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Investigation of Tensile, Impact and Moisture Properties of Abaca Natural Polymer Reinforced Composites

K.G. Prakash, Manjunath K.B, Achutananda K.B, Chandru B.G

Assistant Professor, Department of Mechanical Engineering, RYMEC, Bellary, Karnataka, India
Email-ID: [1]Prakashkg059@gmail.com

Abstract—
The Natural fiber-reinforced polymer composite is growing both in the fields of industrial applications and fundamental research .This paper presents an experimental investigation on the mechanical properties for Abaca natural polymer reinforced composites. The raw material used in the present work is long Abaca fiber. The epoxy resin and hardener are mixed according to the weight ratio. The tests were carried out as per ASTM standards. It was observed that the NPMC has got good properties comparative to man made fiber composite material. SEM analysis has been carried to identify the hybridization bonding. The natural fibers present many advantages as compared to synthetic fibers which make them attractive as reinforcement in composite materials.

Keywords-- Abaca Fiber, Epoxy, Hand layup, Mechanical properties, Sem.

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1. INTRODUCTION

Over the last thirty years composite materials, plastics and ceramics have been the dominant emerging materials. The volume and number of applications of composite materials have grown steadily, penetrating and conquering new markets relentlessly. Modern composite materials constitute a significant proportion of the engineered materials market ranging from everyday products to sophisticated niche applications.

While composites have already proven their worth as weight-saving materials, the current challenge is to make them cost effective. The efforts to produce economically attractive composite components have resulted in several innovative manufacturing techniques currently being used in the composites industry. It is obvious, especially for composites, that the improvement in manufacturing technology alone is not enough to overcome the cost hurdle. It is essential that there be an integrated effort in design, material, process, tooling, quality assurance, manufacturing, and even program management for composites to become competitive with metals.

The composites industry has begun to recognize that the commercial applicationsof composites promise to offer much larger business opportunities than the aerospacesector due to the sheer size of transportation industry. Thus the shift of compositeapplications from aircraft to other commercial uses has become prominent in recent years.

For certain applications, the use of composites rather than metals has in fact resulted in savings of both cost and weight. Some examples are cascades for engines, curved fairing and fillets, replacements for welded metallic parts, cylinders, tubes, ducts, blade on tainment bands etc. Further, the need of composite for lighter construction material and more seismic resistant structures has placed high emphasis on the use of new and advanced materials that not only decreases dead weight but also absorbs the shock &vibration through tailored microstructures. Composites are now extensively being used for rehabilitation strengthening composite materials have a bulk phase, which is continuous, called the matrix, and one dispersed, non-continuous, phase called the reinforcement, which is usually harder and stronger.

The most widely used meaning is the following one, which has been stated by Jartiz "Composites are multifunctional material systems that provide characteristics not obtainable from any discrete material. They are cohesive structures made by physically combining two or more compatible materials, different in composition and characteristics and sometimes in form". The weakness of this definition resided in the fact that it allows one to classify among the composites any mixture of materials without indicating either its specificity.

A composite material is defined as a structural material created by combining two or more material having dissimilar characteristics. The constituent are combined at macroscopic level and are not soluble in each other. One constituent is called Matrix (Resin) phase and the other is called reinforcing (Fibre) phase. Reinforcing phase is embedded in the matrix phase to give the desired characteristics.

2. OBJECTIVES OF THE PRESENT WORK

The objectives of the project are outlined below.

1. Fabrication of Abaca fiber reinforced polymer based composite.
2. Evaluation of mechanical properties like tensile strength, hardness, impact strength etc.

Besides the above the objective is to develop class of composites by incorporating natural abaca fiber reinforcing phases into unsaturated epoxy resin. Also this work is expected to introduce a new class of polymer composite that might find in engineering applications.

3. METHODOLOGY

Design and modification of polymer matrix composite, Based on the composite design the specimen has to be fabricated by using hand lay-up technique. The proper volume fraction of abaca fibers is laminated are cured for a period of 12hr. The sample is cut to a required size for the tests.

Testing of mechanical properties

- Tensile test is to be conducted as per ASTM D3039 standards.
- Impact test (charpy) ASTM D256 standards.
- Hardness test ASTM E10-00 standards.
- Chemical test with base and acids like H_2SO_4, HCL.WATER.
- The ultimate tensile strength and percentage of elongation of the composite will be studied with varying percentage of reinforcement and filler material.

4. MATERIAL SELECTION FOR FABRICATION

Abaca is a leaf fibre which belongs to banana family of plants with the botanical name of Musa Textiles. These leaves are upright, pointed, narrower, and more tapering than the leaves of banana. Abaca is one among the natural fibre–reinforcing materials. Abaca is a hard fibre and is entirely different from true hemp, which is a soft fibre and is the product of Cannabis sativa.

Abaca is superior fibre with its high tensile and folding strength, buoyancy, high porosity, resistance to saltwater damage, and long fibre length up to 3 m. The best grades of Abaca are fine, lustrous light beige in color and very strong. Abaca is the strongest of all natural fibres. It is use as raw material for cordage, fibre crafts, and pulp for the production of specialty paper products like security papers, tea bags, meat casings, nonwoven materials, and cigarette papers.

Table 4.1: Comparison of chemical composition of Abaca with other Natural Fibres

Chemical composition	Abaca (leaf)	Hemp (bast)	Jute (bast)	Sisal (leaf)	Linen (bast)	Cotton (seed)
Cellulose	68.32%	77.5%	64%	71.5%	82%	80-90%
Hemi cellulose	19.00%	10%	20%	18.5%	2%	4-6%
Lignin	12-13%	6.8%	13.3%	5.9%	4%	0-1.5%
Moisture Content	10-11%	1.8%	1.5%	4%	7.7%	6-8%
Ash content	4.8%	3.9%	1%	1%	3.4%	1-1.8%

Table 4.2: Comparison of Physical Properties of Abaca with other Natural Fibres

Physical properties	Abaca	Hemp	Jute	Sisal	Linen	Cotton
Density (gm/cm^3)	1.5	1.48	1.46	1.33	1.4	1.54
Fibre length (Mtr)	2-4	1-2	3-3.5	1	0.9	10-65 mm
Fibre diameter (microns)	150-260	16-50	60-110	100-300	12-60	11-22
Tensile strength (N/m^2)	980	550-900	400-800	600-700	800	400
Elongation	1.1%	1.6%	1.8%	4.3%	2.7-3.5%	3-10%
Moisture regain	5.81	12	13.75	11	10-12	8.5
Youngs modulus (Gpa)	41	30-60	20-25	17-22	50-70	6-10

4.1 The Abaca Plant

The matured Abaca plant consists of about 12 to 30 stalks radiating from a central root system. Each of these stalks is about 12 to 20 feet high and the fiber is stripped from the stem rather than the leaf, with each stalk being cut into sheaths and then strips or 'taxies'. The strips are then scraped to remove the pulp, then sometimes washed and dried. The outer leaves of the plant are wider and contain more but coarser fiber than the inner leaves. Harvesting of the stalks usually takes place between 18 to 24 months from the first shoots. The Abaca plant to the untrained eye can easily be mistaken for the banana plant - without the fruit.

4.2 Extraction Method for Abaca Fibre

Abaca fibre is extracted from the leaf sheath traditionally by stripping using either manual or mechanical process. When either of the process is used, tuxying is employed. Tuxying is the process of separating the outer sheath, which contains primary fibres, from the inner leaf sheath, where secondary fibres are found. The separated outer leaf sheath is called tuxy. An alternative method of extracting abaca fibre is by decortication. In this process, the whole leaf sheath is used to extract the fibre, recovering both the primary and the secondary fibres. In this production is higher compared to the traditional hand stripping and spindle stripping methods. In which the decortications method yields from 3.0 to 3.5% fibre. With the manual extraction process, fibre recovery is at 1.0%.the spindle stripping process yields from 1.5 to 2% fiber. Environmental Benefits includes Erosion control and biodiversity rehabilitation

4.3 Uses of Abaca

Today, it is still used to make ropes, twines, fishing lines and nets, as well as coarse cloth for sacking. There is also a flourishing niche market for Abaca clothing, curtains, screens and furnishings. Fibre craft products like Abaca rugs, doormats, hats, coasters, hot pads, linen and handbags became very much in demand abroad. The fiber craft industry became the second biggest foreign exchange earner for the Abaca industry, next to raw fibre exports. Cordage products include ropes, twines, marine cordage, binders, and cord.

4.4 Epoxy

Epoxy is a thermosetting polymer formed from reaction of an epoxide "resin" with polyamine "hardener". Epoxy has a wide range of applications, including fiber-reinforced plastic materials and general purpose adhesives

Epoxy is a co polymerthat is, it is formed from two different chemicals. These are referred to as the "resin" and the "hardener". The resin consists of monomers or short chain polymers with an epoxies' group at either end. Most common epoxy resins are produced from a reaction between epichlorohydrin and bisphenol-A, though the latter may be replaced by similar chemicals. The hardener consists of polyamine monomers, for example Triethylenetetramine (TETA). When these compounds are mixed together, the amine groups react with the epoxies groups to form a covalent bond. Each NH group can react with an epoxies' group, so that the resulting polymer is heavily cross linked, and is thus rigid and strong. In this experiment we are using L-12 epoxy as the matrix material for the bonding of composites. A substance or mixture added to a plastic composition to take part in and promote or control the curing action, also a substance added to control the degree of hardness of the cured film.

4.5 Composites fabrication

In the present work specimens were prepared for 50% fiber and 50% matrix volume fractions.

Hand Lay Up Technique:

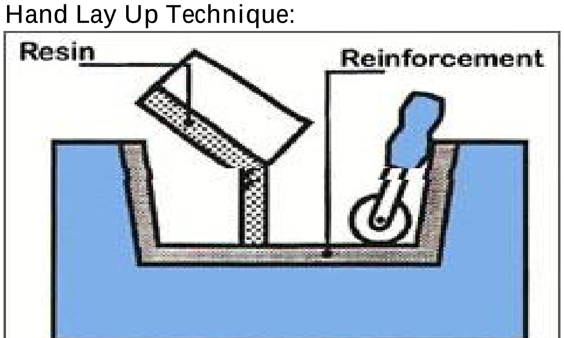


Fig 4.1 Hand Lay Up Technique

Hand layup technique for fabrication of specimens In this presnt work, hand lay-up method of fabricating the composite was applied as the method is cheap, can be comfortability made with available materials, before going to start lamination process, the required no reinforcement layer is cut according to calculation, during this time calculated quantity of epoxy and hardner are measured using measuring jars and poured into beaker.

In the presnt work along with reinforced composites, the procedure is to be followed by calculating the require quantity of epoxy and abaca fabric layers using the law of consistency of volume. Soon after pouring hardner into epoxy, the mixture is kept stirring ,till the completion of lamination using a glass rod , the measured quantity of epoxy is poured in a beaker , and then the hardner is added to the epoxy ,and the mixture is stirred well,this mixture is used for lamination

4.6 Specimen preparation

The specimens were prepared according to ASTM standards. The test specimen along with specimen dimension and standards for different tests are discussed below.

Laminates of abaca fabrics were fabricated by hand lay-up technique in a mold at laboratory temperature. The matrix material used was a medium viscosity epoxy resin (LAPOX L-12) and a room temperature curing polyamine hardener (K-6). This matrix was chosen, since it provides good resistance to alkalis and good adhesive properties.

5. EXPERIMENTAL WORK

The process of performing a scientific procedure, especially in a laboratory to determine something. There are a bewildering number of mechanical tests and test instruments. Most of these are tests are very specialized and have not been officially recognized as standardized tests. Some of these tests however, have been standardized and are described in the publications of the American Society for Testing and Materials. Although many tests have been standardized, it must be recognized that a standardized test may be no better than one that is not considered a standard. One objective of a standard of a standardized test is to bring about simplicity and uniformity to testing and such tests are not necessarily the best for generating the most basic information or the special type of information required by a research problem. The tests may not even correlate with practical use tests in some applications.

5.1 Tensile Test

A tensile test, also known as tension test, is probably the most fundamental type of mechanical test you can perform on material in which a sample is subjected to uniaxial tension until failure. Tensile tests are simple, relatively inexpensive, and fully standardized. By pulling on something, you will very quickly determine how the material will react to forces being applied in tension. As the material is being pulled, you will find its strength along with how much it will elongate.The results from the test are commonly used to select a material for an application, for quality control, and to predict how a material will react under other types of forces. Properties that are directly measured via a tensile test are ultimate tensile strength, maximum elongation and reduction in area. From these measurements the following properties can also be determined: Young's modulus, Poisson's ratio, yield strength, and strain-hardening characteristics.

Tensile test was performed in accordance with ASTM D3039, under displacement control using an UTM/E-40 with resolution of the piston movement of 0.01mm Table. Test specimens were well filed to attain overall length and gauge length of 250 x25x3 respectively and an appropriate cross section.

ASTM D3039 tensile testing is used to measure the force required to break a polymer composite specimen and the extent to which the specimen stretches or elongates to that breaking point. Tensile tests produce a stress-strain diagram, which is used to determine tensile modulus. The data is often used to specify a material, to design parts to withstand application force and as a quality control check of materials. Since the physical properties of many materials can vary depending on ambient temperature, it is sometimes appropriate to test materials at temperatures that simulate the intended end user environment.

5.2 Test procedure

Specimens are placed in the grips of a Universal Test Machine at a specified grip separation and pulled until failure. For ASTM D3039 the test speed can be determined by the material specification or time to failure (1 to 10 minutes). A typical test speed for standard test specimens is 2 mm/min (0.05 in/min). An extensometer or strain gauge is used to determine elongation and tensile modulus. Depending upon the reinforcement and type, testing in more than one orientation may be necessary.State-of-the-art equipment including Align-pro for reduced bending.

5.3 Rockwell hardness test

The Rockwell test is a hardness test based on indentation hardness of a material. The Rockwell test determines the hardness by measuring the depth of penetration of an indenter under a large load compared to the penetration made by a preload. While there are a number of Rockwell tests, the common is Rockwell B. Rockwell C is used on hard materials. When the material is very thin, lighter loads must be used. Resulting in Rockwell 30T, 1ST, Rockwell 15-N, 30-N scales.

5.4 Operation

The determination of the Rockwell hardness of a material involves the application of a minor load followed by a major load, and then noting the depth of penetration, vis a vis, hardness value directly from a dial, in which a harder material gives a higher number. The chief advantageof Rockwell hardness is its ability to display hardness values directly, thus obviating tedious calculations involved in other hardness measurement techniques. It is typically used in engineering and metallurgy. Its commercial popularity arises from its speed, reliability, robustness, resolution and small area of indentation. In order to get a reliable reading the thickness of the test-piece should be at least 10 times the depth of the indentation. Also, readings should be taken from a flat perpendicular surface, because convex surfaces give lower readings. A correction factor can be used if the hardness of a convex surface is to be measured. A correction factor can be used if the hardness must be measured on a round surface.

5.5 Brinell hardness test

Dr. J. A. Brinell invented the Brinell test in Sweden in 1900. The oldest of the hardness test methods in common use today, the Brinell test is frequently used to determine the hardness of forgings and castings that have a grain structure too course for Rockwell or Vickers testing. Therefore, Brinell tests are frequently done on large parts. By varying the test force and ball size, nearly all metals can be tested using a Brinell test. Brinell values are considered test force independent as long as the ball size/test force relationship is the same.

5.6 Impact Test

- **Charpy Impact Test Specimens as Per ASTM Standards**

When the striker impacts the specimen, the specimen will absorb energy until it yields. At this point, the specimen will begin to undergo plastic deformation at the notch. The test specimen continues to absorb energy and work hardens at the plastic zone at the notch. When the specimen can absorb no more energy, fracture occurs.

- **Specimen description**

Charpy test specimens normally measure 55x10x10mm and have a notch machined across one of the larger faces. The notches may be as fallow:

V-notch – A V-shaped notch, 2mm deep, with 45° angle and 0.25mm radius along the base.

5.7 Chemical Test

The fabricated composite is treated with acid & base like hydrochloric acid, sulfuric acid and mineral water. For this the specimen is cut for small dimension of 25x25 mm.The materials are kept in this solution for 6 days. The weight is measured before treating with the chemicals and repeatedly titrated values for every day. Then the values are noted.

5.8 SEM Analysis

The scanning electron microscope (SEM) uses a focused beam of high-energy electrons to generate a variety of signals at the surface of solid specimens. The signals that derive from electron reveal information about the sample including chemical composition, and crystalline structure and orientation of materials making up the sample. Areas ranging from approximately 1 cm to 5 microns in width can be imaged in a scanning mode using conventional SEM techniques (magnification ranging from 20X to approximately 30,000X, spatial resolution of 50 to 100 nm). The SEM is also capable of performing analyses of selected point locations on the sample; this approach is especially useful in qualitatively or semi-quantitatively determining chemical compositions (using EDS), crystalline structure, and crystal orientations (using EBSD). The design and function of the SEM is very similar to the EPMA and considerable overlap in capabilities exists between the two instruments.

The most common SEM mode is detection of secondary electrons emitted by atoms excited by the electron beam. The number of secondary electrons that can be detected depends, among other things, on specimen topography. By scanning the sample and collecting the secondary electrons that are emitted using a special detector, an image displaying the topography of the surface is created.

6. RESULTS AND DISCUSSION

In this study, the tensile, impact test and hardness test and chemical test were carried out on natural polymer fiber reinforced composites to study the effect of variation of different composites. In this section experimental result obtained for tensile, impact and hardness tests and chemical testate widely discussed. The results were analyzed by plotting bar graphs for materials that were having different proportions for different composite materials.

6.1 Tensile Test

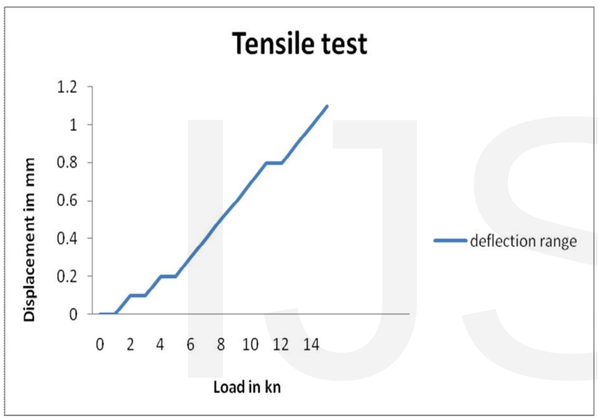


Fig.6.1 Tensile Test Characteristic Graph for Abaca

From the above graph as the load increases the deflection goes on changes from 0 to 0.2 mm. There was slight deflection in between 0 & 0.2 and suddenly the displacement changes on the load goes on increases. At the load 15 KN the displacement changes up to 1.1 mm & that is the breaking point for the tensile specimen, So from this conclusion by the literature survey shows that the nature of the material is Brittle. Hence, it is useful for the brittle application.

Fig6.2. Specimen before, & after testing.

6.2 Impact Test

Impact strength is obtained by dividing the energy absorbed (kg-m) by the cross sectional area of the specimen under the crack tip. Impact test is where in which rapid propagation of cracks without any excessive plastic deformation at a stress level below the yield stress of the material.

Sl.no	Type of Notch	Impact Energy (Joules)	Impact Strength(J/cm^2)
1	U-Notch	3.1	6.2
2	U-Notch	2.5	5
	Average	4.35	8.7
3	V-Notch	000.2	1.28
4	V-Notch	000.8	2.1
	Average	000.5	3.38

Table. 6.1 Impact Strength Report

Fig 6.3 Types of notches specimen

6.3 Rockwell hardness test

The Rockwell hardness has ability to display hardness values directly, thus obviating tedious calculations involved in other hardness measurement techniques. It is typically used in engineering and metallurgy. The hardness measured according to the depth of Indentation under minor load. The Rockwell number represents the difference in depth from the zero reference position as result of the applied load.

Sl. no	Type of Specimen	Rockwell Scale			Rockwell hardness no	Average
		L	60	1/4" Ball		67
1	Abaca Fiber				63	
2	Abaca Fiber				73	
3	Abaca Fiber				65	
		B	100	1/16" Ball		
4	Abaca				60	

	Fiber					64
5	Abaca Fiber				69	
6	Abaca Fiber				63	

Table 6.2 Readings of Rockwell hardness test report

Fig 6.4 Specimen tested for Rockwell hardness test

7.5 Brinell hardness test

The Brinell test is frequently used to determine the hardness of forgings and castings that have a grain structure too course for Rockwell or Vickers testing. By varying the test force and ball size, nearly all metals can be tested using a Brinell test. Brinell values are considered test force independent as long as the ball size/test force relationship is the same.

Sl.no	Type of Specimen	Major load(kg)	Dia of steel ball (D) mm	Dia of indentor (d) mm	BHN kg/mm^2	Average
1	Abaca fiber	187.5	2.5	1.8	62.40	54.79
2	Abaca fiber	187.5	2.5	1.9	54.55	
3	Abaca fiber	187.5	2.5	2.0	47.44	

Table 7.3 Showing the Experimented Chemical Values

Fig 7.5 Specimen tested for Brinell hardness test

Days	Hcl	H_2So_4	Water
Day 1	3.84	4.18	3.73
Day 2	3.96	4.37	3.81
Day 3	3.99	4.4	3.84
Day 4	4.05	4.45	3.95
Day 5	4.07	4.5	3.96
Day 6	4.11	4.87	3.98

Table 7.4 Readings of Chemical test report

7.6 Chemical test

Moisture observation of Hcl is 0.27 grm , $H_2So_4$is 0.69 grm& Water is 0.25 grm from first day to sixth day So delimitation for H_2So_4& it holds good for chemical treatment

Fig7.5 Specimens tested for Chemical test

7.7 SEM Analysis Report

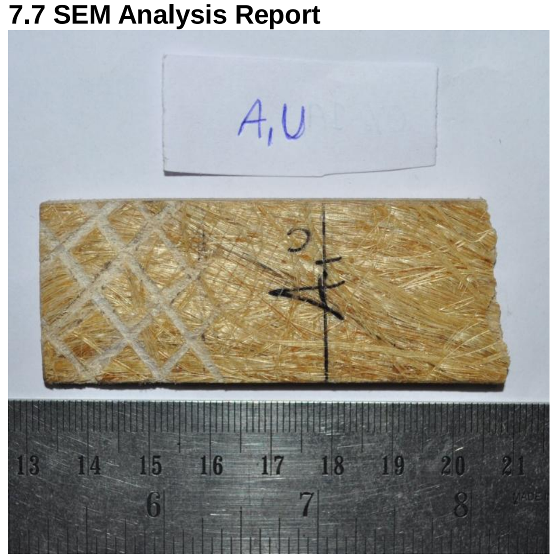
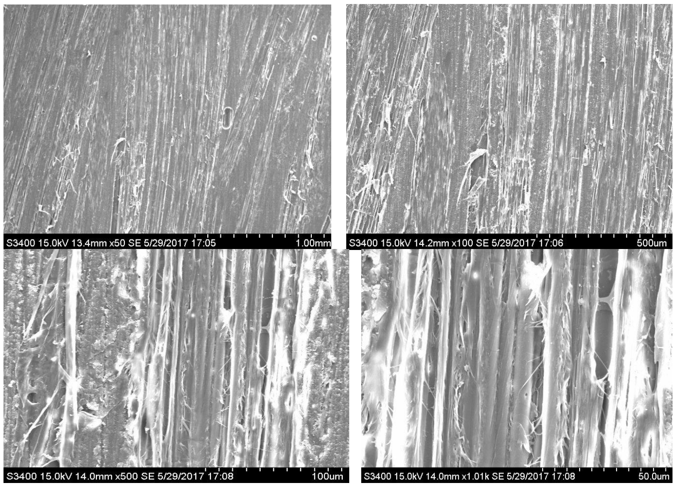
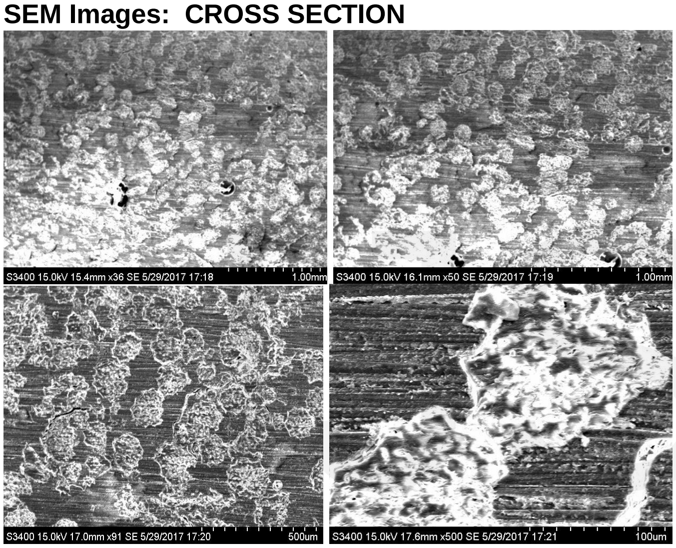


Fig.7.6 SEM Specimen Abaca

SEM IMAGE: SURFACE



SEM Images: CROSS SECTION



8. CONCLUSION AND FUTURE SCOPE

This part of the Paper includes the conclusions drawn out of results obtained from the experimentation and also includes the scope to continue the work further.

The scope in Natural fiber reinforced polymer composites has resulted in replacement of Synthetic fiber reinforced polymer composites in automotive, applications. Natural fibers are cheap, lighter in weight, biodegradable and are easily available as compared to Synthetic fibers. Chemical modification of natural fibers is necessary for increased adhesion between the hydrophilic fibers and hydrophobic matrix.

Scope

To increase the strength of the material and also to make it ductile material some ingredients is to be used to convert and also it changes to elastic property for the betterment of good results.

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