A STUDY ON NATURAL SISAL FIBRE COMPOSITES

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BONAFIDE CERTIFICATE

Certified that this project report titled "A STUDY ON NATURAL SISAL FIBRE COMPOSITES" is the bonafide work of Mr. N. Ponnarasu who carried out the research under my supervision. Certified further, that to the best of my knowledge the work reported herein does not form part of any other project report or dissertation on the basis of which a degree or award was conferred on an earlier occasion on this for any other candidate.

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A STUDY ON NATURAL SISAL FIBRE COMPOSITES

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ABSTRACT

Sisal fibre is a promising reinforcement fore use in composites on account of its low cost, low density, high specific strength and modulus, no health risk, easy availability in some countries and renewability. In recent years, there has been an increasing interest in finding new applications for sisal-fibre-reinforced composites that are traditionally used for making ropes, mats, carpets, fancy articles and others. The mechanical properties of sisal fibre and itself.

Sisal fibre fabrics were made using hand looms. Using this fabric in single, double and four layers composites were made with the polyester resin as a binder.

The composite were made in a compression moulding machine. The composites tested for their mechanical properties such as tensile strength, flexural strength and impact strength. Composites were tested in three possible directions of orientation of fabrics (0^0, 45^0,90^0 orientation). The results show that the four layer fabrics laminates giving the higher level of mechanical properties than single and double layers composites.

Key words: sisal composites, sisal/polyester composites, sisal/natural composites.

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CHAPTER 1

INTRODUCTION

Glass, Carbon, Boron are being increasingly used as reinforcing fibres in FRP (Fibre reinforced plastics) which has been widely accepted materials for structural and non-structural applications. FRP has gained importance due to their higher Specific modulus, high stiffness to weight ratio and high strength to weight ratio compared to conventional materials. These materials are expensive and find their use in high-end applications. Natural fibres like banana, cotton, coir, jute and sisal now attracted the researchers for their applications in consumer goods, low cost housing and other civil structures. Sisal appeals to be a potential candidate because of its commercial availability and their inexpensiveness. In this project plain-woven sisal was used as reinforcing material in the laminates. The effect of layers and lay up angle and the mechanical properties were studied.

The sisal composites were produced with the polyester resin as a bonding agent and the cost of the production is also a considerable one. The sourcing of the raw material is also easy. Because, there are abundant at the village side our country, which is not perfectly used by the people, the production cost of the composites will be cheaper than the other natural composites. The usage of the material should be increased because of its high strength and its appearances. In future it's sure that the sisal composites have a place in the field of composites.

CHAPTER 2

LITERATURE REVIEW

Sisal fibre is one of the most widely used natural fibers and is very easily cultivated. It has short renewal times and grows wild in the hedges of fields and railway tracks[1]. Nearly 4.5 million tons of sisal fibers are produced every year throughout the world. Tanzania and Brazil are the two main producing countries [2].

Sisal fibre is a hard fibre extracted from the leave of the sisal plant (Agave sisalana). Though native to tropical and sub-tropical North and South America, sisal plant is now widely grown in tropical countries of Africa, the West Indies and the Far East [3]. A sketch of a sisal plant is shown in Fig. 2.1 and sisal fibres are extracted from the leaves. A sisal plant produces about 200-250 leaves and each leaf contains 1000-1200 fibre bundles which is com-posed of 4% fibre, 0.75% cuticle, 8% dry matter and87.25% water [1]. So normally a leaf weighing about 600 g will yield about 3% by weight of fibre with each leaf containing about 1000 fibres.

The sisal leaf contains three types of fibres [3]: mechanical, ribbon and xylem. Mechanical fibres are mostly extracted from the periphery of the leaf they have a roughly thickened-horseshoe shape and seldom divide during the extraction processes. They are the most commercially useful of the sisal fibre. Ribbon fibres occur in association with the conducting tissues in the median line of the leaf.

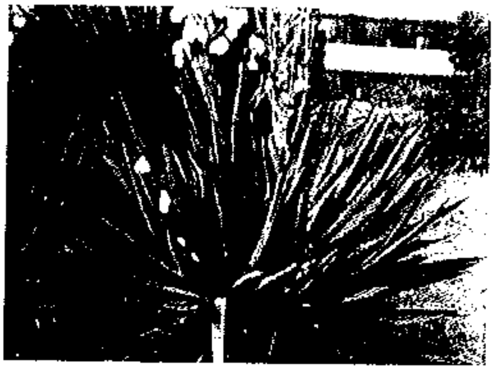

Figure 2.1 Agave Sisalana

Fig. 2.1 shows a cross-section of sisal leaf and indicates where mechanical and ribbon fibres are obtained[3]. The related conducting tissue structure of the ribbon fibre gives them considerable mechanical strength. They are the longest fibres and compared with mechanical fibres they can be easily split longitudinally during processing. Xylem fibres have an irregular shape and occur opposite the ribbon fibres through the connection of vascular bundles as shown in Fig. 2.2. They are composed of thin-walled cells and are therefore easily broken up and lost during the extraction process[2]. The methods include[2] retting followed by scraping[2] and mechanical means using decorticators. It is shown that the mechanical process yields about 2-4% fibre (15 kg per 8 h) with good quality having lustrous colors while the retting process yields a large quantity of poor quality fibres. After extraction, the fibres are washed thoroughly in plenty of clean water to remove the surplus wastes such as chlorophyll, leaf juices and adhesive solids

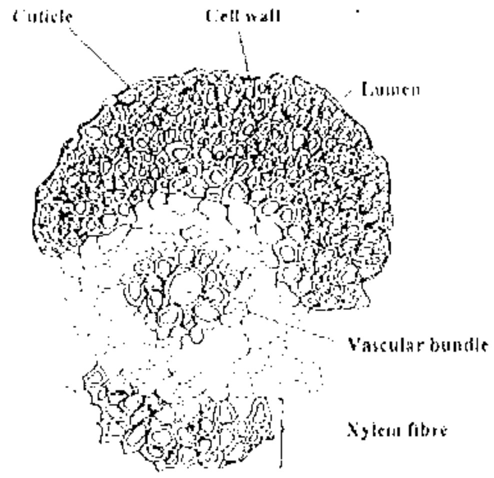

Figure 2.2 cross-section of fibre bundle

The chemical compositions of sisal fibres have been reported by several groups of researchers [4-7] For example, sisal fibre contains 78% cellulose, 8% lignin, 10% hemi-celluloses, 2%waxes and about 1% ash by weight; but again it was found that sisal contains 43-56% cellulose, 7-9% lignin, 21-24% pentosan and 0.6-1.1% ash. More recently, reported[6] that sisal contains 85-88% cellulose. These large variations in chemical compositions of sisal fibre are a result of its different source, age, measurement methods, etc.

Indeed, other researches showed that the cellulose and lignin contents of sisal vary from 49.62-60.95 and 3.75-4.40%, respectively[7], depending on the age of the plant.

The length of sisal fibre is between 1.0 and 1.5 m and the diameter is about 100-300 mm [8]The fibre is actually a bundle of hollow sub-fibres. Their cell walls are reinforced with spirally oriented cellulose in a hemi-cellulose and lignin matrix. So, the cell wall is a composite structure of lingo cellulose material reinforced by helical microfibrillar bands of cellulose. The composition of the external surface of the cell wall is a layer of ligancies material and waxy substances, which bond the cell to its adjacent neighbors. Hence, this surface will not form a strong bond with a polymer matrix. Also, cellulose is a hydrophilic glucan polymer consisting of a linear chain of 1, 4-β-bonded a hydro glucose units [9]and this large amount of hydroxyl groups will give sisal fibre hydrophilic properties. This will lead to a very poor interface between sisal fibre and the hydrophobic matrix and very poor moisture absorption resistance.

Though sisal fibre is one of the most widely used natural fibres, a large quantity of this economic and renewable resource is still underutilized. At present, sisal fibre is mainly used as ropes for the marine and agriculture industry [1]. Other applications of sisal fibres include twines, cords, upholstery, padding and mat making, fishing nets, fancy articles such as purses, wall hangings, tablemats, etc. [10]. A new potential application is for manufacture of corrugated roofing panels that are strong and cheap with good fibre resistance[11]. During the past decade (1987-1998), the identification of new application areas for this economical material has become an urgent task. The use of sisal fibre as reinforcement in composites has raised great interest and expectations amongst materials scientists and engineers.

2.1. PROPERTIES OF SISAL FIBRE

2.1.1. Price

Compared to synthetic fibres, the price of sisal fibre (0.36 US$/kg) is very low [3]. It is about one-ninth of that of glass fibre (3.25 US$/kg) and one five hundredth of carbon fiber (500 US$/kg) for specific price (modulus per unit cost), it (41.67 Gpakg/$) is almost the best next to jute (43.33 GPakg/$) amongst all the synthetic and cellulose fibres.

2.1.2. Properties

Generally, the strength and stiffness of plant fibres depend on the cellulose content and the spiral angle, which the bands of micro fibrils in the inner secondary cell wall make with the fibre axis. That is, the structure and properties of natural fibres depend on their source, age, etc. [12]. The tensile properties of sisal fibre are not uniform along its length [3]. The root or lower part has low tensile strength and modulus but high fracture strain. The fibre becomes stronger and stiffer at mid-span and the tip has moderate properties. Table 2.1.2 shows the properties of sisal fibres as reported by different researchers. Note that except for the structure and properties of the natural fibre itself, experimental conditions such as fibre length, test speed, etc., all has some effects on the properties of natural fibres .[13,14]

Table 2.1.2 Properties of Sisal Fiber

S.No	Density (Kg/m^3)	Moisture Content (%)	Tensile strength (Mpa)	Tensile Modulus (Gpa)	Diameter (μm)	Elongation (%)
1.	1450	11	604	9.4-15.8	50-200	-
2.	1450	11	530-640	9.4-22	50-300	3-7
3.	1030	11	500-600	16-21	-	3.6-5.1
4.	1410	11	400-700	9-20	100-300	5-14
5.	1400	11	450-700	7-13	-	4-9
6.	1450	11	450-700	7-13	-	4-9

Various researchers [1] studied the effects of fibre diameter, test length and test speed on the tensile strength, initial modulus and percent elongation at the break of sisal fibres. They concluded that no significant variation of mechanical properties with change in fibre diameter was observed. However, the tensile strength and percent elongation at the break decrease while Young's modulus increases with fibre length. With increasing speed of testing, Young's modulus and tensile strength both increase but elongation does not show any significant variation. However, at a test speed of 500 mm/min, the tensile strength decreases sharply. These results have been explained in terms of the internal structure of the fibre, such as cell structure, micro fibrillar angle (20-25°c), defects, etc. In rapid mechanical testing, the fibre behaves like an elastic body, i.e. the crystalline region shares the major applied load resulting in high values of both modulus and tensile strength. When the testing speed decreases, the applied load will be borne increasingly by the amorphous region. How ever, at very slow test speeds, the fibre behaves like a viscous liquid. The amorphous regions take up a major portion of the applied load giving a low fibre modulus and a low tensile strength. But at very high strain rates (~500 mm/min), the sudden fall in tensile strength maybe a result of the presence of imperfections in the fibre causing immediate failure.

2.2. INTERFACE MODIFICATIONS

Interfaces play an important role in the physical and mechanical properties of composites [18,19]. The hydroxyl groups that occur throughout the structure of natural fibres make them hydrophilic, but many polymer matrices are hydrophobic so that sisal-polymer composites have poor interfaces. Also, the hydrophilic sisal fibres will absorb a large amount of water in the composite leading to failure by delamination. Better wetting and chemical bonding between fibre and matrix can achieve adequate adhesion across the interface at desirable levels

2.2.1. Sisal/Polyester Composites

The properties of sisal fibre-reinforced polyester composites can be improved when sisal fibres were suitably modified with surface treatment[24]. it was explained that the modified interphase is much less stiff than the resin Matrix and provides a deformation mechanism to reduce interfacial stress concentration[25]. Further, it may also prevent fibre/fibre contacts hence removing the sources of high stress concentrations in the final composites, by improving interfacial adhesion the moisture-induced degradation of composites can be reduced. Treated fibre composites absorb moisture at a slower rate than the untreated counterparts, probably because of the formation of a relatively more hydrophobic matrix interface region by co reacting organo-functionality of the coupling agents with the resin matrix., the strength retention of surface treated composites is higher than that of composites containing untreated sisal fibres.

CHAPTER 3

OBJECTIVE

The main objective in this project is to

- To study the potential for usage of sisal as a reinforcement in a composite material.
- To study the effect of number of layers on the mechanical properties of the composites.
- To study the effect of lay up angles on the mechanical properties of the composites.

CHAPTER 4

METHODS

4.1 Hand and Machine Lay-up

This is the simplest way of manufacturing composites fibre are fabric layers are place on a mould with resin applied to successive layers until the desired thickness is reached. A gel coat is applied on the mould for better quality surface. Prepregs are very suitable for hand lay-up techniques to avoid any wet process. Prepregs are yarns and fabrics that are already impregnated or melted with resin. A roller is used to remove the entrapped air, control the thickness, and guarantee good wet out and smooth surface. The curing usually takes place at room temperature or under heat to speed up the process. Usually polyester and epoxy resins are used for hand lay-up.

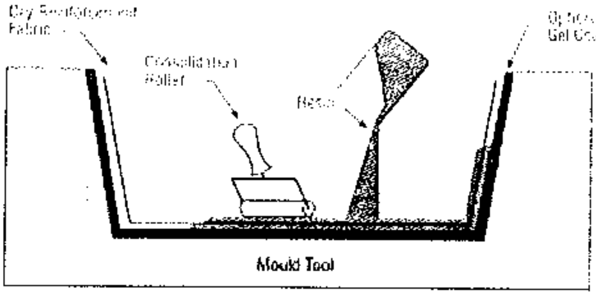

Figure 4.1 Hand and Machine Lay-up

Machine lay-up is the automated from the hand lay-up. Computer controlled automatic tape lying machines are used to lay down fibre or fabric. This process provides consistency and increased speed.

4.2 Spray-up Moulding

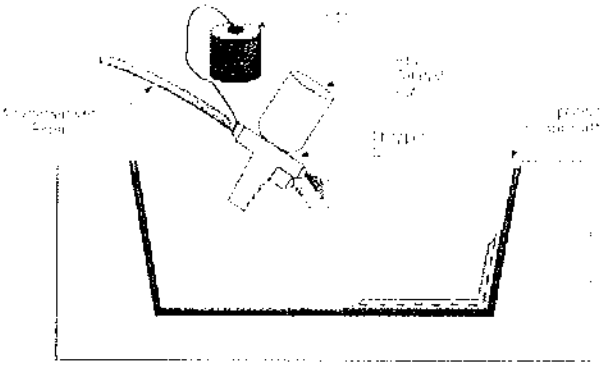

Figure4.2 Spray-up Moulding

Chopped fibres and resin are simultaneously deposited on a mold using spraying equipment. Gel coat is applied by spray gun. Curing takes place at room or elevated temperatures. Polyester and epoxy resins are used.

4.3 Injection Moulding

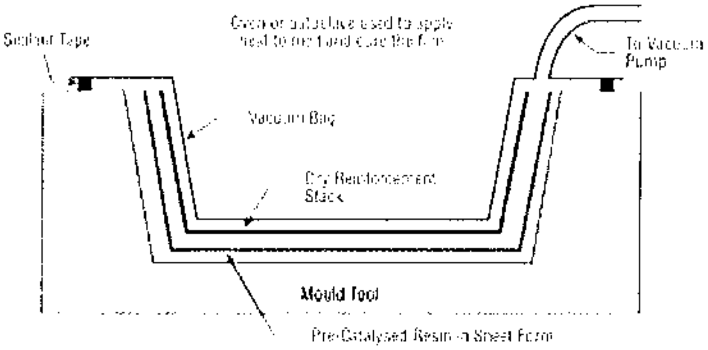

Figure 4.3 Injection Moulding

Injection moulding is similar to metal die-casting. It is a high-pressure process to produce thermoplastic and thermo set parts. The matrix is melted and forced into the mould cavity, where it freezes and is ultimately ejected as a finished part. The injection moulding process permits final part detail and can be easily automated. The part and mould can be designed such that near-net shape parts can be manufactured. There is a limit to the amount and types of fibre reinforcement that can be included in an injection-moulded part. The injection moulding process of thermoplastic and thermo sets is slightly different. In the thermoplastic injection moulding process, molten thermoplastic material is forced through an orifice into a cold mould where it solidifies. In thermo set injection moulding, a reacting material is forced into a warm mould where the material further polymerises or cross-links to a solid part.

4.4 Pultrusion

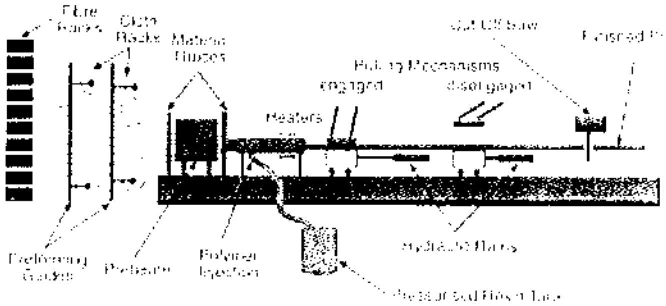

Figure 4.4 Pultrusion

Continuous reinforcement fibres or roving are drawn through a resin bath for impregnation and through a heated die to produce the desired shape and control the resin content in continuous process. Pultrusion is especially suitable for unidirectional reinforcement for simple cross sectional structures such as circular rods, tubes, channel and I beams. Drawing velocity and mould temperature is critical during the process. Polyester and epoxies are commonly used in pultrusion. The resulting composite has excellent mechanical properties due to good fibre alignment and high fibre fraction.

4.5 Compression Moulding

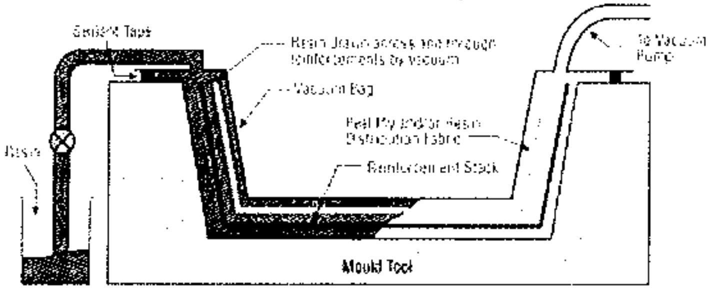

Figure 4.5 Compression Moulding

In this method, prepregs or wet impregnated textile performs are placed into an open mould. The mould is closed and heat and pressure are applied until the structure is formed and cured. Adjusting the final distance between press platens can control the laminate thickness. Excess resin is usually allowed to escape. Both thermosetting and thermoplastic polymers are suitable for compression moulding. The textile performs can be vacuumed before moulding to eliminate air bubbles in the composite. Compression moulding is especially suitable for manufacturing flat or slightly curved planes or laminates. The advantages of compression moulding includes low cost, little mineral waste with close tolerances, part to part uniformity and reproducibility, good control of fibre to resin ratios and void content, and shorter cycle times. The compound can be heavily filled with little orientation of resin or additives.

4.6 Resin Transfer Moulding (RTM)

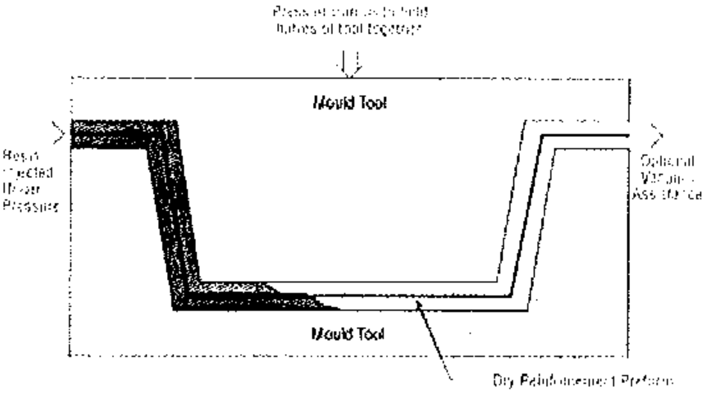

Figure 4.6 Resin Transfer Moulding (RTM)

Resin transfer moulding also called resin injection moulding, is suitable for manufacturing of high fibre volume fraction (up to 70%) composite structures. In the RTM process, the resin system is transferred, at low viscosity and pressure, into the textile perform already placed in the closed mould. The resin system may consists of resins, curing agents, catalysts, promoters, inhibitors, etc., which may be premixed or mixed during the process using an on-line static mixer. The resin system is then injected in to the mould .the resin is transferred at the pressure of 20 - 80 psi and/or with a vacuum in the range of 26-29 inch Hg. For good filling and wetting characteristics, viscosity of the resin should be less than 100 cP at injection temperature. After filling with resin, the mould is sealed and heated for curing. Boron, Kevlar, Glass, ceramic and graphite textile reinforcement structures are suitable for RTM. Woven, stitched, braided, knit and other performs can be consolidated in the RTM process. Typical resin materials are polyester and epoxy. RTM offers high production rates, more consistent parts, materials and labour savings.

CHAPTER 5

MATERIALS AND METHODS

Sisal fibre obtained from the AGAVA plant was manually twisted to produce the yarn. The yarns where then conditioned and taken for weaving. Normally sisal fibres are twisted in wet condition because of its stiffness, the moisture will act as a lubricant to the fibres while twisting.

5.1 FIBRE EXTRACTION

The fibre from the leaf of the AGAVA plant has to be extracted. First the leaves were bundled and then it is stacked in the water for a week and then the fleshy part in the leaf is split from the leaf. The process of removing the fibres from the leaf is known as.

Then the fibres are cleaned and washed well and then it is cleaned well from the foreign materials and fibre to fibre separation is done and sent for the next process.

5.2 Spinning of Sisal Yarn

The sisal yarn is very hard in nature and then wetting agents were used to wet the material to assist the skinning operation. Here normally water is used so that the fibre cohesion is carried out and then compact, good quality yarn is obtained. The opening is done normally by hand and then the drafting and twisting is done manually and then the twisted yarn is finally wound in the spindle form and it is taken for the next operation.

A special care is to be taken while spinning, otherwise we can't achieve the uniform yarn. For fixing the twist in the yarn, wetting agents are used.

5.3 Weaving of Sisal Yarn

The Sisal yarn produced, were then woven in a handloom with suitable modifications. Weaving of sisal yarn is a risky task due to its density. Normally these yarns are manually twisted and the uniformity is also very poor. While weaving the shed depth is minimised to reduce the strain put on the warp yarns. Due to very high stiffness of the yarn weaving is done at wet condition, that is to improve the elongation of the yarn .the yarn particulars and fabric particulars are given below

Yarn count - 1 Ne
Twist - 2 tpi
Tensile Strength
Fabric particulars
EPI - 5
PPI - 12
Weave: plain (1/1)

5.4 COMPOSITE FABRICATION

Two major steps in manufacturing of composites are wetting of textile reinforcement structure with resin (matrix) and curing which is 3D formation of a polymer network. During curing, hardening of resin takes place and bonding is formed between the resin and the fibres in the reinforcement structure (consolidation). Curing can be done unaided or with application of heat and / or pressure for faster polymerisation. Most widely used methods are given below (1987))

In our work a simple hand lay-up method has been used for preparation of composite. The working surfaces were coated with wax and pva for easy removal of the laminates from the mould, the matrix material was prepared from commercially available room temperature curing GP Polyester Resin, Catalyst in a weight ratio of 1:0.015 respectively purchased from a private company source. The resin catalyst was thoroughly mixed together followed by the vacuum treatment for 3 to 5 min to remove the air bubbles. Before the commencement of composite fabrication the sisal fabrics were dried in an oven at 100° C for 3hrs to remove moisture in the fabric. Each layer of fabric is then pre impregnated and placed one over another in the mould. The brush was used to push away any air cavities to the sides before applying pressure. The resin-impregnated fabrics were cured at room temperature for 24 hrs laminates with different number of layers (single, double and four layers) and with different stacking configurations 0,90,[0]2,[0/90],[0]4,[0/90/90/0],[0/45/45/0], where prepared and are shown below. The weight fraction of laminates was 33%. Composite laminates of 30*30 cm was prepared by the above method.

5.5 Types of lay-up

5.5.1 [0] (Weft layer)

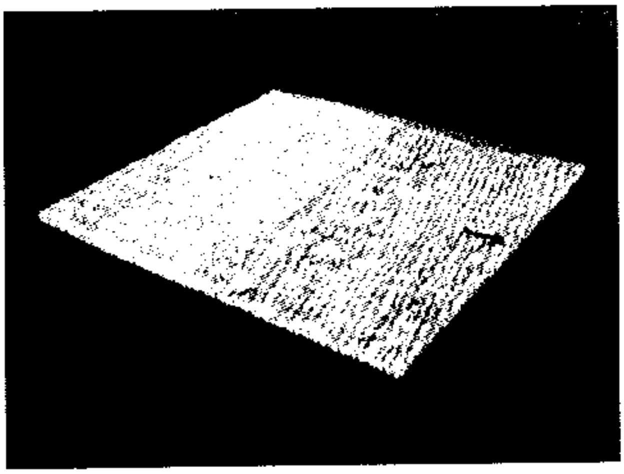

Fig. 5.5.1 [0] (Weft layer)

No of layers – 1

Angle of lay – [o] (Weft)

5.5.2 [o]$_2$ (Weft on Weft)

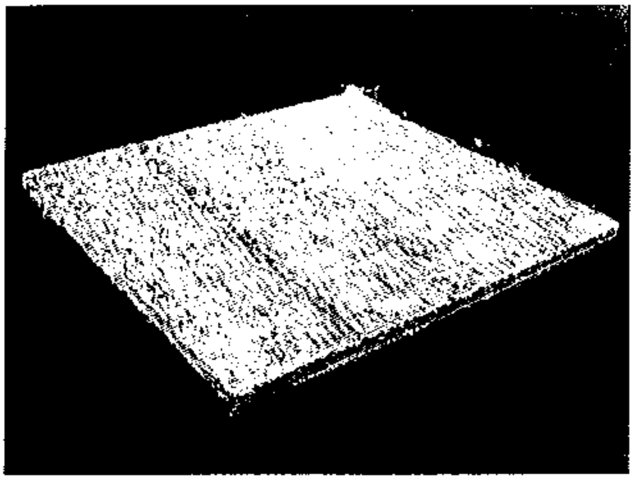

Fig.5.5.2 [o]$_2$ (Weft on Weft)

No of layers – 2

Angle of lay – [o]$_2$ (Weft on Weft)

5.5.3 [0/90] (Weft on Warp)

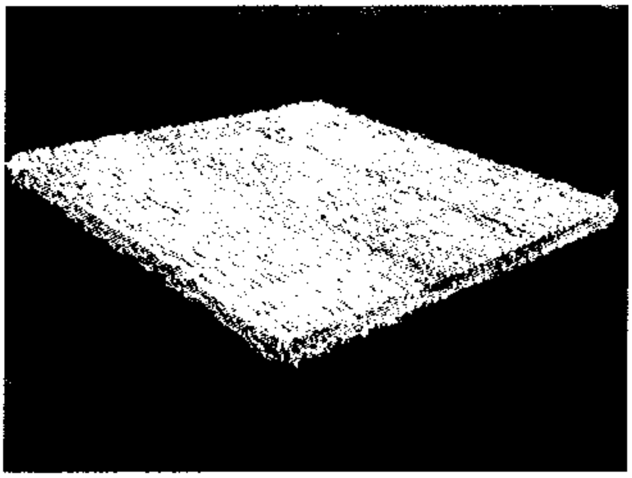

Fig. 5.5.3 [0/90] (Weft on Warp)

No of layers – 2

Angle of lay – [o]$_2$ (Weft on Warp)

5.5.4 $[0]_4$ (Warp on Warp)

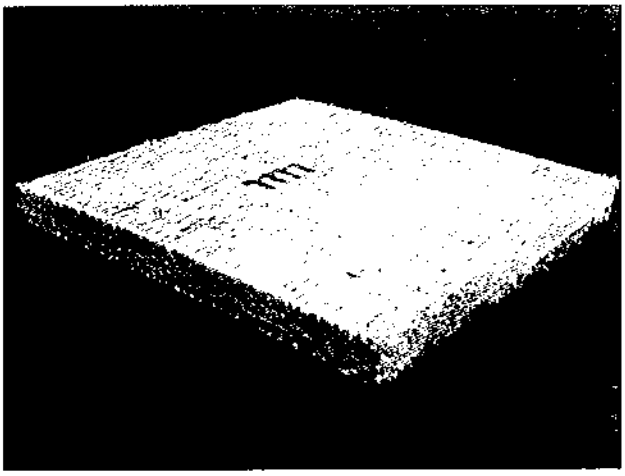

Fig.5.5.4 $[0]_4$ (Warp on Warp)

No of layers – 4

Angle of lay – $[o]_4$ (Warp on Warp)

5.5.5 [0/90/90/0] (Warp on Weft)

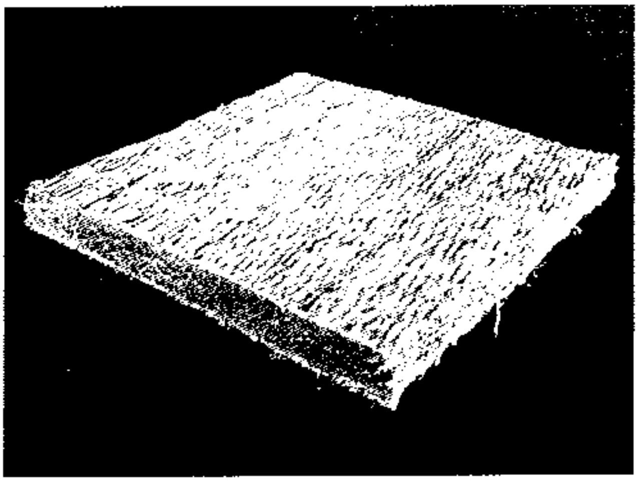

Fig.5.5.5 [0/90/90/0] (Warp on Weft)

No of layers – 4

Angle of lay – [0/90/90/0] (Warp on Weft)

5.5.6 [0/45/45/0] (Weft on45^0 angle lay)

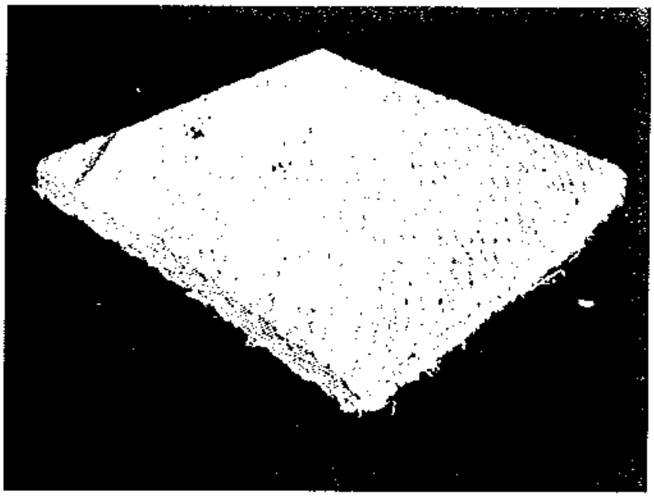

Fig. 5.5.6 [0/45/45/0] (Weft on45^0 angle lay)

No of layers – 4

Angle of lay – [0/45/45/0] (Weft on angled fabric)

5.6 TESTING OF SAMPLES

5.6.1 Tensile Test

Tensile test was carried out in INSTRON4301 tester according to ASTM 3039 standards. The dimensions of the specimens are 250*25.4mm. The thickness of single, double, four layer laminates were 3, 5and 10mm respectively. The crosshead speed was kept at 2mm per minute.

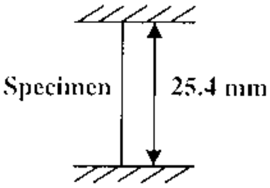

Fig. 5.6.1 Tensile Test

5.6.2 Flexural Test

Flexural test was carried according to ASTM D970 standards. Flexural test was done in a 3-point bending load using instron4301 tester. The dimensions of the specimen are given below.

Monolayer laminate = 100*13*3mm
Double layer laminate = 100*15*5mm
Four layer laminate = 200*13*10mm.

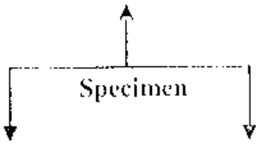

Fig. 5.6.2 Flexural Test

5.6.3 Impact Test

Impact test was carried out according to ASTM D256 standards. Unnoticed specimens were used for the impact strength tester the sample size of impact specimens were

Monolayer laminate = 65*15*3mm
Double layer laminate = 65*15*5mm
Four layer laminate = 65*15*10mm

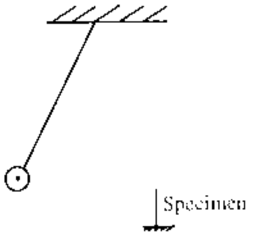

Fig.5.6.3 Impact Test

CHAPTER 6

RESULTS AND DISCUSSION

6.1. Tensile Test

The major factors which affect the tensile strength of woven composite are, woven design, volume fraction, cover factor (EPI,PPI,) apart from the kind of resin used for making the composites,

Fig 6.1. gives the tensile strength of woven composites with two layers and four layers, it is evident from the fig that the tensile strength of four layer laminate is higher than two layer laminates

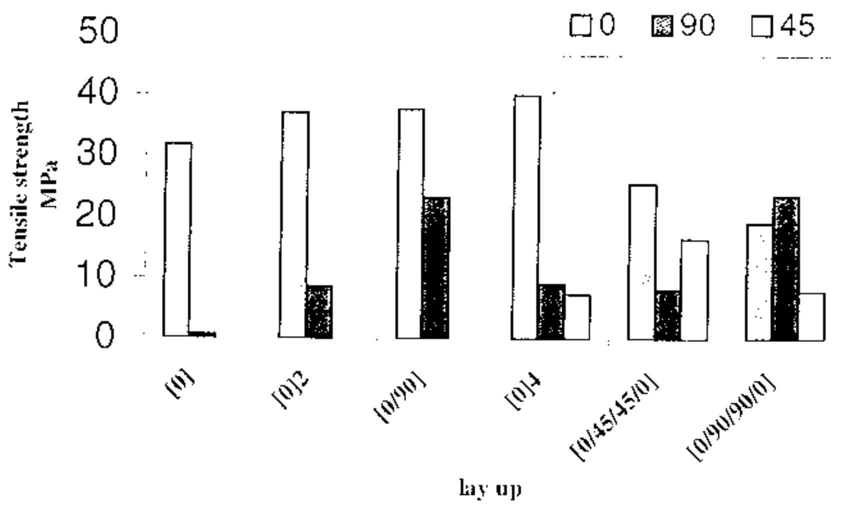

Fig 6.1.Tensile Testing Result.

From the Figure 6.1 it can be noted that as the lay up angel is changed from $[0]_2$ to [0/90] in case of two layers laminate the tensile strength and the modulus are changed. Due to the change in amount of load bearing yarns. In case of $[0]_2$ lay up difference in warp and weft tensile strength is observed .The tensile strength is higher in wet direction compared to warp direction, this is due to less amount of load bearing elements in warp direction can be ascertained from fabric particulars table. But with change in layer to [0/90] it can be note that the tensile strength in both directions is found to improved.

With four layer laminates lay up angels with [0]$_4$, [0/+45/-45/0], [0/90/90/0] were tried with [0]$_4$ lay up It can be observed from the results that the tensile strength changes as the testing direction changes from 0° to 90°.

In case of [0/90/90/0] as the test direction changes from 0°, 45°, and 90° improvement in tensile strength values in both directions (warp & Weft) were observed with [0/+45/-45/0] lay up laminates, change in test direction increase in the tensile strength is observed in 45° angle compared to 0° direction .

Table 6.1 Tensile Test Results

S.No	**Lay up Angle**		**Tensile strength M Pa**
1	[0]	0°	31.9
		90°	0.75
2	$[0]_2$	0°	37.06
		90°	8.6
3	[0/90]	0°	37.708
		90°	23.2
4	$[0]_4$	0°	40.1
		45°	7.4
		90°	9.16
5	[0/+45/-45/0]	0°	25.6
		45°	16.38
		90°	8.03
6	[0/+90/-90/0]	0°	19.14
		45°	7.88
		90°	23.68

6.2.Flexural Test

The flexural strength of the composites is determined by the strength of fibre bundles bridging the fracture plans as shown in fig 6.2. If more amounts of fibre bundles are presented while flexural load is being applied more will be its flexural resistance that is reflected in the flexural modulus and flexural strength of the samples.

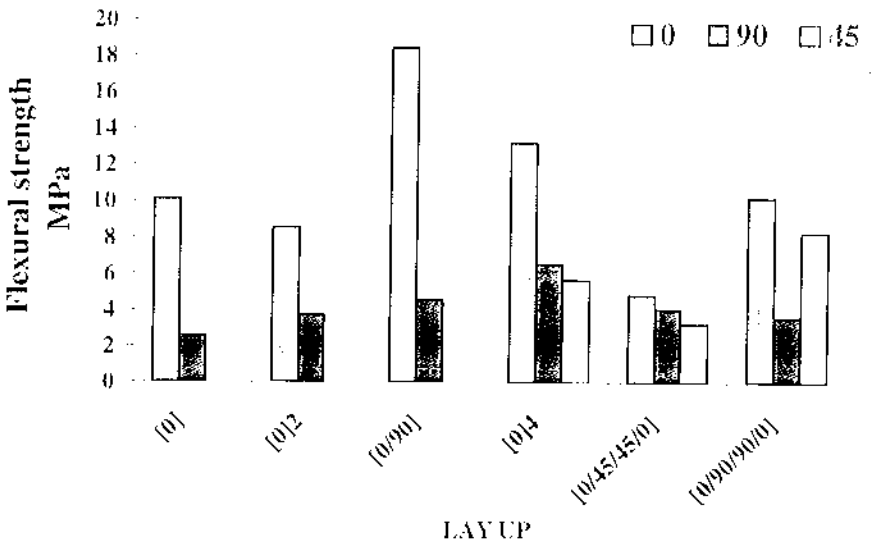

Fig 6.2Flexural Strength Result

From the table 6.2 it can be seen that as the number of layer increases the flexural strength values also increases. More over it can be noted in single, double, and four layer laminates as the lay up angle is changed the flexural strength values also changes with the change in test direction from 0°, 45° and 90°. The improvement in flexural strength in respective directions is attributed to the presence of more amounts of fibre bundles in this direction.

Table 6.2 Flexural Test Results

S.No	Lay up Angle		Flexural strength M Pa
1	[0]	0°	10.101
		90°	2.588
2	$[0]_2$	0°	8.567
		90°	3.791
3	[0/90]	0°	18.491
		90°	4.599
4	$[0]_4$	0°	13.268
		45°	5.734
		90°	6.565
5	[0/+45/-45/0]	0°	4.865
		45°	3.287
		90°	4.112
6	[0/+90/-90/0]	0°	10.248
		45°	8.382
		90°	3.668

6.3 Impact Test

The impact is a dynamic phenomenon that depends on myriad of parameters such as test parameters, material parameters and process parameters. These impacts test in values the relatively high contact forces acting on a small area over a period of short duration with both elastic and plastic deformation leading fracture.as shown in the fig 6.3

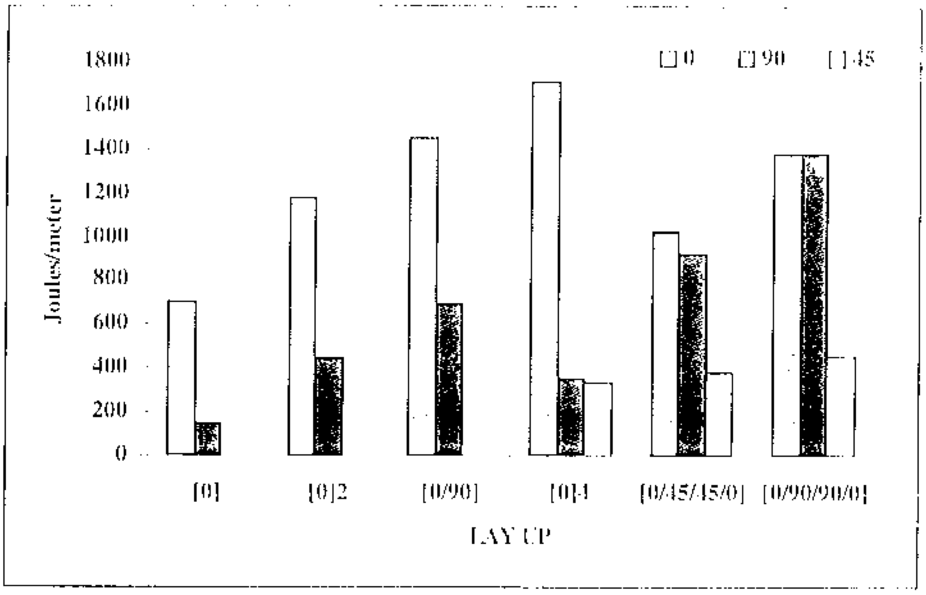

Fig 6.3 Impact Test Result

Composites in general observe energy through fracture mechanism such as delaminating, shear cracking, and fibre damage; however some portion of energy is absorbed through elastic and plastic deformation of fibre and matrix. The impact values of the laminates are given in the table 6.3

The impact values from the above table indicate that impact resistant of the laminates is affected by the number of layers and the lay up angle. The high impact value of the laminates is due to the presence of more amounts of fibre bundles present in that direction. in all cases impact values are higher when weft yarns are presented in test the direction

Table 6.3 Impact Test Results

S.No	Lay up Angle		Impact strength M Pa
1	[o]	0°	700
		90°	416.66
2	$[0]_2$	0°	1176
		90°	450
3	[0/90]	0°	1450
		90°	690
4	$[0]_4$	0°	1709.1
		45°	340
		90°	360
5	[0/+45/-45/0]	0°	1020
		45°	380
		90°	920
6	[0/+90/-90/0]	0°	1381.8
		45°	460
		90°	1380

CHAPTER 7

CONCLUSION

Composites are gaining importance in current day-to-day affairs for their light weight and high strength. In this project natural fibre sisal was used as reinforcement in making the composite laminates. Natural composites can be used in lot of our day-to-day usage material such as furniture, doors, tables, chairs, etc.

From this project following conclusions are reached.

- Tensile properties of composites can be tailored by changing lay-up angle and number of layers
- Flexural properties of the composites are dependent on lay-up angle and number of layers
- Impact properties of the composites are dependent on lay-up angle and number of layers

The composite were made in a compression moulding machine. The composites tested for their mechanical properties such as tensile strength, flexural strength. Composites were tested in three possible direction (0^0, 45^0,90^0 orientation). The results shows that the four layer fabrics laminates giving the higher level of mechanical properties than single and double layers composites.

CHAPTER 8

SCOPE FOR FUTURE WORK

Sisal-textile-reinforced composite is an important area in which little work has been done. Sisal fibers can be woven into textile performs and impregnated with resins by resin transfer moldings (RTM) or resin film infusion (RFI) to make superior but more economical composites.

Microstructure of the interface between sisal fibre and matrix still needs to be investigated and the interfacial properties should be studied with more rigorous single fibre pullout and fragmentation tests. The relationship between interface and bulk composite properties should be established.

Fracture toughness and fracture mechanisms of sisal-fibre composites do not seem to have been studied in any depth in previous published works. This is important if new improved materials are to be developed for safe usage against crack growth.

Mechanical properties of sisal-fibre composites measured from tests quite often disagree with the rule of mixtures. A full explanation can only be obtained if the interface strength and the failure mechanisms are known. Further work is needed particularly to explain `hybrid' effects in sisal/glass composites.

Economical processing methods must be developed for the composites because of the very low price of sisal fibers. The relationship between mechanical properties and processing methods should be established.

New applications should be found for sisal-fibre-based composites. Hybrid fibre composites with sisal and other fibers rather than glass may open up new applications. For example, from the economics point of view, sisal fibers may be hybridized with carbon or aramid fibers to reduce the costs of these expensive fibers reinforced composites whilst maintaining their good mechanical performance.

Recycling (including burning) characteristics and methods of sisal-fibre-reinforced composites are important aspects of this new material but there are very few published data to date. Recycling is an attractive future research direction that will provide socio-economic benefits.

CHAPTER 9

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