Synthesis and Characterization of Mechanical Properties of Natural Fibre Reinforced Composite Using Sisal and Abaca Fibre

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Abstract- *The global demand for wood as a building material is steadily growing, while the availability of this natural resource is diminishing. This situation has led to the development of alternative materials. Of the various synthetic materials that have been explored and advocated, composites claim a major participation as building materials. There has been a growing interest in utilizing natural fibres as reinforcement in composite for making low cost construction materials in recent years. Natural fibres are prospective reinforcing materials and their use until now has been more traditional than technical. Among the various natural fibres, Sisal and Abaca is of particular interest in that its composites have high impact strength besides having moderate tensile and flexural properties compared to other lignocelluloses fibres. In this project surveyed the research work published in the field of Sisal and Abaca and reinforced polymer composites with special reference to the structure and properties of Sisal and Abaca, processing techniques, and the physical and mechanical properties of the composites.*

Keywords: Natural fibre (abaca, sisal), Epoxy resin, Hardener.

I. INTRODUCTION

The use of fiber-reinforced composites is the key to lightweight construction, which is indispensable for modern life. Aerospace, automotive, shipbuilding or railway, rotor blades for wind energy generators or sports equipments – the applications for fiber-reinforced composites are manifold. Glass or carbon fibers, woven, unidirectional or multiaxial, are the most common reinforcements. Thermoplastic or thermosetting materials are used as matrices.

In many high-performance applications epoxy resins are used as matrix materials. All known manufacturing technologies for fiber-reinforced composites are used in the industry in combination with epoxy resins. Ski poles are made by using filament winding of carbon fibers in combination with anhydride cured epoxy resins. Machine parts are manufactured by using amine cured glass fiber prepregs. Profiles are produced by pultrusion using liquid resin systems. Aerospace parts are made by using carbon fiber prepregs based on tetra functional epoxy resins cured with aromatic amines in an autoclave. The most popular manufacturing technologies are injection technologies like resin transfer moulding (RTM), single-line injection (SLI), vacuum assisted resin transfer moulding (VARTM) etc. due to the relatively short manufacturing cycles. Rotor blades for wind energy generators are manufactured mainly by using vacuum-assisted infusion techniques. However, the viscosities of the resin systems used for injection technologies need to be low.

In engineering composite parts, e.g. a crank shaft for a sports car, the reinforcing fiber or fabric are nonwoven and their orientation towards the force along the part are of utmost importance. However, the choice of resin and hardener is important as well – to match performance as well as production cycle needs. Of course any improvement of the resin performance is welcome to help to improve the performance of the composite parts.

Introduction To Fibers

In our everyday life timber plays a significant role. However timber resources are getting depleted continuously while the demand for the material is ever increasing. According to the literature, by the beginning of the next century the wood will be scarce for the whole world (Singh, 1982). This situation has led to the development of alternative material.

Among the various synthetic materials that have been explored and advocated, plastics claim a major share as wood substitutes.

Plastics are used for almost everything from the articles of daily use to the components of complicated engineering structures and heavy industrial applications (Rai & Jai Singh, 1986). Plastics find an extensive application in buildings as flooring material because they are resistant to abrasion, have a low heat conductivity and low water absorption, sufficient hardness and strength.

They fail to swell when moistened, readily take on varnishes and paints. Hardware items like door and window frames, flushing cisterns, overhead water storage tanks and water fittings are commercially available and are finding acceptance in the building industry. Plastics are used to manufacture various sanitary wares, which include wash basins, bathtubs, sinks, shower cabins, washing racks and others. Plastic pipes are widely used in the installation of various industrial purposes, water supply etc.

However, during the last decade, the study of filled plastic, the study of filled plastic composites has simulated immense interest in meeting the future shortage of plastic materials (Lightest, 1983). In fact, synthetic fibres such as nylon, rayon, aramid, glass, polyester and carbon are extensively used for the reinforcement of plastics (Erich et al., 1984; Lawrence et al., 1995).

Nevertheless, these materials are expensive and are non-renewable resources. Because of the uncertainties prevailing in the supply and price of petroleum based products, there is every need to use the naturally occurring alternatives. In many parts of the world, besides the agricultural purposes, different parts of plants and fruits of many crops have been found to be viable sources of raw material for industrial purpose. In recent years, polymer composites containing vegetable fibres have received considerable attention both in the literature and in industry.

The interest in natural fibre reinforced polymer composites is growing rapidly due to the high performance in mechanical properties, significant processing advantages, low cost and low density (Satyanarayana et al., 1990a,b). Natural fibres are renewable resources in many developing countries of the world; they are cheaper, pose no health hazards and, finally, provide a solution to environmental pollution by finding new uses for waste materials.

Fibre Types And Scientific Names

The following table 1.1 describes the fibre types and its scientific names.e most striking technical developments of recent years have been the rapid growth of World Wide Web. Web sites are identified by Uniform Resource Locator (URL) address. The browser access uniform resource locator entered

Common	Scientific Name	Fibre	Family	Native Region	Uses
Flax	Linum usitatisimum	Bast (stem)	Linaceae	Eurasia	Linen fabrics, seed oil
Ramie	Boehmeria nivea	Bast (stem)	Urticaceae	Tropical asia	Textiles (blended with cotton), paper, cordage
Hemp	Cannabis sativa	Bast (stem)	cannabaceae	Eurasia	Cordage, nets, paper
Jute	Sativa	Bast (stem)	Tiliaceae	Eurasia	Cordage, burlap, bagging
Kenaf	Corchorus capsularies, Corchous olitorious	Bast (stem)	Fabaceae	Central asia	Cordage.fire, hoses
Sisal	Agave sisalana	Hard (leaf)	Agavaceae	Mexico	Cordage, bagging, coarse fabrics
Abaca	Musa textiles	Hard (leaf)	Musaceae	Philippines	Marine cordage, paper
Coir	Cocos nucifera	Fruit fibre	Aracaceae	Philippines	Rugs, mats, brushes

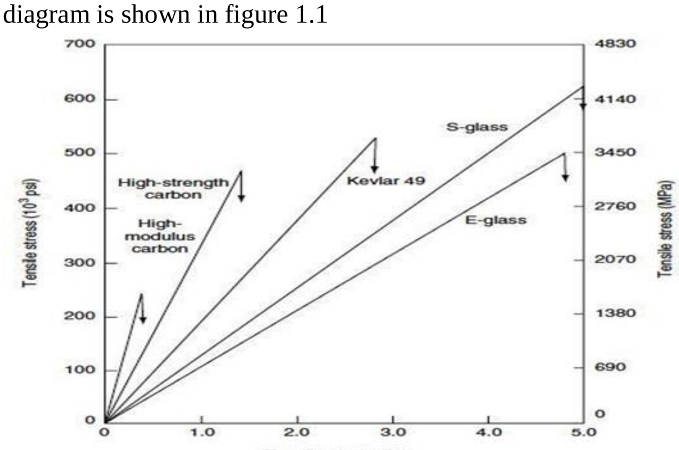
Stress Strain Relationship of Various Fibres

The cumulative distribution of strength is given by the following equation:

F(σfu) = 1- exp [-(Lf / Lo) (σfu / σo) ∞]

Where F(σfu) represents the probability of filament failure at a stresslevel lower than or equal to F(σfu).The parameters and so in equation are called the Weibull parameters, and are determined using the experimental data.

A can be regarded as an inverse measure of the coefficient of variation. The higher the value of a, the narrower is the distribution of filament strength. The scale parameter so may be regarded as a reference stress level. The stress strain diagram is shown in figure 1.1



Tensile stress–strain diagrams for various reinforcing fibers.

Fig.1.1 Stress Strain diagram

Manufacturing Methods

The sisal fiber lies along the length of the leaf, being most abundant near the surface of the leaf where it is long and strong. The interior fibers are weaker, and they are usually removed during processing. It is usually obtained by machine decortications in which the leaf is crushed between rollers and then mechanically scraped. The fiber is then washed and dried by mechanical or natural means.

Abaca is also called Manila hemp, abaca is extracted from the leaf sheath around the trunk of the abaca plant (Musa textiles), a close relative of the banana, native to the Philippines and widely distributed in the humid tropics. Harvesting abaca is laborious. Each stalk must be cut into strips which are scraped to remove the pulp. The fibers are then washed and dried.

Handlay Up Method

There are numerous methods for fabricating composite components. Some methods have been borrowed (injection molding, for example), but many were developed to meet specific design or manufacturing challenges.

Selection of a method for a particular part, therefore, will depend on the materials, the part design and end-use or application.

Composite fabrication processes involve some form of molding, to shape the resin and reinforcement. A mold tool is required to give the unformed resin /fiber combination its shape prior to and during cure.

Resins are impregnated by hand into fibres which are in the form of woven, knitted, stitched or bonded fabrics. This is usually accomplished by rollers or brushes, with an increasing use of nip-roller type impregnators for forcing resin into the fabrics by means of rotating rollers and a bath of resin. Laminates are left to cure under standard atmospheric conditions.

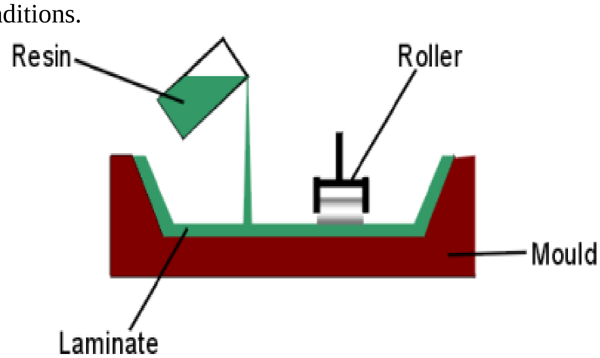


Figure 1.2 shows the Hand lay up process.

Hand lay-up is the simplest and oldest open molding method of the composite fabrication processes. Glass or other reinforcing mat or woven fabric or roving is positioned manually in the open mold, and resin is poured, brushed, or sprayed over and into the glass plies.

Testing Of Composites

The mechanical tests of the composite includes tensile, flexural, impact were performed in order to find the mechanical properties of the composite.

Tensile Test

Tensile tests measure the force required to break a plastic sample specimen and the extent to which the specimen stretches or elongates to that breaking point.

These tests are use to apply a stress to a material and record the materials response to this stress. The mathematical definition of stress (S) is the load (P) on a body distributes over the cross sectional area of that body.

$$\mathbf{S = P / A}$$

A tensile stress tends to pull a member apart; a compressive stress tends to crush or collapse a body; a shear stress tends to cleave a structural member; a torsion stress tends to twist a member; a bending stress tends to deflect a member. Figure 4.2 shows the tensile testing machine.

These machines apply a tensile load when one end of the test sample is attached to a movable cross head with the other end fixed to a stationary member. The cross head is then driven in such a manner as to pull the sample apart. A tensile test is performed by instrumenting the sample with an electrical device to measure strain (extensometer) and then stretching the sample until it falls. The stretch, both elastic and plastic, is called strain. Elastic strain is recoverable when the loads are removed; plastic strain by definition is irrecoverable. A material response to the three major forms of stress – tension, compression, and shear can be measured on a universal testing machine.

ASTM D-638 Tensile Test Procedure

Specimens are placed in the grips of the universal tester at a specified grip separation and pulled until failure. For ASTM D 638 t he test speed is determined by the material specification. Figure 1.3 shows the tensile test specimen.

Fig.1.3 Tensile Test Specimen

Impact Test

The data is often used to specify appropriate materials for applications involving impact. The test is also used to evaluate the effect of secondary finishing operations or other environmental factors on plastic impact properties. Figure 1.4 shows the impact test specimen.

The specimen is clamped onto the testing platform. The crosshead, with the attached Tup, is raised to the appropriate height and is released so it impacts at a specified speed. A load-deflection curve is produced

Fig.1.3 Impact Test Specimen

Flexural Properties Testing

The flexural test measures the force required to bend a beam under three point loading conditions. The data is often used to select materials for parts that will support loads without flexing. Flexural modulus is used as an indication of a material’s stiffness when flexed. Since the physical properties of many materials (especially thermoplastics) can vary depending on ambient temperature, it is sometimes appropriate to test materials at temperatures that simulate the intended end use environment.

Fig.1.3 Flexural Test Specimen

ASTM D790 Flexural Test Procedure

Most commonly the specimen lies on a support span and the load is applied to the center by the loading nose producing three point bending at a specified rate. Figure 1.3 shows the Flexural Test Specimen.

The parameters for this test are the support span, the speed of the loading, and the maximum deflection for the test. These parameters are based on the test specimen thickness and are defined differently by ASTM and ISO.

II. EXPERIMENTAL INVESTIGATION

In this chapter, the detailed analysis is carried out for a specimen via UTM (Universal Testing Machine) and to find the Tensile, flexural, Impact, Hardness and Temperature distribution respectively for the generated specimen.

2.1 UTM [UNIVERSAL TESTING MACHINE]

A Universal Testing Machine (UTM), also known as a Universal tester, materials testing machine or materials test frame, is used to test the tensile strength and compressive strength of materials. The “Universal“ part of the frame reflects that it can perform many standard tensile and compression tests on materials, components, and structures (in other words, that it is versatile).

2.2 UTM PROCEDURE

The setup and usage are detailed in a test method, often published by a standard organization. This specifies the sample preparation, fixturing, guage length (the length which is under study or observation), analysis, etc.

The specimen is placed in the machine between the grips and an extensometer if required can automatically record the change in guage length during the test.

If an extensometer is not fitted, the machine itself can record the displacement between its cross heads on which the specimen is held. However, this method not only records the change in length of the specimen but also all other extending / elastic components of the testing machine and its drive systems including any slipping of the specimen in the grips.

Only the machine is started it begins to apply an increasing load on specimen. Throughout the tests the control system and its associated software record the load and extension or compression of the specimen.

2.3 ANSYS

ANSYS is a complete FEA software package used by engineers worldwide in virtually all fields of engineering. ANSYS is a virtual prototyping technique used to iterate various scenarios to optimize the product.

SOME SPECIFIC CAPABILITIES OF ANALYSIS

Static Analysis

It is the used to determine displacement, stress etc. under static loading conditions. Ansys can compute linear and non-linear types. (e.g. the large strain hyper elasticity and creep problems)

Thermal Analysis

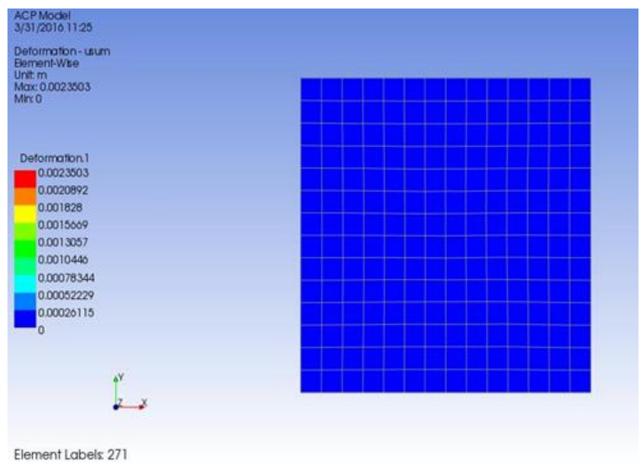
The steady state analysis of any solid under thermal boundary conditions calculates the effect of steady thermal load on a system (or) component.

PROCEDURE

1. Start →Program → Ansys → Ansys product launcher
2. Preference → Thermal →Ok
3. Preprocessor → Element Type → Add→ Add→ Solid → Quad 4 node 55 → Ok
4. Material Properties → Material Library → Import Library → SI (MKS) → Ok

   Browse → C: Program file → Ansys INC →V140 → Ansys → Matlib → select any one material → open → Ok → close
5. Modelling → create → Area → Rectangle → By 2 corners → Width =100, Height = 100 → Ok
6. Meshing → Mesh Tool → Global , Set → Element type = 10 → Click small size → Mesh → Select the object → Ok
7. Solution → Define load → Apply → Thermal → Temperature → On lines → Select the left line
8. → Temp Value = 40º → Apply → select the right side line → Temp value = 120º C → Ok
9. Solution → Define Load → Apply → Convection → on lines → Film coefficient = 20, Bulk Temp = 20º C → Ok
10. Solve → Current LS → Ok
11. General postprocessor → Plot Result → Contour Plot → Nodal Solution → DOF Solution → Nodal Temp → Ok

To check the Temperature at various point: Query Result → Subgrid solution → DOF solution → Temperature → Ok → click any point on the object Temperature value displayed on the screen.



III. RESULT AND DISCUSSION

Tensile test is a very common testing method that is used to establish the tensile force or crush resistance of a material and the ability of the material to recover after a specified dimension. The tensile & Flexural test results are tabulated as shown in Table.3.1

Table 3.1 Tensile & Flexural test observation for Composite Material

Test Taken	**Thickness (mm)**	**Load in kN**	**Displacement in mm**
Tensile	3	7.28	6.72
Flexural	3	29	16.01

Table 3.2 Impact & Hardness test observation for Composite Material

Test Taken	Thickness (mm)	Load kN	Test value's
Impact	3	7.286	298 J
Hardness	3	20	436 HBW

Table 3.3 Comparison of Tensile and flexural tests for various natural fibre composites

S.No	Test Parameters	Sisal-Abaca		Sisal-Jute		Sisal-Coir	
		Load kN	Elongation mm	Load kN	Elongation mm	Load kN	Elongation mm
1	Tensile	7.286	6.72	7.286	7.24	7.286	5.72
2	Flexural	29	16.006	29	17.006	29	14.006

From the above table 3.3, the value of tensile and flexural strength as we measured on universal testing machine is higher compared to the Sisal and Jute composite. The Tensile and flexural strength increases and their values are 6.72 kN and 29 kN respectively.

An experiment was conducted on the stability and strength of sisal & abaca through three full scale tests. The following conclusions were made from the full-scale tests, it was clear that the global flexural buckling is the main failure mode of the fibre properties.

The maximum stress it withstands before failing is its ultimate tensile strength. Ultimate tensile strength (UTS), often shortened to tensile strength (TS) or ultimate strength, is the maximum stress that a material can withstand while being stretched or pulled before failing or breaking.

IV. CONCLUSION

The characterization of the Abaca and Sisal fibre have the higher mechanical properties (Tensile, Flexural, Impact and Hardness) when compared to the sisal and coir composites.

Due to the low density and high specific properties of Sisal and Abaca fibres, composites based on these fibres may have very good implementations in the automotive and transportation industry.

The systematic and persistent research there will be a good scope and better future for Sisal and Abaca fibre – polymer composites in the coming years.

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