
8. Acrylic fibres
    (a) Orlon.
    (b) Acrilan.
    (c) Dynel.
9. Vinyl derivatives
10. Vinyon H.H.

2.2.3 **Sawdust**

The chief raw materials used for the sample preparation are PVC and Saw Dust fiber. PVC is collected from local market. Sawdust fiber is used as reinforcement agent, obtained from Sawmill. Saw dust fiber is a complex mixture of chemical compounds, which are built up by natural process during the growth of the plant stem. The composition of Saw Dust fiber is not uniform. The condition of soil, climate, maturity of the plants, retting etc. Make considerable variation in the constituents of the fiber. Sawdust is kept 24 hours for drying. Dried sawdust is separated by sieve analyzer.

2.2.4 Advantages of natural fibers

1) Low specific weight, which result in a higher specific strength and stiffness than glass. This is a benefit especially in parts designed for bending stiffness.

2) It is a renewable resource, the production requires little energy, CO_2 is used while oxygen is given back to the environment.

3) Predicable with low investment at low cost, which makes the material an interesting produced for low wage countries.

4) Eric ally processing no wear of fooling no skin irritation.

5) Thermal recycling is possible, where glass causes problem in combustion furnaces.

6) Good thermal and acoustic insulating properties.

Disadvantages of natural fibers

1) Lower strength properties, particularly its impact strength.

3) Variable quality, depending on unpredictable influences such as weather.

4) Moisture absorption, which cases swelling of the fibers.

5) Restricted maximum processing temperature.

6) Low durability, fiber treatment can improve this considerably.

7) Poor fire resistance.

2.2.5. Principles of fiber reinforcement

The mechanical properties of a composite can depend on many factors as alluded to in the introduction. Basically, these factors include the specific properties of the matrix and the reinforcing agents, their respective volume fraction, the shape, size distribution and orientation of the reinforcing phase and the bond between the reinforcement and it matrix. Let us examine in more detail the relationships between these factors and their influence on the mechanical behavior of composite materials.

2.3 Composite Materials

Composite materials have been classified in many ways depending on the ideas and concepts that need to be identified. A useful and all embracing classification in set out with some examples. Most naturally occurring materials derive their superb properties from a combination of two or more components, which can be distinguished readily. When examined in the body, which have high strength combined with enormous, flexibilities, are made of stiff fibers such as collagen embedded in a lower stiffness matrix.

A microscopic examination of wood and bamboo reveals a pronounced fibril structure, which is very apparent in bamboo when it is fractured. It is not surprising that bamboo has been called natural fiberglass.

Practically, everything is a composite material in this world. Thus a common piece of metal is a composite of many grains (or single crystals). Such a definition would make thing quite unwieldy. Therefore, it must be agreed on an operational definition of composite materials for our purposes in this text. We shall call a material that satisfies the following conditions a composite material.

1) It is manufactured (naturally occurring composite, such as wood are excluded).
2) It consists of two or more physically and/or chemically distinct, suitably arranged or distributed phases with an interface separating them.
3) It has characteristics that are not depicted by any of the components in isolation.

The composite idea can be related also to the macro seal. This is particularly relevant to engineering components, which may consist of two or more materials combined to give a performance in service, which is superior to the properties of the individual materials.

Similarly, Concrete beams, which have excellent compressive strength, are given some strength in tension by reinforcing the concrete with steel bars. Helicopter blades combine structural material for strength and stiffness with erosion resistant materials to protect the leading edges from damage.

Overall, the properties exhibited by a composite material are strongly influenced by the properties of the individual constituents, their respective amounts, shape, orientation and distribution, plus any synergistic interaction bet" these constituents when they are combined in composite formation.

It can be made by mixing the separate materials in such a way that the dispersion of one matrix in the other can be done in a controlled way to achieve optimum properties. The properties are superior and possibly unique in some specific respects, to the properties of the individual components.

Fibrous polymeric compounds are non homogeneous compound materials, their base is a polymeric matrix reinforced by fiber or particles. For the sound selection of the experimentally determinable characteristics and mathematical apparatus for processing the best results, it must be determined to which of isotropic and an isotropic materials classes does the material belong. Depending on the she relationship of reinforced elements and their arrangement in the polymeric matrix two large groups of reinforced materials can be identified randomly reinforced (matrix and particles) and regularly reinforced or oriented (matrix continuous fibers) materials. The first group of materials incorporates reinforcement consisting of particles the sizes of which are commensurate in all direction or of discrete fibers, for example, short fiber length, whiskers etc. The matrix plays a minor role in the tensile load carrying capacity of a composite structure. However, selection of a matrix has a major influence on the internal shear as well as in plane shear properties of the composite material. The interaction between fibers and matrix is also important in designing damage tolerant structures.

Finally, the process ability and defects in a composite material depend strongly on the physical and chemical characterization such as viscosity, melting point and curing temperatures of the matrix.

The primary consideration in the selection of a matrix on is its basic mechanical properties. For high performance composites the most desirable mechanical properties of a matrix are-

1) High tensile modules, which influences the compressive strength of the composite.

2) High fracture toughness, which controls ply delaminating and crack growth. For polymeric matrix composite, there may be other considerations such as good dimensional stability at elevated temperatures and insistence to absorb moisture and solvents. The former usually means that the polymer must have high glass transition temperature. In practice, the glass transition temperature should be higher than the maximum use temperature. Resistance to absorb moisture and solvent means that the polymer should not dissolve, swell, crack, or other wise degrade in hot /wet environments or when exposed to solvents.

Traditionally, thermo set polymers (also called resin) have been used as a matrix mater for fiber reinforced composites. Starting materials used in the polymerization of thermo set polymers are usually low molecular weight liquid chemical with very low viscosity. Fibers are either pulled through or immersed in the chemicals before the polymerization reaction begins. Since the viscosity of the polymer at the time of fiber incorporation is very low, it is possible to achieve a good wet-out between the fibers and the matrix without the aid of high temperature or pressure. Among other advantages of using thermo set polymers are their thermal stability and chemical resistance. They also exhibit much less creep and stress relaxation then thermo plastic polymers. The disadvantages are their limited storage life (before the final shape is molded) at room temperature, long fabrication time in the mold and low strain to failure, which also contributes to their low impact strengths.

The composite material contains a matrix and fibers. Polymer used may be PVC, PP, PE,

2.3.1. Broad Classification of composite materials

1) Natural composite

Wood, bone, bambeo, sawdust, muscle Natural composite and other tissue materials.

2) Micro composite materials: Metallic alloys e. g. steels, tongued thermo plastic, e.g. impact polystyrene, ABS. Sheet molding components Reinforced thermoplastics.

3) Macro composites

(Engineering products)

Galvanized steel, Reinforced beams, Helicopter blades Skis. A more relevant classification concerned with micro compesite based on size, shape and distribution of the two/ more phases in the composite can be made. Classification of micro composite materials

1) Continuous fibers in matrix aligned, random

2) Short fibers in matrix- aligned, random.

3) Particulates (spheres plate, ellipsoids, irregular in matrix).

4) Dispersion strengthened as for three above, with particle size$<10^{-8}$ m.

5) Lamellar structures.

6) Skeletal or interpenetrating networks.

7) Multi component, fiber, particles etc. According to the composite committee of German society for Metallurgy the following groups comprise the composite materials.

4) **Fiber composite:** Refractory whisker or polycrystalline fiber are imbedded into a matrix for improvement of mechanical properties.

5) **Laminated composites:** Metallic foils and foil like structures respectively, as well as thin ribbons are imbedded into a matrix, or the composite is built up from layers of various materials or by layers made of laminates (i, e. foil, ribbons, sheet etc) and the matrix.

6) **Material with surface layers**- In contrast to the ideal materials these layers are very thin. They are applied by different methods and include points. The layer thickness ranges from a few mm to 100m. They serve for corrosion and oxidation protections and improvement of wear, and impact other physical properties to the material surface.

7) **Particle composite**: This group encompasses a wide range of materials. It includes for instance the embedding of nonmetallic inorganic particles for improvement of mechanical properties of matters (Dispersion hardened metals) and also materials which consists of non-metallic binder phase (hard metals)

2.3.2. Manufacturing routes for fiber Reinforced plastic products [27]

Different types of composite material based on plastic manufacturing process are-Bag molding process, Resin Sheet Molding Compound (SMC) Process, Compression molding, Resin transfer molding (RTM), and Vacuum Assisted resin Transfer Molding (VARTM) etc.

Some descriptions of manufacturing of PMC are given in the following table

manufacturing routes : Outline of fabrication and processing methods.

1) Hand lay-up : Chopped stand mats, woven moving and other fabrics made form. The fibers are plagued on the mould and impregnated with fusion by painting and rolling. Layers are built up until design thickness is achieved. Molding cures without heat or pressure.

2) Spray up : Chopped roving and resin sprayed simultaneously into prepares prepared mould and rolled before the Resin cures.

3) Vacuum bag, pressure bag, : Layers of fiber usually unidirectional sheets are pre impregnated with resin and partially cured to form a pre- peg. The pre-peg sheets are stacked or the mould surfaces in predetermine orientation, covered with a flexible bag, and consolidated using a vacuum or press bag in and autoclave at the required using temperature.

4) Filament wondering : Continuous roving or stands of fibers are feel over rollers and guides through a bath of resin and then word, using a program controlled machine, into a mandrel at predetermined angles. The resin in partially or completely cured before removing the component, usually a tube from the mandrel.

5) Centrifugal castings : Mixtures of fiber and resin are introduced into a Rotating mould and allowed to cure in a site.

6) Hot press molding : Heated matched dies or tools are loaded with raw Material (sheet molding compound SMC, dough Molding compound DMC, cloth or Unidirectional Pre-peg) pressed to the shape of the cavity and cured.

7) Injection molding Transfer molding	: Molten or plasticized polymer mixed with short fibers is infection, usually at high pressure, into the cavity of a split would and allowed to solidify or curing.
8) Pultrusion	: A continuous feed officers, in pre- selected orientations is impregnated with resin and poured Through a heated die to give the shape of the final Section (e.g. tubes or I-beam) partial or complete Cure occurs during passage through the die.
9) Cold Press Molding	: A low pressure and low temperature in which fibers are impregnated with resin and then pressed bet" matched dies. Heat is generated during the cure.
10) Resin injection	: Fibers in cloth form are placed in the tool, which is injection at low pressure into the cavity and flows through the to fibers to fill the mould space. :
11) Reinforced reaction in involving to compounds injection molding	:Which are mixed immediately before injection is used. Fibers are either placed in the closed mould before resin is injected or added as short fibers to one of the resin components to form .slurry before injection.

2. 3.3. Reinforced Plastics

Reinforced plastics, also called polymer composites, are now important clues of engineering materials. They are distinguished by attractive mechanical properties and corrosion resistance unique flexibility in design capabilities and ease of fabrication. The word "composite" means, "consisting of two or more distinct parts." Polymer composites consist of one or more discontinuous phases embedded in a continuous phage polymer matrix.

The discontinuous phase is usually harder and stronger than the continuous phase, and is called the reinforcement. The matrix can be classified as thermoplastic (capable of being separately hardened and softened by increase and decreases, respectively, in temperature) or thermo set (changing into a substantially infusible an insoluble material when cured by the application of heat, or through chemical means).

The properties of composites are strongly influenced by the properties of their constituents and the distribution and interactions among them. The constituents usually interact in a synergistic way, providing properties that are not accounted for by a simple volume fraction sum of the components. Along with the volume fraction and the distribution of discrete units in the discontinuous phase, the interfacial area plays an important role in determining the extent of interaction between the reinforcement and the matrix and in this way - the final properties, is dominated by the chemistry and theology of the matrix resin and by the type and physical form of the reinforcement.

The use of reinforcing agent makes it possible for any thermo set- or thermoplastics matrix property to be improved or changed to meet varying requirement. Most polymer composites developed thus far have been fabrication to improve mechanical properties such as strength, stiffness, or toughness. The strengthening efficient of the discontinuous phase play the most important role in these product and the strengthening mechanism depends strongly on the geometry of the reinforcements. Therefore, polymer composition can be classified according to reinforcement geometry.

2.4 Mechanical Properties of Composites

2.4.1 Deformation

When an engineering material (as composite) is subjected to forces, such as those typically imposed by service loads, its atoms may be displaced from their equilibrium positions. Any displacement from the position or separation results in an energy increase. This requires work, with is supplied by the forces creating the displacement. Thus it is clear that this premise holds whether the material is stretched, causing the atoms to separate, thus bringing attractive forces into play, or compressed, bringing the atoms closer together and causing repulsion.

2.4.2 Elastic deformation

The displacement of atoms from their equilibrium positions constitutes deformation. Such deformation is termed elastic if the atoms can resume their equilibrium positions when the imposed forces are released. Elastic deformation then is recoverable and indicates the relative resilience of a material. For example, a rubber band can be stretched quite far yet snap back to its original dimensions upon being released. A slightly different manner of stating this concept of elasticity is that it is the property of a material to return to its initial form and dimension after the deforming force is removed.

The process of elastic deformation is presented schematically in the figure. Here the atoms are repented as "hard" spheres on a lattice, when no forces are applied, the assume equilibrium separation (a). A relatively small tensile force tends to pull the atoms apart producing elastic deformation (σ_E).Their separation is now slightly larger than a_0. However, when the force is released, the atoms resume their equilibrium positions and no deformation or displacement remains. The material is restored to its initial condition.

2.4.3 Plastic deformation

If the engineering material undergoes deformation, which exceeds the elastic capability (elastic limit) to restore the atoms to their equilibrium positions, the deformation is permanent and termed plastic. Plastic deformation is non-recoverable and leaves the atoms permanently displaced from their original positions where the forces are released. Deformation of materials may be entirely elastic, or elastic plus plastic. The total deformation may then consist of the combined elastic and plastic portion.

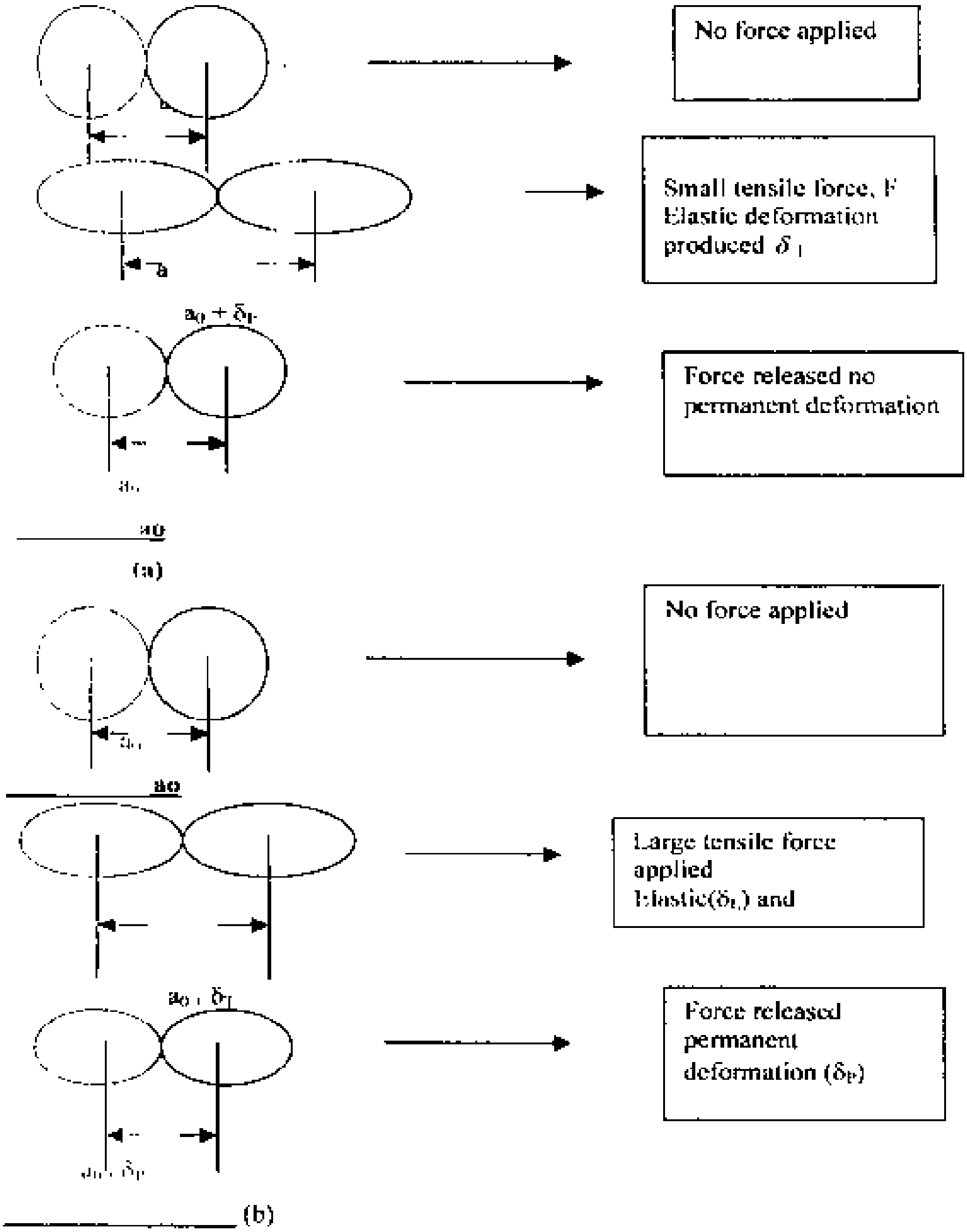


Figure 2.1 Schematic illustration of deformation in (a) elastic deformation (b) elastic plastic

Plastic deformation of engineering materials is permanent in that work or energy must be supplied to restore the atoms to their original equilibrium positions. For instance, the effect of this type of deformation can be alleviated by thermal treatments, when necessary.

2.4.4Engineering strain:

We have just briefly examined the response of atoms to deformation by mechanical forces. It this concept of atomic displacement is extended to bulk engineering materials, we can define the deformation in terms of the original dimensions of the material under consideration in other words, ratio of the dimensional change to the original dimension. For example, consider a bar of Length (l_0) as shown in the figure. Under the action of an applied load (p) this bar experiences deformation [28] and elongates to a new length (l_f). The ratio of this change in length to the original length (to) is the "average linear strain" (e) and can be expressed as follows:

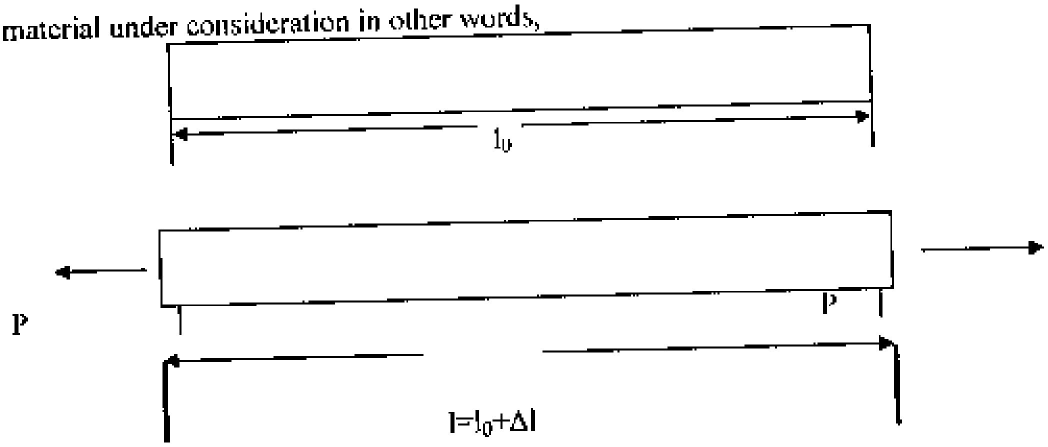


Figure 2.2 Deformation of a bar produced by axial load

$$e = \frac{\Delta l}{l_o} = \frac{l_f - l_o}{l_o}$$

This quantity is referred to as the average linear strain because only the dimensional change in the axial direction is considered and it is considered over the entire length of the sample. In reality, because its volume remitters constant, the bar diameter does decrees slightly, resulting in a decrease in the cross – sectional area, but for small strains this response in usually in significant. Average strain (e) is commonly referred to as the engineering strain and expressed in units of in/in or mm/mm. However, stem may also be treated as a dimensionless quantity because these units cancel.

2.4.5 True strain

Since a material undergoing deformation is continuously changing its dimension (i.e. length and width or diameter), a more precise definition of strain is given by the ratio of the change in dimension to the instantaneous dimension [29]. In the case of round bar, this may be viewed as the change in length (dl) with respect to the instantaneous length (l) at any point in the process. This ratio is actually the true strain (E) and is expressed as follows.

$$E = \frac{dl}{l}$$

A more specific expression for E is obtainer by placing some limits on the above equation. For example, if the initial length is to and the final length is t_f, we can integrate this equation as follows.

$$E = \int_{l_0}^{l_f} \frac{dl}{l}$$

$$= [\ln l]_{l_o}^{l_f}$$

$$= (\ln l_f) - (\ln l_o)$$

$$= \ln \frac{l_f}{l_o}$$

The engineering strain (e) is related to the true strain and this relationship can be demonstrated as follows.

$$e = \frac{l_f - l_o}{l_o}$$

$$\text{or, } e = \frac{l_f}{l_o} - 1$$

$$\text{or, } \frac{l_f}{l_o} - e = 1$$

Then substituting these results we obtain

$$E = \ln (e + 1)$$

2.4.6 Shear strain

In addition to linear strain, an engineering material can experience shear strain (γ), this type of strain is due to the displacement of parallel planes through a certain angle (Θ) as shown in the fig.4.5 The shear strain is therefore defined as the ratio of the displacement (x) to the distance (h) between the planes, expressed as follows: γ

$$= \frac{x}{h}$$

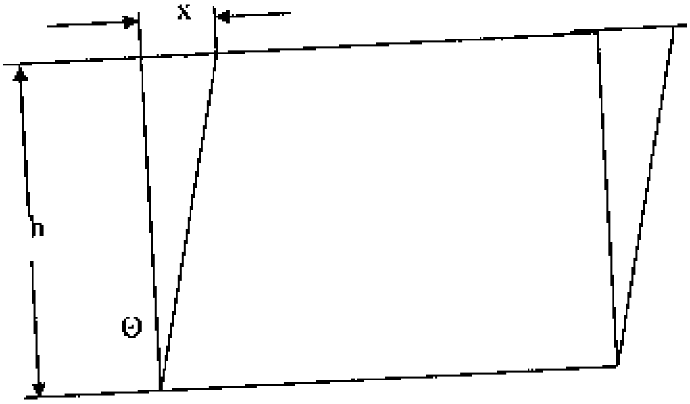


Fig 2.3 Shear displacement on parallel planes of a solid material

2.4.7. Stress

'Stress' is the result of the internal response that a material exhibits when forces are imposed on it. To simplify matters at this point, we will assume that the forces acts

2.4.7. Stress

'Stress' is the result of the internal response that a material exhibits when forces are imposed on it. To simplify matters at this point, we will assume that the forces acts uniformly over a certain area, Then we can state that the internal espouse, the stress, is a force per unit area.

Consider the load (P) applied to the cylindrical bar in figure. The bar remains intact, indicator that the external force is balanced internally by a response of the material. It we section this bar at any particular location (normal to the axis of the applied load) p must be opposed by the stress [28] produced in each elemental area. It these increment of area become smaller and smaller in the limit-

$$P = \sigma dA$$

Since it previously assumed that the force uniformly applied over the cross section, the summa of stress over the entire area may be expressed a follows:

$$P = \sigma \int_0^A dA$$

$$\text{Or, } P = \sigma A$$

Therefore, the stress can be expressed as –

$$\sigma = \frac{P}{A}$$

Where, σ = average stress

P = load or force

A = cross sectional area over which the force act.

Stress is commonly denoted in units lb/m^2, or in international units (SI) of Pascal (Pa), Since the Pascal is a rather small value of stress, it is customary to express stress values in mega Pascal (M Pa), where the prefix M stands for 10^6.

2.4.8 *Engineering* stress

A common application of the stress concept is termed the engineering stress. This particular expression, which is used in many design calculations and analyzes is given as

Follows:

$$\sigma = \frac{P}{A_0}$$

The only modification to our basic stress equation is A_0, which represents the original area; therefore, engineering stress treats cross sectional area as a constant. Although this is not completely accurate, for elastic striations in the loading direction the corresponding changes in cross sectional area are generally small. Furthermore, most design and structures are based on service conditions in the structures, are based on service conditions in the elastic range, thus the engineering stress is very useful parameter,

2.4.9 True stress

The concept of engineering stress treats the area under consideration as a constant (A_0).In reality, however, the area does not remain constant and in the case of am axially loaded tensile bar , gradually decreases as the stress (and corresponding manifestation of Poisson's ratio effect.

The true stress therefore can be expressed as follows:

$$\sigma_{tr} = \frac{P}{A_i}$$

Where A_i is the actual instantaneous area over which the force is acting. Ordinarily, the true stress in larger than the engineering stress. However, in the elastic region, change in area is usually inconsequential and the engineering stress in sufficiently accurate. When the elastic timid is exceeded and plastic strain come into play the di

The true stress is (σ_{tr}) is related to the engineering stress (28) in the following manner.

$$\sigma_{tr} = \frac{P}{A_i}\frac{A_0}{A_0}$$

$$= \frac{P}{A_0} \quad \frac{A_0}{A_i} = \sigma\frac{A_0}{A_i}$$

In this type of analysis the volume of matrun is constant (even thought the dimensions may change). Therefore the following relationships also applied.

Initial volume (V_0) = instantaneous volume (V_i)

$$V_0 = V_i$$

$$\text{or, } A_0 l_0 = A_i l_i$$

$$\text{or, } \frac{A_0}{A_i} = \frac{li}{lo}$$

Substituting above gives us –

$$\sigma_{tr} = \sigma \frac{l_i}{l_o}$$

But from the section on strain, since t is any instant in time it is equivalent to l_f, we can substitute for l_i/l_0 as follows:

$$\sigma_{tr} = (e + 1)$$

Thus, the true stress equals the engineering stress times the quantity engineering strain plus 1.

2.2.10. Stress Strain Relationship: Hooke's law [30]

In most materials for values of stress below the elastic limit, stress is proportional to strain as follows:

$$\sigma = Ee$$

In order to analyze the stress strain behavior of a composite will consider a simple situation where a matrix containing continuous cylindrical fibers is deformed in direction pratlle to the long axis of the fiber, as illustrated in the following. If we can assume that no slippage occurs at the interface between the fibers and matrix, the elongation is the same in both phases. There fore, the engineering strain in the composite may be expressed as-

$$Ec = e_f = e_m = \Delta l / la$$

Where,

e_f = Strain of fiber

e_m = Strain of matrix

Further more, when these strain are elastic the engineering stress in the respective composite can be determined by applying Hook's law as follows-

$$\sigma_t = E_f . \varepsilon_f$$

$$\sigma_m = E_m . \varepsilon_m$$

Where

σ_t = Stress of fiber

σ_m = stress of matrix

E_f = elastic constant of fiber

E_m = elastic constant of matrix

In most cases, the modulus of the fiber is greater than that of the matrix, buy design thus, for a given strain the stress in the fiber is greater than the matrix stress. Although this is a bray-simplified analysis it serves to illustrate the extremely important concept fiber reinforcement. Generally, the fibers are more highly stressed than the matrix when a load is applied to the composite. The mechanism permits transfer of the stress from the matrix to the reinforcing phase. As a result, the composite can sustain greater stress them the un-reinforced matrix material. This concept of utilizing the advantages of one material such as high modulus or high strength, in conjugation with the advantages of another, such as low density of corrosion resistance, is the very essence of composite material.

2.4.11. Elastic modulus

The elastic modulus (E) is a measure of the stiffness of an engineering material. Examination reveals that for a given stress; greater values of E result in smaller elastic strains, meaning that the higher the elastic modulus, the smaller elastic strains, meaning that the higher he elastic modulus, the smaller the response of the structure to a particular stress, this parameter is important for design and amylases purpose, especially in computing the allowable displacements and deflections of engineering components or structure.

Although the modulus of elasticity is a structure insensitive property, it is intended by temperature. As temperature is increased E decreases, thereby reducing the stiffens of a material. This reduction in elastic behavior is due to an inverse relationship between the modulus and the inter-atomic or inter-ionic distance in metals and ceramics respectively. Therefore as we increase and E gradually decreases. [25]

2.5 Electrical Conduction Mechanism

Introduction

This chapter begins with a brief discussion of the existing theories on the dc electrical conduction mechanisms, which are followed by descriptions of the experimental techniques used in the measurements of J-V characteristics and thermally activated of current density of different samples, are discussed on the basis of the different existing theories on dc electrical conduction mechanisms.

2.5.1. Theories on DC electrical conduction mechanism

Polymerization of organic compounds by glow discharge technique has been known for about three decades and used for producing polymer thin films. Because of their ***high*** resistivity, these materials have found important applications as insulators are capacitors in integrated microelectronics, passivation layers for integrated circuit, etc. is the dc electrical conduction in plasma-polymerized materials, the carriers may either be electronic or ionic in nature and conduction is considered through the film, rather along the plane of the film. The low field properties, which are usually ohmic in nature but the high field electrical properties cannot be described by a single conduct:-process. Usually various field strength ranges manifest different electrical conduction mechanisms. The charge carriers may be electrons, holes, ions, or polarons. Discussion of the four ways are given below [31, 32]

a) Band Conduction: Thermally activated electrons can be injected from the valence band to the conduction band of the insulator if the forbidden bandwidth is small enough. The electrons may be thermally activated over the reduced thermal excitation into the conduction band from trapping levels in the dielectric.

b) Tunneling Process: The tunneling of electrons may take place from metal cathode into the conduction band from trapping levels in the dielectric directly between the valence band and the conduction band from the valence band directly into the metal electrode .

c) Impurity Conduction: In this process electrons hop from one trapping (impurity level) center to another without going up into the conduction band .

d) Space Charge Effects: In some cases charge injection into the conduction band, tunneling or impurity conduction may result in a build up of space charge within the bulk material, which sets a limit on the charge transport. When the injected carrier density is greater than the free carrier density, current becomes space-charge-limited. In general, if the carrier generation process is slower than transport of the carrier: through a dielectric, the conduction is controlled either by Schottky or PF mechanism At reasonable applied fields there will normally be a sufficient supply of carrier [33] available to enter the insulator from the cathode(negatively biased electrode) H replenish the carriers drawn out of the bulk of the insulator. Under these conditions the J-V characteristics of the sample will be determined by the bulk properties of -insulator; this conduction process is thus referred to as bulk-limited. At high fields, or *H* the contact is blocking, the current capable of being supplied by the cathode to lie insulator will be less than that capable of being carried in the bulk of the insulator. Under these conditions the J-V characteristics of the sample will be controlled primarily by conditions existing at the cathode-insulator interface; this conduction process referred to as being emission-limited or contact-limited.

A power law can express the variation of current density with voltage in a mataai generally:

$$J \propto V^{n} \quad \text{..} (1)$$

where, n I s a power factor. When n is unity, the conduction is ohmic. If the value of n is less or more than unity, then the conduction process is other than ohmic.

Direct current resistivity at responsible applied fields there will normally be a sufficient supply of carriers available to enter the insulator. From the J-V characteristics of a sample, it could be understand the conduction process by the bulk properties of the insulator, bulk limited or contact limited.

Electrical conduction is the transport of charge carriers through a medium under the influence of an electrical field. The electrical conductivity is obtained by measuring the current flowing through a piece of the materials and using the sample dimensions to calculate [33] from the equation.

$$\sigma = (d/AV)\, I, \quad \text{..} (2)$$

Where d (m) is the sample thickness, A its area (m^2), and V the potential across the material in volts.

The usual type of electrical measurement has involved measuring the current as a function of potential, temperature and in some cases ambient atmosphere. The conductivity and its changes with voltage, ambient atmosphere and temperature are then related to the physicl processes through to be according in the material. Frequently, it is found that the conductivity varies exponentially with temperature T(K) according to the equation

$$\sigma=\sigma_0\exp\left(E_r / kT \right) \qquad (3)$$

Where k is the Boltzmann constant and E_r is the activation energy.

The resistivity is the reciprocal of conductivity.

2.5.2. Thermally activated conduction processes

(a) Electronic conduction

The band theory of solids has been applied to understand the electrical behavior polymers. An important feature of the band system is that electrons are delocalized spread over the lattice. Some delocalization is expected when an atomic orbital or atom overlaps appreciably with those of more than one of its neighbors.[34,35]In polymer system, the conductivity is influenced by the factors such as dopant level, morphology of polymer, concentration of conducting species, temperature, etc.

(b) Ionic conduction

In bulk material ionic conduction occurs due to the drift of defect under the influence of an applied electrical field. The degrees of ionic impurities that may be totally ignored in the context of other properties may have a significant effect on conductivity. A theoretical expression may be derived for the current density,

$$J=\sinh\left(eaE/2kT\right) \qquad (4)$$

Where E is the electric field and a is the distance between neighboring potential wells, e=electronic charge.

2.6 Theory of Thermal Analysis

2.6.1 Differential Thermal Analysis (DTA)

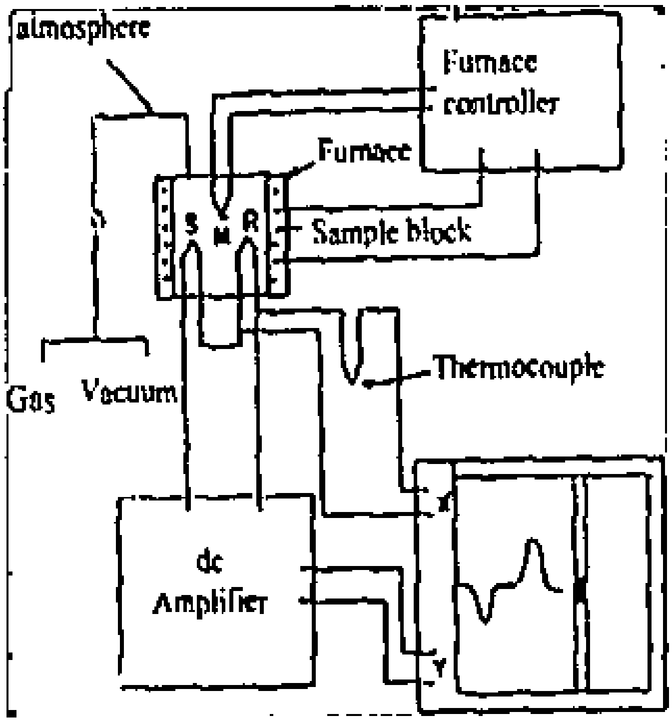
The term thermal analysis is frequently used to describe analytical experimental techniques, which are used to investigate the behavior of a sample as a function of temperature. On heat-treatment organic or inorganic polymers may undergo structural physical and chemical changes due to dehydration, phase transition, molecular reorientation, destruction of crystalline, oxidation and decomposition, incorporation some functional groups, etc. A systemic investigation of the thermal behavior polymers in air, vacuum or in inert atmosphere provides information about the nature the changes a takes place in polymers. Such changes can conveniently be understood employing DTA and TGA [36]

The technique of DTA is an important tool to study the structural and phase changes occurring both in solid and in liquid materials during heat treatment. These changes may be due to dehydration, transition from one crystalline form to another, destruction of crystalline structure, melting, oxidation, decomposition, degradation temperatures etc. DTA is a process of accurately measuring the difference in the temperature between a thermocouple embedded to a sample and a thermocouple in a standard inert material such as aluminum oxide while both are being heated at a uniform rate.

The principle of DTA consists of measuring heat changes associated with the sisal or chemical changes occurring when any substance is gradually heated, The thermocouple (platinum-platinum rhodium 13%) for DTA is incorporated at the end of the of the balance beam ceramic tubes, and the temperature difference between the holder on the sample side and the holder on the reference side is detected. This signal is amplified and becomes the temperature difference signal used to measure the thermal change of the sample.

These difference of temperatures appears because of the phase transitions or chemical reactions in the sample involving the evolution of heat and is known as exothermic reaction or absorption of heat know as endothermic reaction. The exothermic and endothermic reactions are generally shown in the DTA traces as positive and negative deviations respectively from a base line. So, DTA offers a continuous thermal record of reactions in a sample. The areas under the bands or peaks of DTA spectra are proportional to the amount of heat absorbs or evolved from the sample under investigation, where temperature and sample dependent thermal resistance are the proportionality factors. Thus DTA is needed primarily for the measurement of transition temperature.

Fig.2.4 Principle of DTA measurement

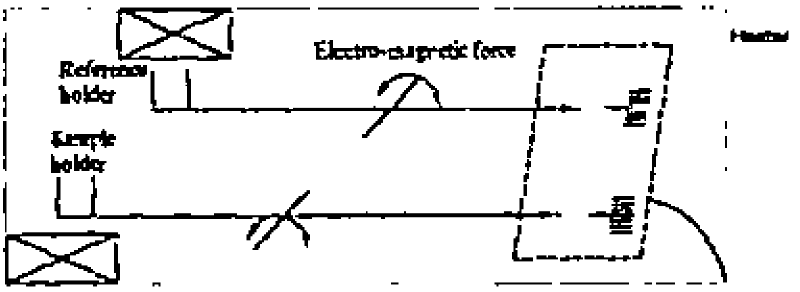


2.6.2
Thermogravimetric Analysis

The TGA is a special branch of thermal analysis, which examines the mass change of a sample as a function of temperature in the scanning mode or as a function of time in the isothermal mode. Not all thermal events bring about a change in the mass of the sample(for example melting, crystallization or glass transition), but there are some very important exceptions which include absorption, sublimation, vaporization, oxidation, reduction and decomposition. The TGA is used to characterize the decomposition and thermal stability of materials under a variety of conditions, and to examine the kinetics of the physico-chemical processes occurring in the sample. Sample weight changes are measured as described below in Fig.

Figure shows the sample balance beam and reference balance beam independently supported by a driving coil/pivot. When a weight change occurs at beam end, the movement is conveyed to the opposite end of the beam via the driving coil/pivot, when optical position sensors detect changes in the position of a slit. signal from the optical position sensor is sent to the balance circuit. balance circuit supplies sufficient feedback current to the driving coil so that the slit is to the balance position. The current running to the driving coils on the sample and The current running to the driving coil on the reference side is detected and converted into weight signals.Fig.4.7 Principal of TGA measurement.

2.5 Differential Thermal Analysis-Differential form of thermogravimetric is defined DTG.



CHAPTER-3

PREPARATION AND TESTING OF SAMPLE

Preparation
3.1. Raw Materials
3.2. Sample Preparation Procedure
3.2.1 Sawdust separation
3.2.2. Mixing
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3.7 Electrical Measurements
  3.7.1 Introduction
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  3.7.2 Direct current-voltage and direct current- temperature measurements

Sample Preparation

3.1.1 **Raw Materials:** The chief raw materials used for the sample preparation are Poly vinyl Chloride (PVC) and Sawdust. PVC is collected from local market. Sawdust were collected from sawmill.

Sawdust of Garjan wood

Scientific name of Garjan -*Dipterocarpus turbinatus*.

Table 1 shows the size distribution of collected sawdust. From the sawdust two groups having two size 1) 1mm-500µm and 2) 500 µm-125 µm are separated for experimentation. The chemical composition of size was performed according to the TAPPI standard method Table show chemical composition of sawdust.

Table 1 Sieve Analysis of Sawdust

Sawdust	Amount%
<4>2mm	2.37
<2>1mm	2.23
<1>500mic	48.94
<500>250mic	34.07
<250>125mic	11.12
<125>63mic	1.82
<63>45mic	.492
<45>Pan	.526

Contents	Amounts (wt%)
Lignin	25.7
Hemi cellulose	22.1
Alpha cellulose	42.4

Equipments: Several equipments were bused in the fabrication of polymeric matrix composite. The main equipments are as follows:

1. Paul OttoWeber-Press
2. Hounsfield test equipment
3. Oven
4. Blender
5. Sieve shaker

P/O/Weber Press

The compression - molding process is very widely used to produce articles from polymer materials. Above picture shows a typical mold employed for compression molding. The mold is made of two halves- the upper and the lower halves or the male and the female. In most cases, the lower half contains a cavity when the mold is closed. The gap between the projected upper half and the cavity in the lower one gives the shape of the molded article.In this research work, we worked with a type of mold which have the upper and lower halves but have no cavity in any half in the mold. These two halves are completely plane with smooth surface platens which also acts as heater and cooler simultaneously. In this of molding process one have to make die for casting with his desired size. We made a die, which has a ring of inside diameter 146 mm and outside diameter 158 mm, and have two disc (or plates) on each side, each of 7.5 mm in thickness. In compression molding, the polymeric materials and sawdust are subjected to heat and pressure in a single stoke. This is accomplished by using a hydraulic press with healed plants. Molding time can be as high as 120°c and initial pressure 50KN heating pressure 100KN. The actual time and pressure depends on the theological, thermal, and other properties of the plastic and sawdust % to be molded. The composite are placed into the die so as to fill the die As the mold closes down under pressure, the composite is squeezed or compressed between the two halves and competed to shape inside the die. Under the influence of heat, the compacted mass get cured and hardened to shape. After completion of healing the mold is allowed to cold down. When cooling is completed the cold mold is taken remolded by hand or any suitable device. The following photograph shows the Paul-Otto Weber Press

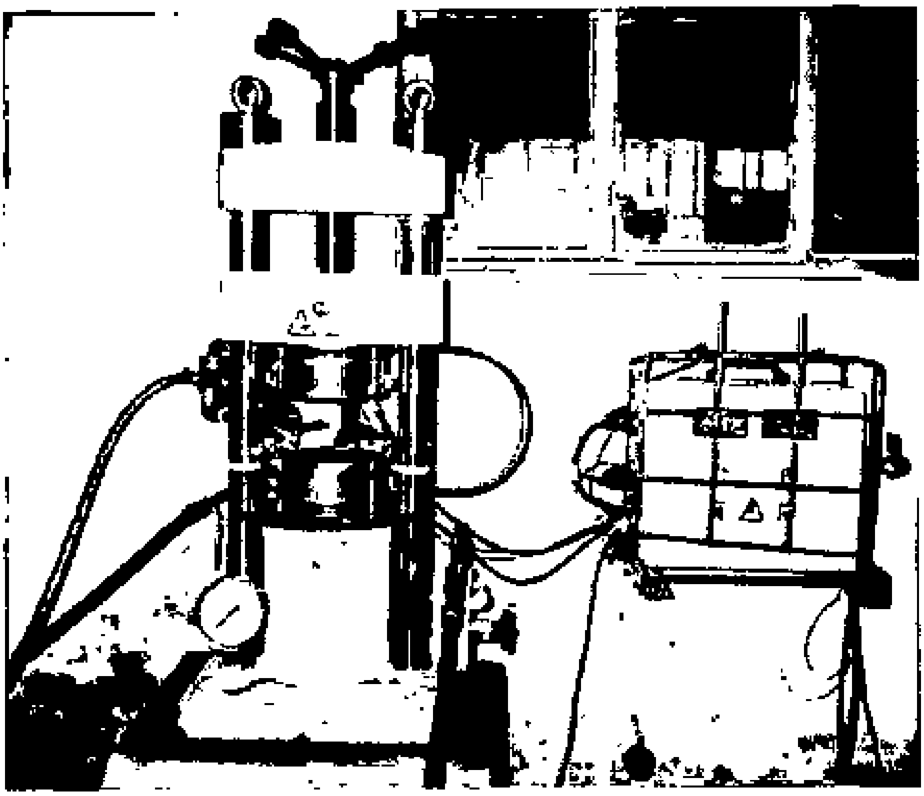


Fig. 3.1 shows the Paul-Otto Weber Press.

3.2 Sample Preparation Procedure:

The samples were prepared in the following steps-

3.2.1 Sawdust separation

Table 1 shows the size distribution of collected saw dust. From the sawdust two groups having size i) 1 mm-500 um and ii) 500 um -125um are separated for experimentation. To get sized sawdust by sieve analyzer, shows the size distribution of collected saw dust. From the sawdust two group having size i) 1 mm-500 micron and ii) 500-125micron are separated for experimentation. Sieving time 20 min and amplitude 20 min.

3.2.2. Mixing

Mixing is the major part for this experimentation. If the mixing of the sawdust and matrix are not done homogeneously, the quality of the products obtained will be very poor. So more the homogeneously mixed raw materials, more improved properties of the products will we get to get homogeneous mixing we used a blender where blending was done for three minutes at 400rpm for each specimen.

3.2.3. Casting

Special molding device is made by steel to very close tolerance for the molding process. The mixture of sawdust and matrix is cast by simply pouring the mixture into the mold and leveling it to the desired thickness. Only slight stamping or hammering on the mold is required for sufficient compaction

3.2.5. Curing and controlling

On pouring the fiber or matrix mixture into the special molding device, sufficient pressure of 50-100 kN is applied to get the desired shape and possible homogeneity. The applied pressure is measured by using a pressure gauge, set in the device. Heating is done electrically and the temperature set at 120° C. Only 1.45 minutes is required to reach the temperature. The temperature was kept for 30 min. After completion of heating the initial pressure was set zero and an additional pressure of 50kN was applied to avoid the kind of voids and to have a thickness. This additional pressure was kept for one hour.

3.2.6. Cooling and de molding

Cooling is essential throughout the curing operation. Cooling was done by tap water through the outer area of the heating plates of the hydraulic press machine. Cooling time is required for 15 minutes. When the specimen is made by the Weber Pressure hydraulic press the specimen is removed by a set up device which is made as a makeshift device. After the cooling the specimen adheres very strongly and so that we can not separate it from the mold. So for the de molding a device is necessary which we made as a makeshift.

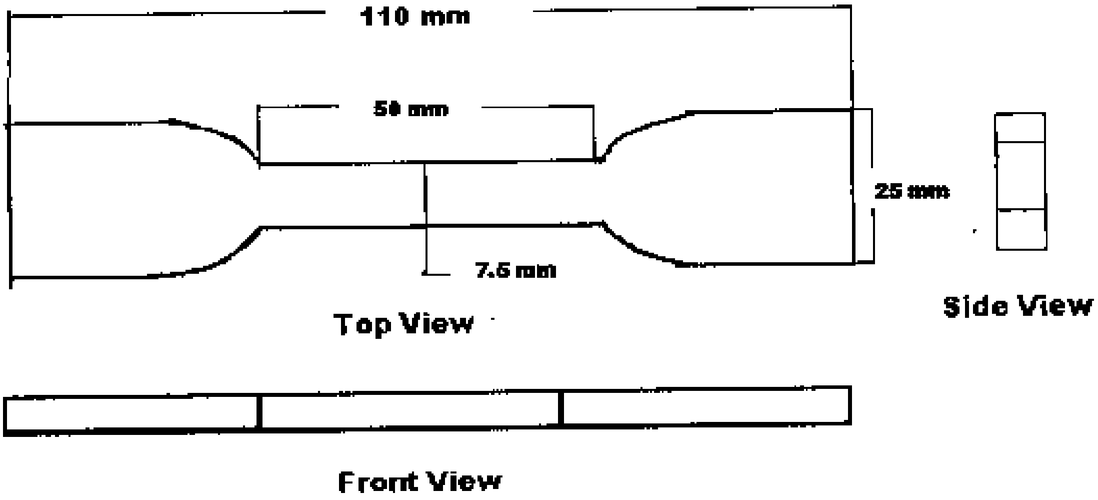


Figure 3.2.4 Different views of the tensile test specimen

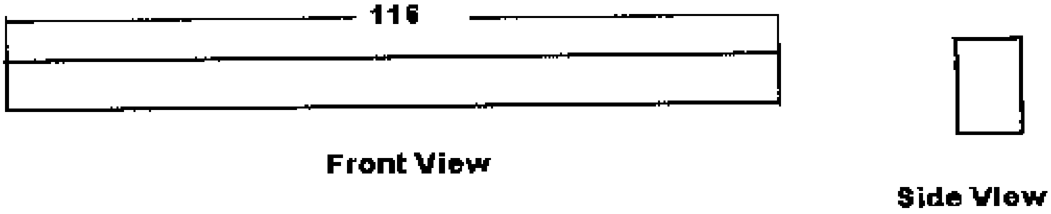


Figure 3.2.5 Different views of flexural test specimen

Testing

3.4. Bulk density: Bulk density specimen was prepared according to the ASTM C-134

$$D = W_s/V$$

Where, D = Density of the specimen, Kg/m^3 W_s = Weight of the specimen, Kg, and V = Volume of the specimen, m^3.

In this way the density of each sample is measured [40]

3.5. Mechanical Testing

3.5.1. Universal testing machine (UTM): Hounsfield UTM 10KN (H10KS) was used for test of tensile, flexural strength, compression shear and other mechanical and physical properties of materials. The following photograph shows the machine.

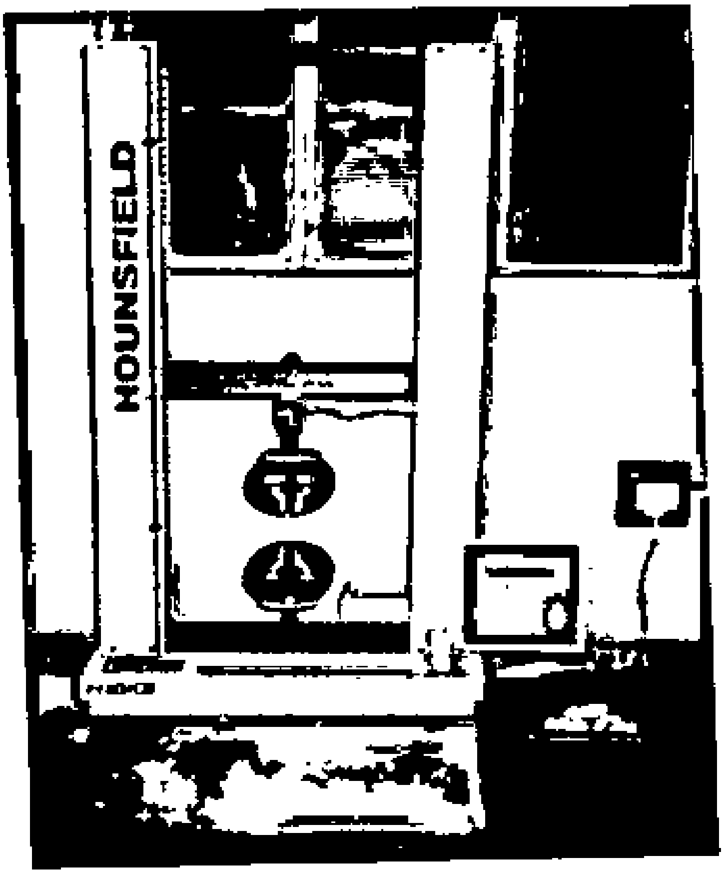


Fig.3.4 shows the Universal testing machine.

3.5.2. Electric Balance (HP200): The electrical balance used for measurement weight of the sample. The balance is sensitive and it can measure 1/1000 gm accurately.

3.5.3. Testing method:

a) Tensile Strength (i):

Tensile specimen was prepared according to ASTM Method

The test speed was 1 mm/min.

Tensile Strength=Applied load of the load bearing area/Cross sectional area

$$
\begin{aligned}
6 &= P/A \\
&= P/A.KN/mm^2 \\
&= 10^3 P/A.N/mm^2 \\
&= 10^3 P/A.N/10^{-6} m^2 \\
&= 10^3 P/A.M\,Pa
\end{aligned}
$$

b) **Energy calculation** [43]

The total energy absorbed by a specimen is calculated by calculating the area under the load vs. displacement curve of that specimen, and the area under the curve is calculated by using the trapezoidal method.

We know, the area of a trapezoidal = width X average length

Considered this example: following is a tensile load Vs. displacement curve of a specimen. Now, considered our target is to calculate the area under the curve that means the energy absorbed by the specimen.

We can divide the area under (the curve in numerous trapezoid shaped segments and thus, each segment will consider as a trapezoid.

Let's, consider a segment where X values are from 0.02 to 0.05 mm and corresponding Y values becomes 240N and 402N respectively.

That is $X_1 = 0.02$mm

$X_2 = 0.05$mm

And, $Y_1 = 240$N

$Y_2 = 402$N

So the with of the defined trapezoid is= $(x_r x_2)$

= (0.05-0.02) mm

= .03m

And the average height = $(yi+y_2)/2$

= (240+402)/2N =321 N

So, the area of the trapezoid will be = width x average height

= (x_r-x_2) x $(yi+y_2)/2$ = (0.03 x 321) N-mm = 9.63 Now, to calculate the energy absorbed per m^2 we need to divide the obtained result by the cross sectional area of the specimen. Let, the cross sectional area of the specimen is =32mm so, the energy per m^2 will be = (9.63/32) KJ/m^2

= 0.3009 KJ/m^2 similarly the area under the segments can be calculated and then by summing up all the values of these segments the total area under the curve can (be obtained. Thus, the total energy absorbed will be =8 (area of trapezoids)

c) Tensile strain

Tensile strain is calculated according to ASTM D-638M-91a.

Tensile strain =Extension /25

d) Flexural Strength [41]

Flexural specimen was prepared according to ASTM D790M, 3 point loading. The specimen dimension was 125 x 10 x 6-8 mm and support span was 96 mm. The test speed was taken as 2.6 mm/min. The strength may be calculated for any point of the load deflection by means of the following equation-

$S = 3PL/2BD^2$

Where,

S = stress in the outer fibers at mid span, M Pa,

P = load at a given point on the load — deflection curve, N

L = support span, mm, B = width of specimen tested, mm, D = depth of tested specimen, mm.

e) **Flexural Strain**: Flexural specimen was prepared according to ASTM D&()M, 3 point loading. Nominal fraction change in the length of an element of the outer surface of the test specimen, where the maximum strain occurs. It may can be calculated for any deflection using the following equation.

$\mathcal{E}_f = 6Dd/L^2$

Where, $\mathcal{E}_f$ =Main strain in the outer surface, mm/mm.

D= Maximum deflection of the center of the beam, mm
d= Depth, mm.

(f) Tangent Modulus of Elasticity-

The tangent modulus of elasticity often called the modus of elasticity is the ratio, within the elastic limit of stress to corresponding strain. It is calculated by drawing slope of the tangent to the initial straight line portion of the load deflection curve by equation……

$E_B = L^3 m/4bd^3$ where, E_B=modulus of elasticity in banding

L= Support span

b= Width of beam tested

d= depth of beam tested

m= Slope of the tangent to the initial straight line portion of the load deflection curve.

3. 6. Thermal Testing

3.6.1 Thermal Analysis

Thermal analysis includes a group of techniques where some physical property of the sample is monitored under controlled conditions with variation of temperature at a program rate. When the mass change is monitored the results, which indicates chemical reactions, are called Thermo gravimetric (TG). When heat absorption is monitored, the result indicate crystallization, phase change etc. as well as reactions. This is called Differential analysis (DTA).Together, they are a powerful method of analysis.

3.6.2. TG/ DTG Analysis

The TG/DTA modules use a horizontal differential system balance mechanism. Sample weight changes are measured as described below:

Sample balance beam and reference balance beam are independently supported by driving coil/pivot. When a weight change occurs at the beam end, the movement is conveyed to the opposite end of the beam via the driving coil/pivot, when the optical position sensors detect changes in the position of a slit .The signal from the optical position sensor is sent to the balance circuit. The balance circuit supplies sufficient feedback current to the driving coil so that the slit return to the balance position. The current running to the driving coil on the reference side and the current to the driving coil on the reference side is detected and converted into weight signals. Differential form of thermo gravimetric is defined DTG.

DTA Analysis

The thermocouple for DTA measurement is incorporated in the end of each of the balance beam ceramic tubes, and the temperature difference between the holder on the sample side and the holder on the reference side is detected. The signal is amplified and becomes the temperature difference signal used to measure the thermal change of the sample.

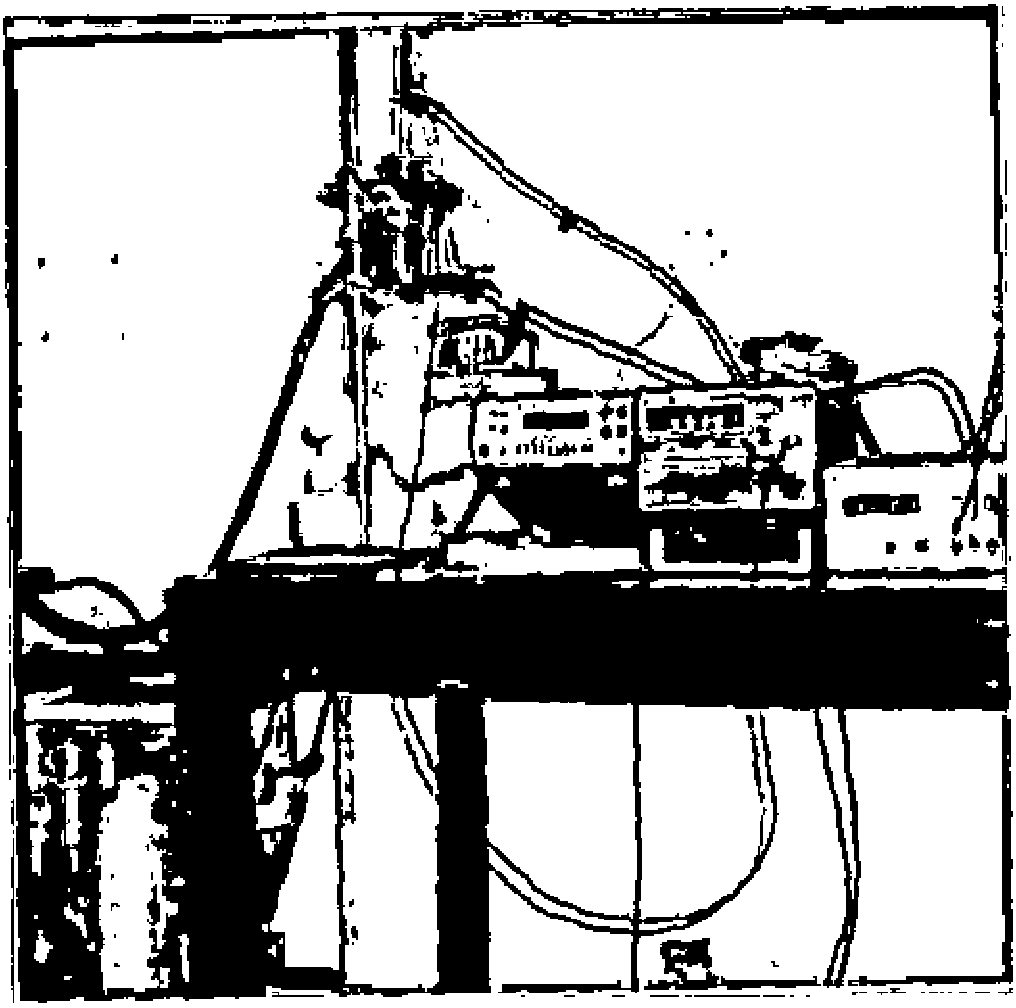


Fig:60 Photograph shows the DC measurement setup

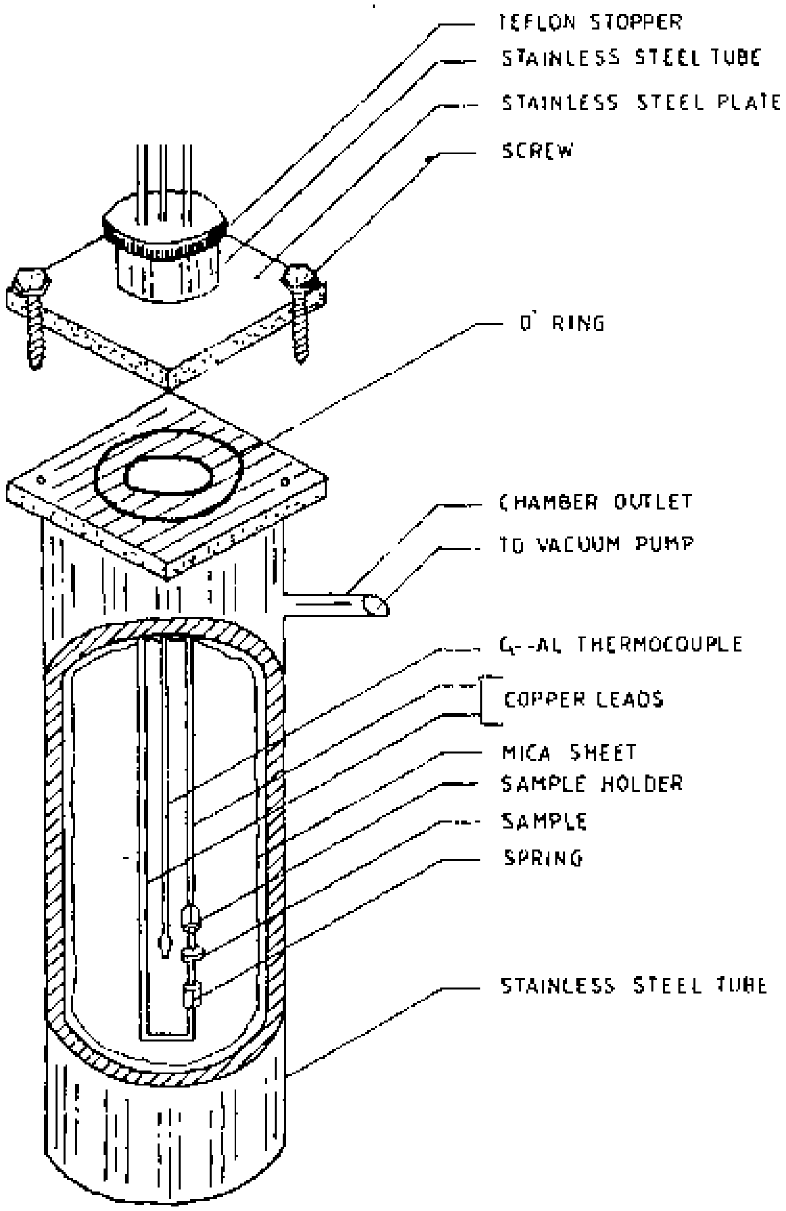


Fig. 3.6:The schematic diagram of the specimen chamber

3.7 D.C. Electrical Properties of composite

3.7.1. Introduction: The D.C. measurement set up is shown in fig- For D.C. electrical measurement of composite, electroding, Keithly 614 electrometer, D.C. power supply, specimen chamber and heating coil are used. A brief description of these instruments is given below.

3.7.2. Instrument used in Electrical measurement

The following equipment was used for D.C. measurement.

a)Keitbiey 614 electrometer: A Digital Keith ley **614** electrometer (model 614, Keithly instrument Inc. Cleveland, Ohio, USA) was used for dc current measurement. It can measure a wide range of D.C. voltage, currents, resistance range of this model is from 1 ohm to $2*10^{''}$ ohm using the constant current range as low as $10^{''14}$ A. Voltage range is 10 uv to 20 v with an input impedance of greater than 5* 10 ohm.

b)D.C. Power supply: A regulated D.C. power supply (Model Agilent 6545 A) was used

for electrical measurements. This unit is capable of supplying voltage. D. C. from 0 to 120 v with a current range 0 to 1.5 A. The input voltage of this unit is 220 v a. c.

c)Oil Rotary Pump: An oil rotary pump was to evacuate the specimen chamber. A pressure of about $10^{'12}$torr can be attained using this pump

d)Specimen Chamber: Specimen chamber shown in fig 4.1 is designed and fabricated in the laboratory with the help of university workshop. This unit is basically consists of **two** main parts, mainly the stainless steel tube and the sample holder.

A stainless steel tube having inner diameter of .045m and length 0.24 m is used. The lower end of the tube is closed by welding a circular piece of stainless steel sheet. At the top of the tube one flat stainless steel sheet ($.092x.09m^2$) with a circular hole (diameter .045 m)at its centre is welded. Another stainless steel (same as above) with a hole of the same dimension is welded to a stainless steel sheets. This prevents the air leakage when it is evacuated. The upper portion can be fixed to the lower portion by screws. The top opening is closed tightly with a Teflon stopper. A thick layer of mica sheets placed on to the inside wall and bottom of the stainless sheet tube for electrical insulation. The distance bet^n the lead is about .014 m. This is a side tube welded to the stainless steel tube which acts as an outlet of the chamber. A rotary vacuum pump is connected to the chamber through the side tube with the help of the rubber tube. By this pump a pressure of about can be obtained. Required temperature in the chamber can be maintained by a heating tape which is wrapped outside the steel tube and its temperature is controlled by available transformer.

e)**Heating tape:** A heating tape was used to heat the specimen chamber. It is about 1.75 m long and .03 m width tape and having the resistance of 15 ohm/m. It can be wrapped around the specimen chamber easily.

f) **Variac:** A Yamabishi volt side (type ss-260-10 No 38-1) was connected to the heating tape and controls required temperature.

g)**Keithly Micro voltmeter**: In this experiment two microvoltmeter DMMC(Model 197 A) was used. One meter was used for measurement of e. m. f. across a Cr-Al thermo couple attached to the specimen! Another meter was used for measurement of current through the specimen for different voltage and different temperatures.

h)**Electroding**: Silver Paint was pasted at opposite flat faces of specimen for good electrical conduction. Then specimen was kept for a several hours for complete drying of the paint before taking conductivity measurement.

3.7.2. DC current voltage and current temperature measurement

i) **DC current voltage (I-V) measurement**: A Keithley 614 electrometer and microvoltmeter DMMC was set in the current mode for recording the current through the sample at different applied voltages. In this case voltage was varied from 0 to 120 volt.

j) **Current**-Temperature measurement: The electrometer was set in current model for the direct measurement of current at different temperature . To raise the temperature, the specimen chamber was heated by a heating tape which can be easily wrapped around the specimen chamber.

CHAPTER-4

RESULTS AND DISCSSION

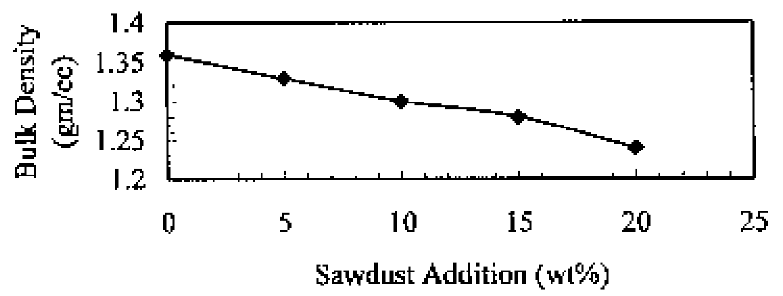
RESULTS AND DISCUSSION

Physical and Mechanical properties of PVC-sawdust composites

4.1 Bulk Density

Fig.4.1 shows the effect of sawdust addition on bulk density of composite materials. With the increase of sawdust addition the density decreases and follows the mixture rule

Fig.4.1 Effect of Sawdust Addition on BulK Density of PVC-Sawdust Composite



Similar effect was found by Kuriger and Alam [47] in the carbon fibre reinforced PP composites. The density of virgin PVC product is 1.36g/cc, the value is in the range of 1.30-1.58g/cc found in the literature [48].The density of sawdust was found to be in the range of 0.5-0.8 g/cc, which is lesser than that of PVC. As a result the density of the composites decreases with the increase of sawdust addition.

4.2 Flexural Properties

Fig. 4.2 shows the effect of fiber addition on flexural strength of PVC-Sawdust composites, It reveals that the flexural strength of fabricated product slightly increases with the increase of sawdust addition. For PVC flexural strength is found to be 15 M Pa. Up to20 (wt%) sawdust addition both the sawdust and the matrix bear the load and make resistance to slip as in the case of age hardening of metals. The sawdust's are well distributed and the interfacial bonding between the sawdust and matrix is high.

Consequently flexural strength slightly increases with the increase of sawdust addition. Similar effect was found by Shabname [48].

Fig 4.2 Effect of Sawdust Addition on Normalized Flexural Strength on PVC-Sawdust Composites

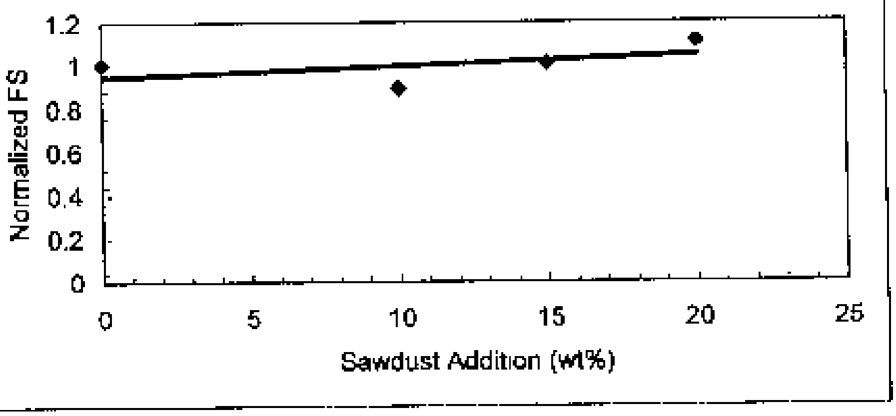


Fig. 4.3 shows the effect of sawdust addition on flexural strain of PVC-sawdust composites. It is seen that the flexural strain of fabricated product increases with the increase of fiber addition. For PVC flexural strain is 0.007%. Here the percentage of strain increases continuously with the increase of sawdust addition.

Fig. 4.3 Effect of Sawdust Addition on Flexural Strain on PVC-Sawdust Composites

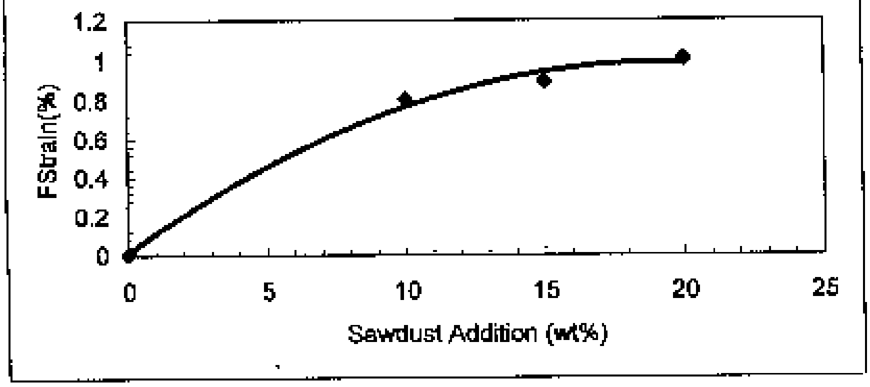
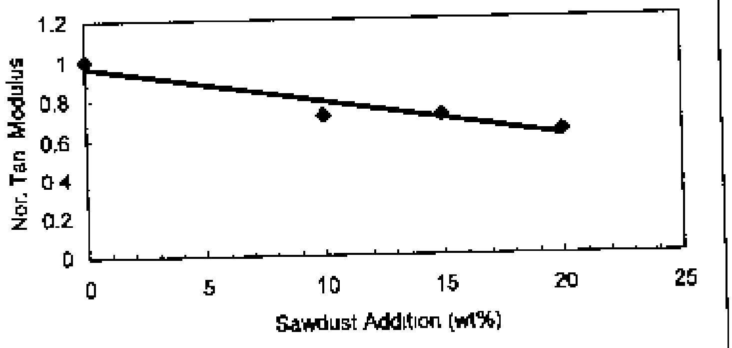


Fig. 4.4 shows the effect of sawdust addition on Tensile modulus of PVC-sawdust composites. It shows that tensile modulus decreases with the increases of sawdust

addition(TM -21291.25 M Pa). Composition of the sawdust and the polymer are not well distributed.

Fig. 4.4 Effect of Sawdust Addition on Tan Modulous of PVC-Sawdust Composites



4.3 Tensile Properties

Fig. 4.5 shows the effect of sawdust addition on tensile strength of PVC-Sawdust composites. It reveals that the tensile strength of fabricated product increases with the increase of sawdust addition. For PVC tensile strength is 8.395 M Pa. The increase in tensile strength is probably caused by a number of reasons including a) dispersion of the sawdust in the matrix b) moisture pick up and c) decrease of interfacial defects between PVC and sawdust composites. Interfacial bonding between the sawdust and matrix may be become well. Similar effect was found by Shabnam [48]

Fig. 5 Effect of Sawdust Addition on UTS of PVC-Sawdust Composites

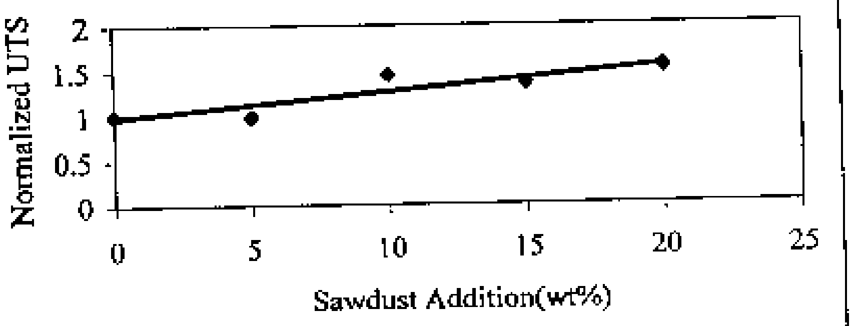


Fig. 4.6 shows the effect of sawdust addition on normalized tensile strain. It reveals that the strain decreases with the increase of sawdust addition For PVC tensile strain is 3.13MPa. It is apparent that the elongation decreases with increasing sawdust content.

Fig.4.6 Effect of Sawdust Addition on Normalized Tenslie Strain

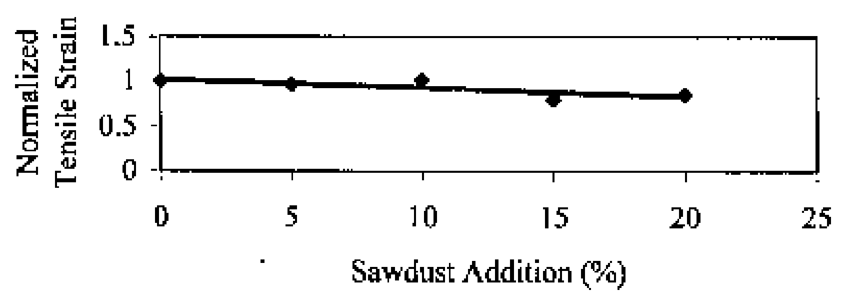


Fig. 4.7 shows the effect of sawdust addition on Young modulus of PVC-sawdust composites. It shows that the Young's modulus of fabricated product increases with the increase of sawdust addition Young modulus for PVC is 489.111MPa. The presence of sawdust restrict the slip resulting in lesser ductility and consequently the % of elongation decreases continuously with the increase of sawdust addition. Young's modulus is a stiffness of a material. Thus stiffness of PVC sawdust composites increases of sawdust addition continuously within the limit of the present study.

Fig.4.7 Effect of Sawdust Addition on Young Modulus of PVC -sawdust composites

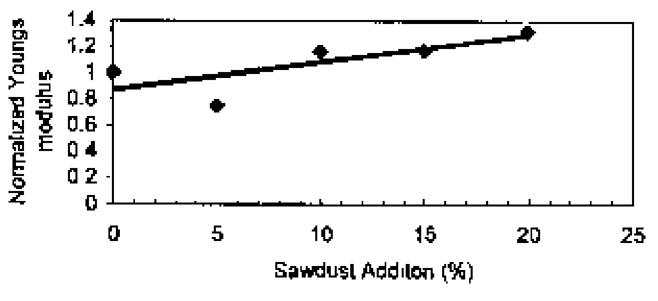


Fig. 4.8 shows the effect of fiber sawdust addition on normalized fracture energy of PVC-sawdust composites The fracture energy of a material is a quantitative measure of the fracture toughness of it. It is observed that the fracture energy of the composite increases with the increase of sawdust addition. This increase in fracture energy may imply that the toughness of the composite becomes better due to the addition of sawdust up to the wt% of sawdust added in this study.

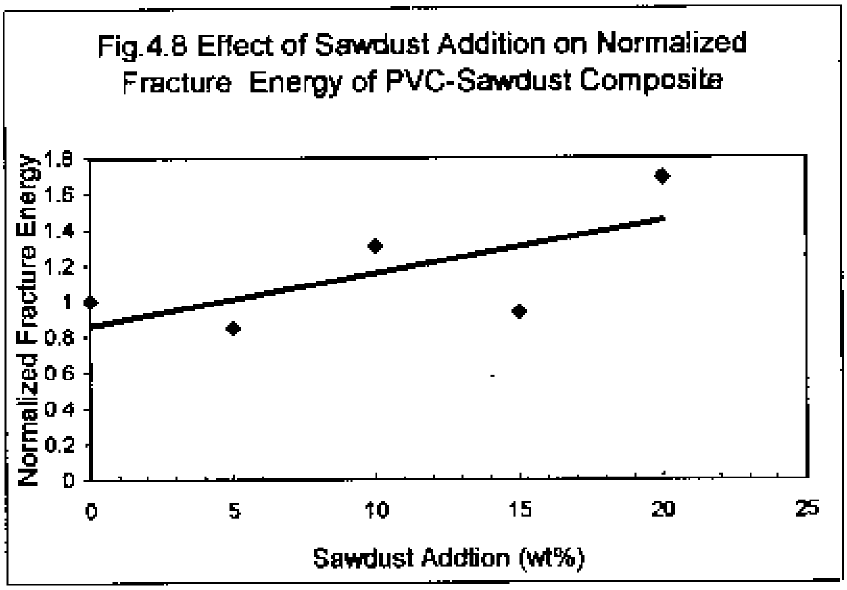


Fig.4.8 Effect of Sawdust Addition on Normalized Fracture Energy of PVC-Sawdust Composite

Fig. 4.9 shows the effect of sawdust size on flexural strength of PVC sawdust composite. It reveals that the flexural strength of fabricated product increases for the maximum value at 500-125micron size and after that it remains constant

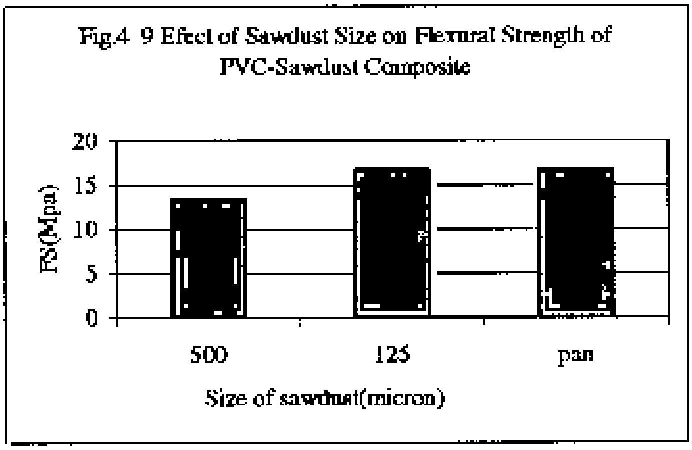


Fig.4 9 Effect of Sawdust Size on Flexural Strength of PVC-Sawdust Composite

Fig.4.10 shows the effect of sawdust size on flexural strain of PVC-sawdust composite It shows that the flexural strain of fabricated product increases up to 500-125 micron with decreasing sawdust size and then remains constant.

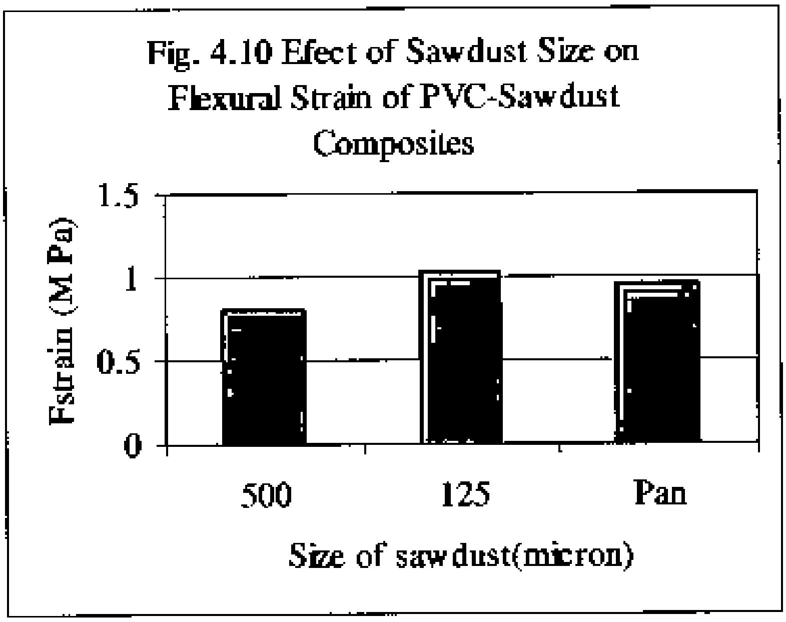


Fig.4.11 shows the effect of sawdust addition on UTS of PVC –sawdust composite. It is observed that the UTS of fabricated decreases for the value at 500-125 micron size after that it contain same value.

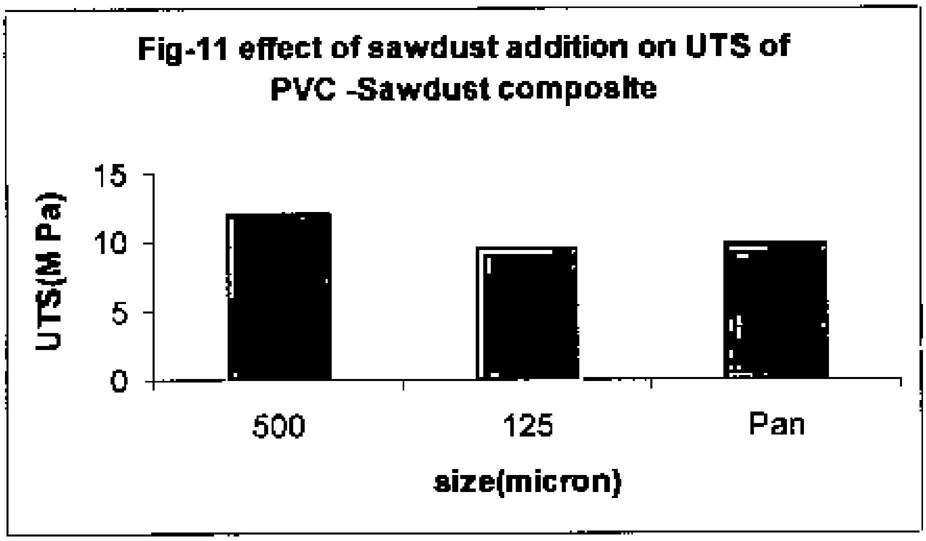


Fig.4.12 shows the effect of sawdust addition on max .strain of PVC –Sawdust composite. It reveals that the max. strain of fabricated product decreases for maximum value at (1)1-500(2) 500-125micron size after that it may constant.

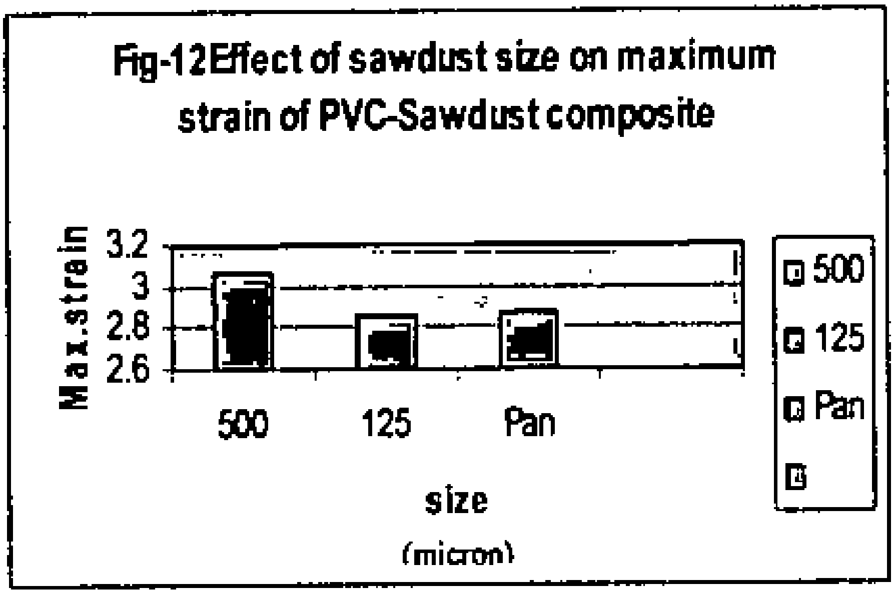


Fig-12Effect of sawdust size on maximum strain of PVC-Sawdust composite

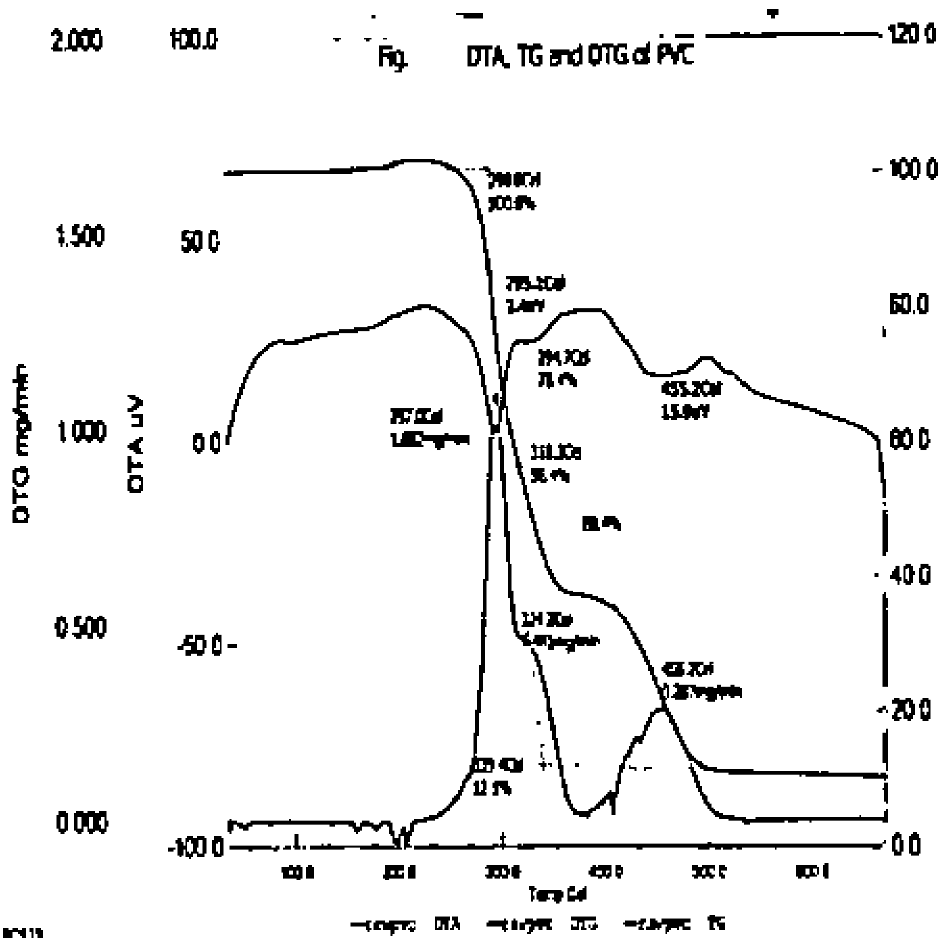


Fig.4.13 shows the DTA, TG and DTG curves of PVC.

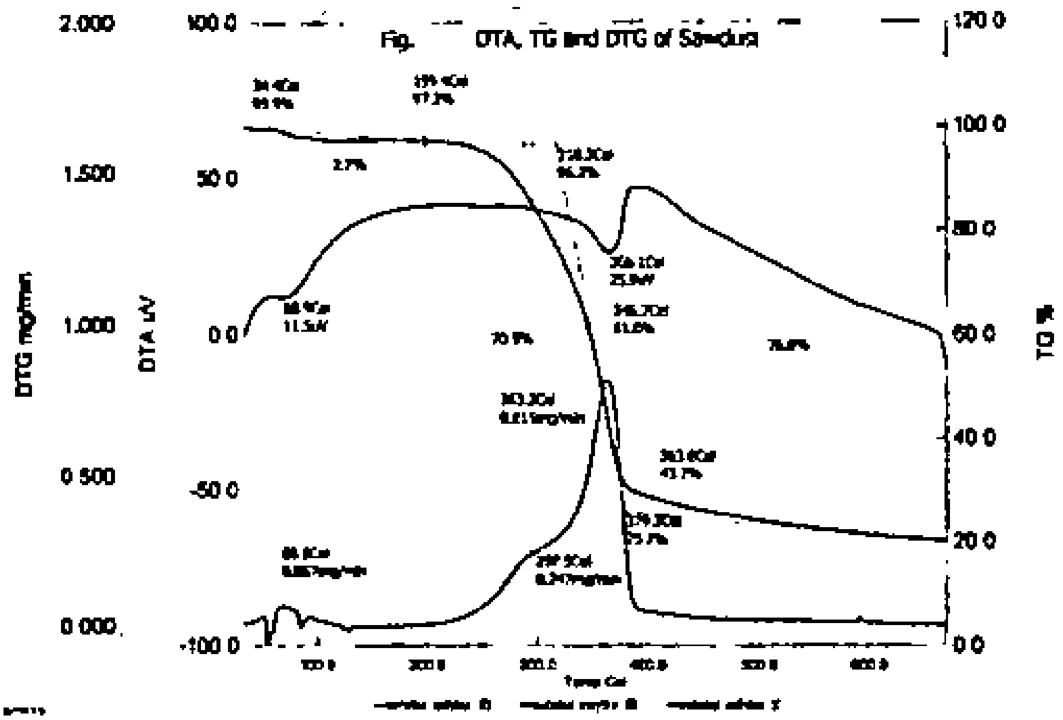


Fig 4.14 shows the DTA, TG and DTG curves of sawdust.

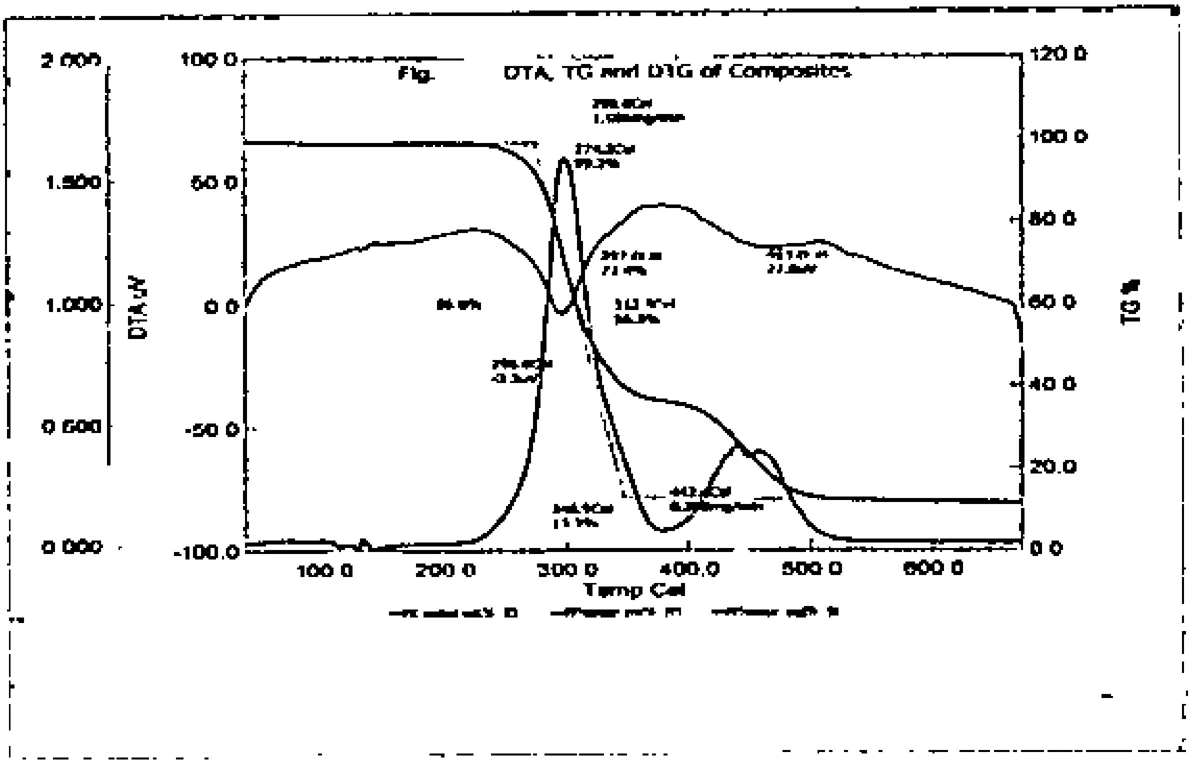


Fig.4.15 shows the DTA, TG and DTG curves of composite.

Fig 4.16 Shows the DTA of PVC, sawdust and composite.

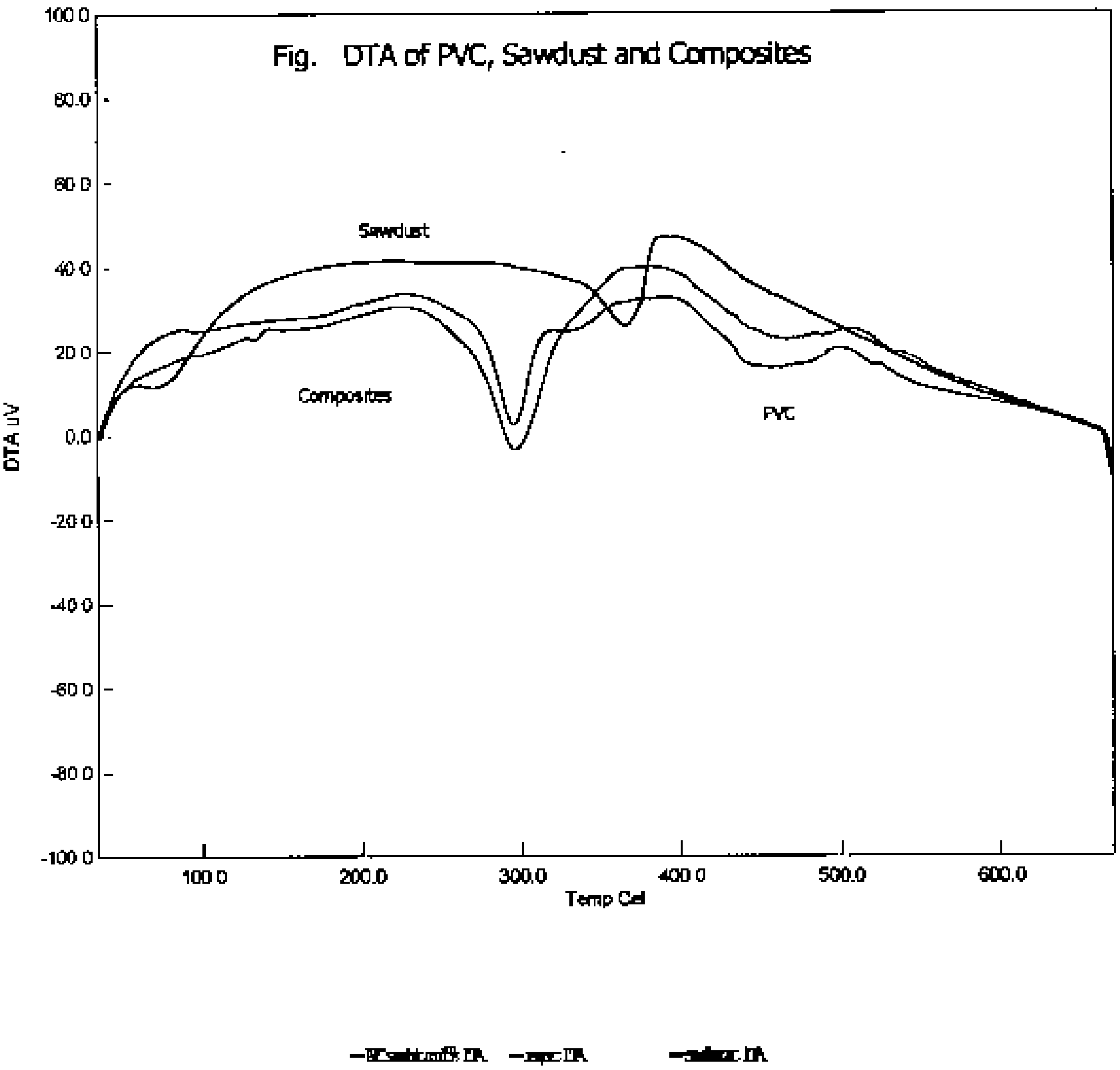


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Fig. 4.17 shows the TG of PVC, sawdust and composite

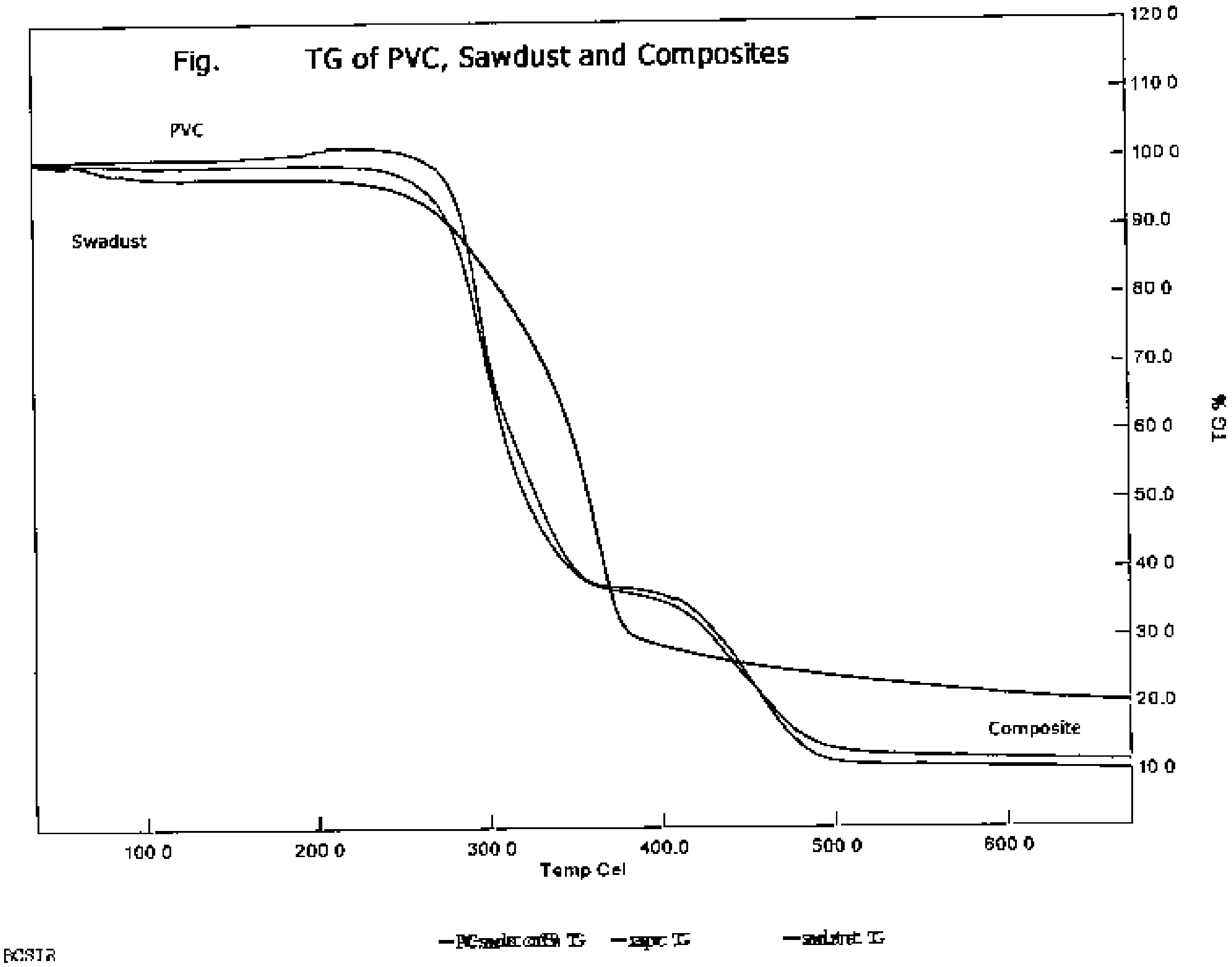
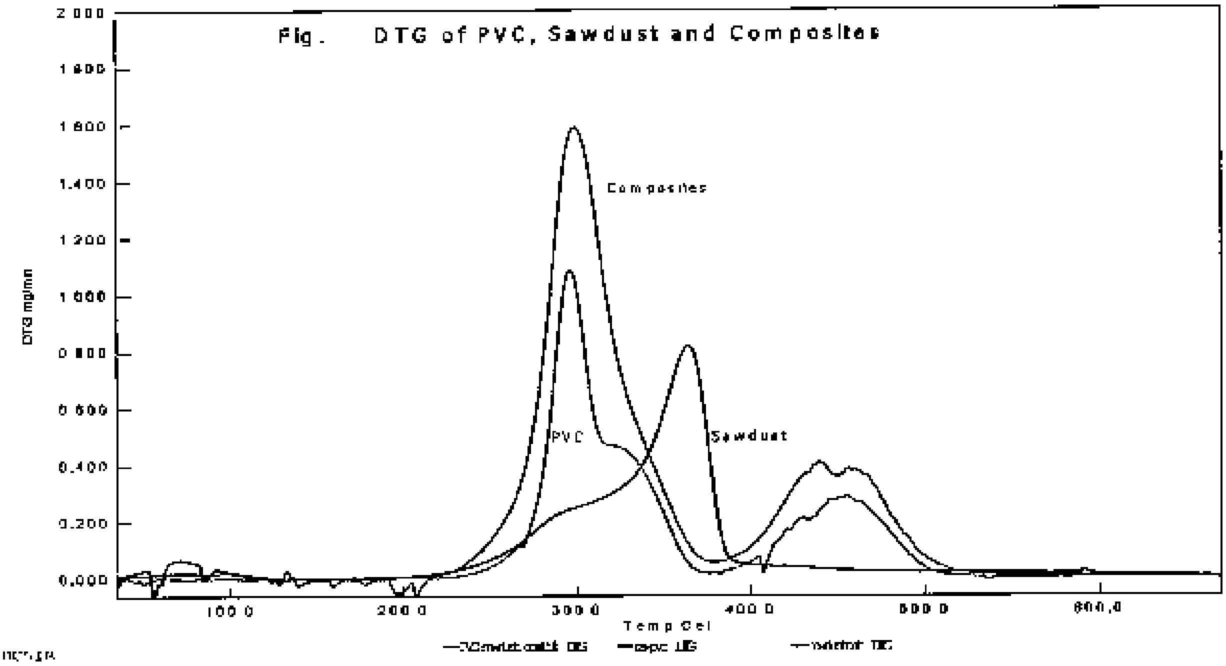


Fig 4.18 Shows the DTG of PVC, sawdust and composite.



4.5 Thermal Analysis

Fig.13 shows the DTA, TG and DTG curves of PVC. The TG curve shows that major degradation occurs in two stages. DTA curves of PVC shows two endo thermic peaks at 295.1^{0}C and 455.2^{0}C.1st degradation (TG), 1st DTA peak and 1st DTG are related. And similarly 2nd degradation, 2nd DTA peak and 2nd DTG are related. The first one is for dehydrochlorination and another one is for depolymerization DTG curves of PVC depict that the maximum degradation occurs at the temperature 297^{0}C with the rate of 343.59 mg/min. Two DTG peak obtained at 297.0^{0}and 455.20^{0}c.

Fig.14 shows the DTA, TG and DTG of sawdust The TG curve shows an initial 2.7% loss corresponds moisture content. Then the mass is continuous losing having initial slower rate and ending is the faster rate. The lighter substances remove initially and then havier material removed.(e.g. lignin)Two endo thermic DTA peak were obtained. The peak at 68.9^{0}c is for removal of moisture. And the 2nd one 365.1^{0}c is corresponds to major degradation. Two DTG peaks were also found at 297.5^{0}c and 363.2^{0}c which are corresponds to removal lighter material and heavier material. DTG curve of sawdust depicts that the maximum degradation occurs at the temperature 363.2^{0}C with the rate of 0.815mg/min. DTA curve of sawdust shows two endothermic peaks at 68.5^{0}C and 365.1^{0}C

Fig. 15 shows the TG, DTA and DTG curves of a compesite. This fig. are reveals that TG of composite two stage degradation temperature Here DTG shows two peaks one is at 274.3^{0}C. Where for DTA two endothermic peaks one is at 312.5^{0}C another is 463.0^{0}C.

Fig.16 shows the DTA traces of PVC, sawdust and a composite. It shows that the top curve is for sawdust, bottom one is for PVC and the curve for composite in between them. DTA of sawdust shows two endothermic peaks at 73.9°c and 365.8°c. Here 1s peak for water absorption. On the other hand, one peak is found at the same temperature as that for PVC and composite at 294.5°C.The effect of sawdust addition was also found in the composite curve peak at 294.5° C.

Table 1 DTA for PVC, sawdust and composite.

Sample	1st Peak(^{0}C)	2nd Peak(^{0}C)
PVC	294.5	457.2
Sawdust	73.9	365.8
Composite	294.5	457.2

Fig.17 shows the TG curves of PVC, sawdust and a composite. The top one is for PVC, bottom one is for sawdust and middle one is for composite.

Here for sawdust onset temperature 317.8^{0}C where PVC and composite the nearest temperatures are 279.2^0 and 274.4°C respectively two stages of degradation TG curves of PVC and composite show. On the other hand for sawdust degradation occurs in one stage. Lastly 20% residue of sawdust remains where as 10% for PVC and 11.9% residue for composite are observed. The onset temperature and 50% degradation of temp of sawdust are much higher than those of PVC and composite.

Fig18 shows DTG of PVC, sawdust and composite. For composite and PVC there are two peak.

Table-2 DTG of PVC, sawdust, composite.(wt 10% sawdust)

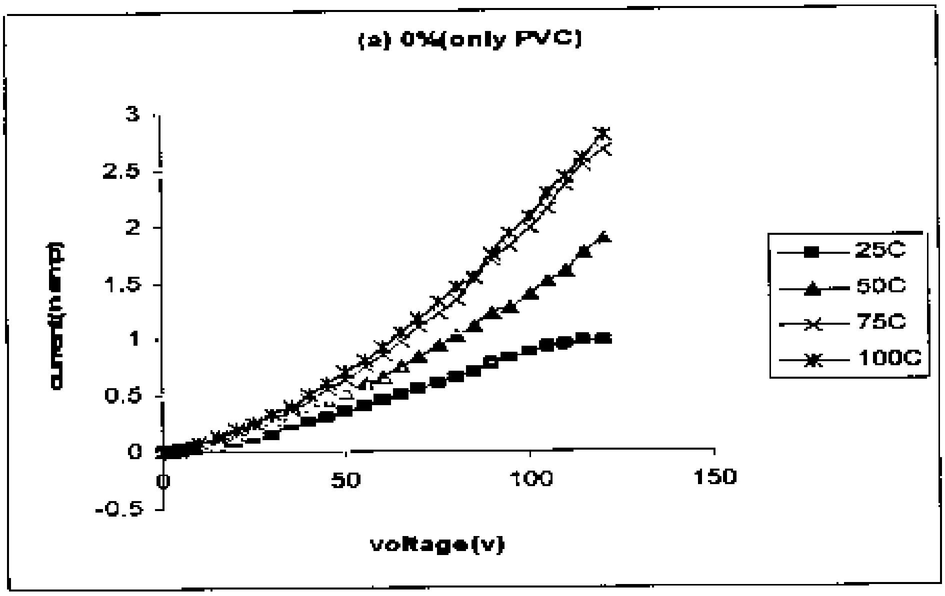
Sample	Maximum at(^{0}C)	Degradation rate mg/min
PVC	296.7	1.08
Sawdust	364.6	0.82
Composite	299.1	1.58

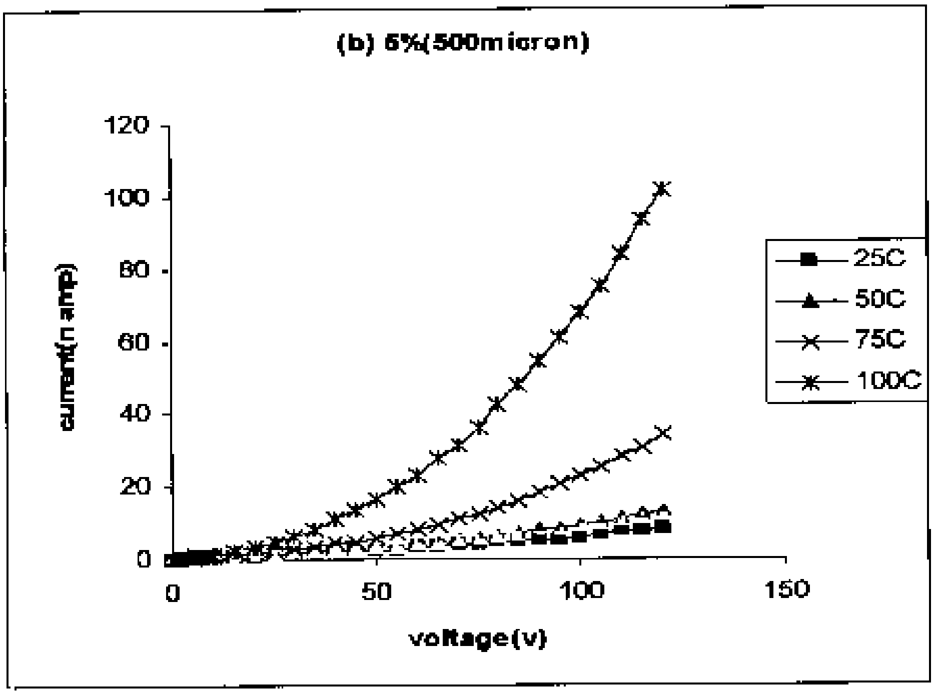
Table 2 shows the maximum degradation temperature for PVC and composite accordingly are296.7 and 299.1°C respectively where maximum temperature for sawdust

is 364.6°C.Nearest degradation rate for PVC and composite respectively are1.085 mg/min and 1.585 mg/min

But for sawdust it occurs at the rate of 0.85 mg/min.2nd stage degradation temperature for PVC and composite are455.4°C and 460.2°C respectively.

Here in the fig 4.19 with the increases of voltage, current increases linearly in the lower temperature. The addition of sawdust in PVC may significantly increase the electrical conductivity. It is seen that the dc electrical conductivity of the composites increases as the concentration of sawdust increases It might be due to the increase of polar groups in the composites and dipole originating from the presence of asymmetric excess electron in the polymers. So it is obvious that as the polar molecules concentration increases, the number of electrical charge carries increases resulting in higher conductivity.


(a) 0%(only PVC)


(b) 5%(500micron)

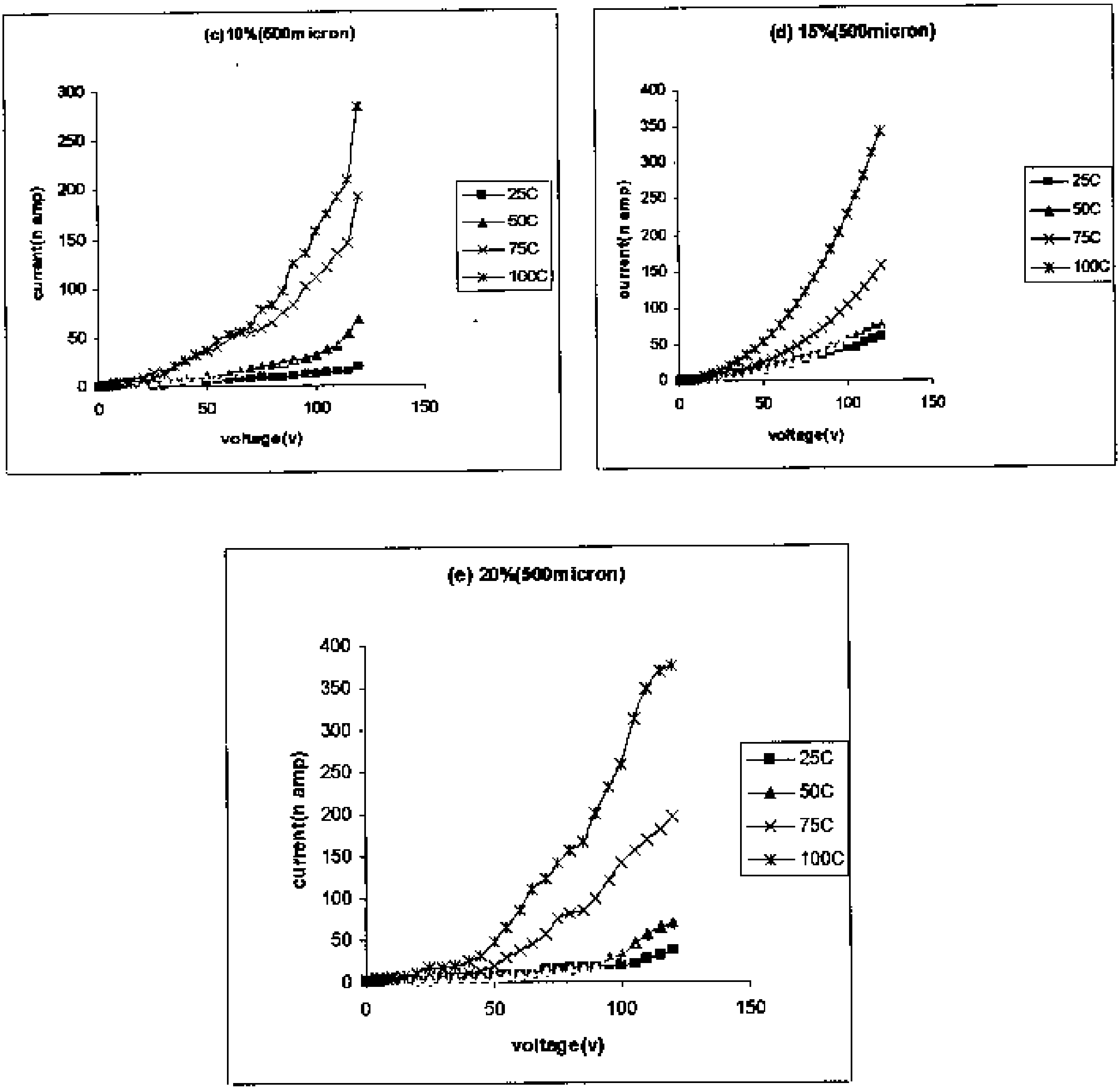


Fig. 19 I-V curves at different temperature for PVC- sawdust composite with different sawdust (500micron)

The variation of current with voltage for different size sample is shown in this Fig.4.20. It is observed that the conductivity increases as sawdust size decreases.

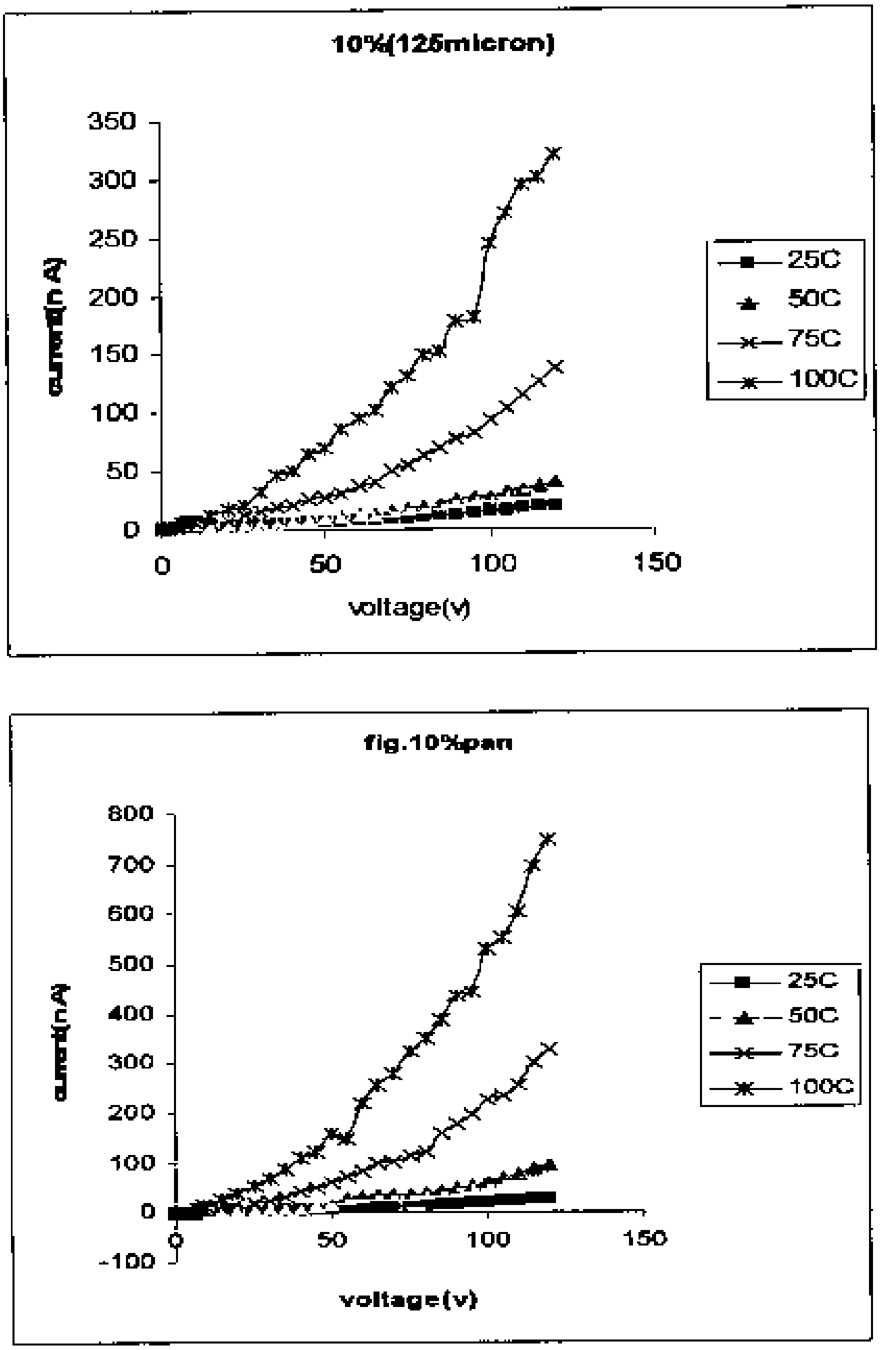


Fig. 20 I-V curves at different temperature for PVC composite with 10wt% Sawdust of 125micron and pan.

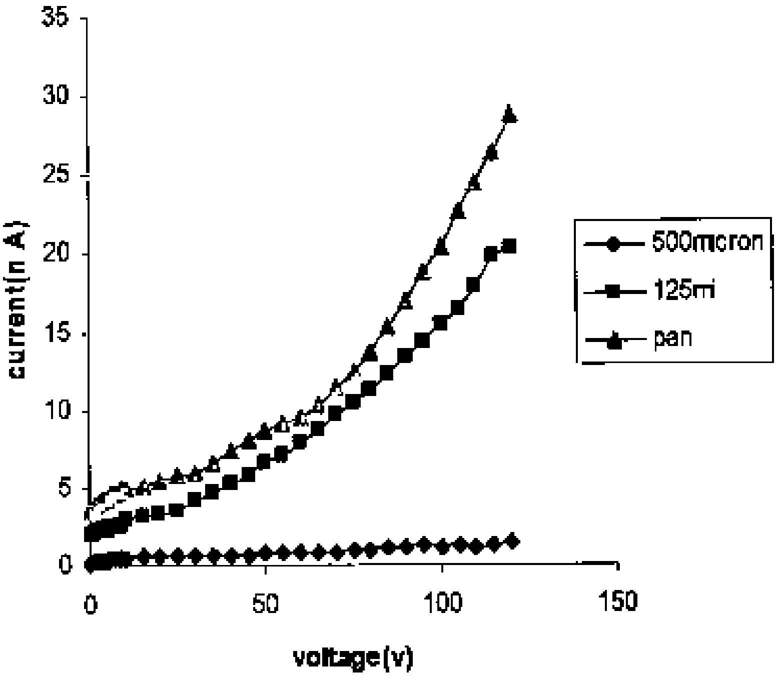
Current at different voltage follows the $J \propto V^n$ law. The value of 'n' close to unity. This means that the conduction is ohmic in the lower temperature.

Table 3 : n values from I-V curves

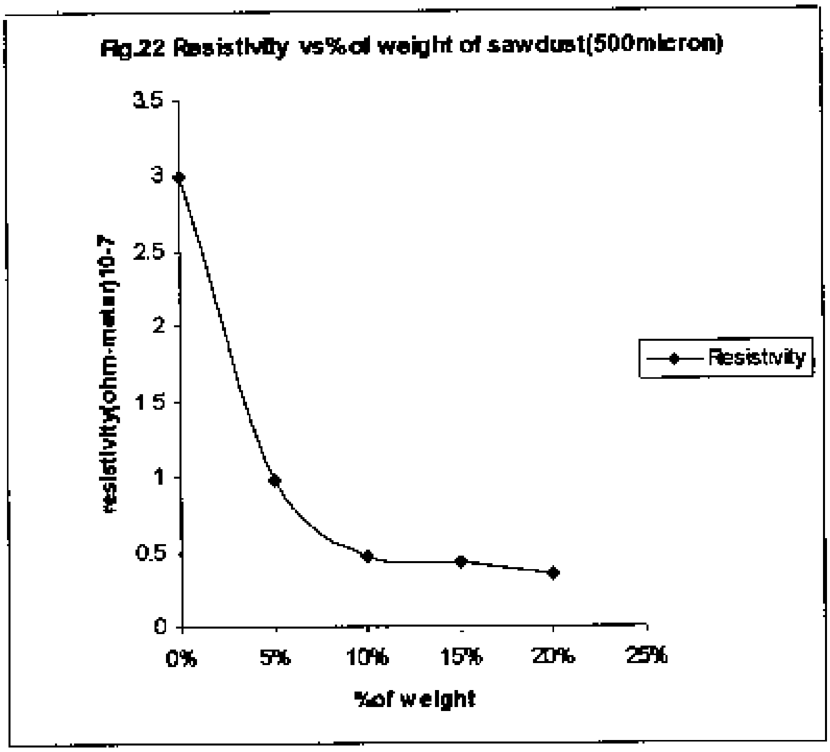
Samples (wt%)	n valus
0	0.83
5	1.05
10	1.64
15	1.69
20	0.97

The variation of current with voltage for the composites with different size sawdust is shown in Fig 4.21. It is observed that current increases with the increasing voltage linearly. When size is fine, conductivity increases with the increasing voltage.

Fig.4.21 I-V curves at room temperature for different size sawdust composite.



From fig 4.22, up to 10% resistivity decreases drastically and then it decreases slowly. Initial decreases I the resistivity of the composites may be due to presents of hydroxyl ion because of the presence of absorbed water and lignin in the sawdust. Above 10(wt%) the resistivity decreases slowly because the further addition of sawdust does not contribute any more to the conduction.



CHAPTER-5

CONCLUSIONS

5.1 Conclusions

5.2 Suggestion for future work

5.1 Conclusions

The polymer-natural fiber composites are important for their low cost, environment friendly and biodegradability. For this reason PVC – sawdust composites with different wt% of sawdust have been prepared by hot press molding method. The physical, mechanical, thermal and electrical properties have been investigated.

Based on the studies of physical, mechanical, thermal, electrical properties of PVC-sawdust composites following conclusions may be drawn

1) Bulk density of the composites decreases with the increase of sawdust addition.

2) The flexural strength of the fabricated product slightly increases and flexural strain also increases with the increase of sawdust addition. The tangent modulus decreases with the increase of sawdust addition. The sawdust may not be well distributed in PVC matrix. Fracture energy of PVC-sawdust composite increases with the increase of sawdust addition. The flexural strain of fabricated product increases up to125 micron with decreasing sawdust size and then remains constant.

3) For the composites, the tensile strength increases with the increase of sawdust addition. On the other hand, the tensile strain decreases with the increase of sawdust addition.. The Young's modulus increases with the increase of sawdust addition. Therefore stiffness of PVC- sawdust composites increases with the sawdust addition continuously. Also it is observed that UTS of fabricated product decreases for the sawdust of 500-125 micron size after that it is more or less constant.

4) From I-V characteristics of the composites for different % of weight it is observed that I-V curve shows ohmic behavior in the lower temperature. The dc electrical resistivity of the composites decreases as the concentration of sawdust increases. Initially decreases rapidly and than it decreases slowly.

5) From the TG, DTA, DTG curves of PVC, sawdust and composites it is found that the thermal behavior lies between those of PVC and sawdust. Thermal stability increases with the increase of sawdust.

In the end, the outcome of this study indicates that these materials can be used in the industrial and household application.

Suggestion for further work

The following experiments can be carried out for understanding of the electrical behavior of these materials.

1. Optical properties can be carried out by UV spectroscopic study.
2. A. C and D.C. electrical properties of a large series of different size sawdust are to be studied.
3. Fillers are commonly employed in PVC compounds in order to reduce cost. They may also be employed for technical reasons. China clay, calcium carbonate etc. are used for general purpose work. Such samples can be investigated.
4. The dielectric constant, loss factor and the dielectric strength may be measured to find the dielectric application of the materials.
5. Further detail physical and mechanical properties should be investigated.

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