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Analysis on Natural Fibre Sisal and Areca Polymer Based Composite Material

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ABSTRACT

Present days natural fibers have transformed the matter of research field among various fields of study to inculcate it in the manufacture of composites instead of the production of composites using areca and sisal polymer-based composite. This is due to respective advantages related to natural fibers like eco-friendly, low cost, convenience in copiousness, and biodegradability. Stacks of work have been carried out in the production of natural fiber-reinforced polymer composites, using natural fibers like areca and sisal polymer-based composite and their mechanical properties have been studied. Here is an attempt made on the literature survey of areca and sisal fibre built polymer composites where different properties of areca and sisal fibers, its adulthood level, surface treatment effect on properties of fibers, composite formation with different matrices, its mechanical properties have been highlighted.

Keywords: Areca, Sisal, Flexural Strength, Mechanical properties.

1. INTRODUCTION

India endowed with an abundant availability of natural fibre such as Jute, Coir, Sisal, Pineapple, Ramie, Bamboo, Banana etc. It is focused on the development of natural fibre composites primarily to explore value-added application avenues. Such natural fibre composites are well suited as wood substitutes in the housing and construction sector. The development of natural fibre composites in India is based on two pronged strategy of preventing depletion of forest resources as well as ensuring good economic returns for the cultivation of natural fibers. The developments in composite material after meeting the challenges of aerospace sector have cascaded down for catering to domestic and industrial applications. Composite is a wonder material with light-weight and high strength-to-weight ratio and stiffness properties have come a long way in replacing the conventional materials like metals, wood etc. The material scientists all over the world focused their attention on natural composites reinforced with Jute, Sisal, Coir, Pineapple etc. It is primarily to cut down the cost of raw materials.

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 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 applications of composites promise to offer much larger business opportunities than the aerospace sector due to the sheer size of transportation industry.

Thus the shift of composite applications from aircraft to other commercial uses has become prominent in recent years. Increasingly enabled by the introduction of newer polymer resin matrix materials and high performance reinforcement fibers of glass, carbon and aramid the penetration of these advanced materials has witnessed a steady expansion in uses and volume. The increased volume has resulted in an expected reduction in costs. The applications as composite arm oring designed to resist explosive impacts, fuel cylinders for natural gas vehicles, windmill blades, industrial drive shafts, support beams of highway bridges and even paper making rollers. 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 containment bands etc.

Further, the need of composite for lighter construction materials 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 micro-structures. Composites are now extensively being used for rehabilitation/ strengthening of pre-existing structures that have to be retrofitted to make them seismic resistant or to repair damage caused by seismic activity. Unlike conventional materials (e.g., steel) the properties of the composite material can be designed considering the structural aspects. The design of a structural component using composites involves both material and structural design. Composite properties (e.g. stiffness, thermal expansion etc.) can be varied continuously over a broad range of values under the control of the designer. Careful selection of reinforcement type enables finished product characteristics to be tailored to almost any specific engineering requirement.

The use of composites will be a clear choice in many instances, material selection in others will depend on factors such as working lifetime requirements, number of items to be produced (run length), complexity of product shape, possible savings in assembly costs and on the experience & skills the designer in tapping the optimum potential of composites. In some instances, best results may be achieved through the use of composites in conjunction with traditional materials.

2. ARECA FIBRE

Among all the natural fibre-reinforcing materials, Areca appears to be a promising material because it is inexpensive, availability is abundant and a very high potential perennial crop. It belongs to the species Areca catechu L., under the family palmecea and originated in the Malaya peninsular, East India. Major industrial cultivation is in East India and other countries in Asia. In India, areca nut cultivation is coming up on a large scale basis with a view to attaining self sufficiency in medicine, paint, chocolate, Gutka, etc. It is estimated that about 6 Lakh tonnes of areca husk is available in south West-India. The husk of the Areca is a hard fibrous portion covering the endosperm. It constitutes 30–45% of the total volume of the fruit. Areca husk fibers are predominantly composed of hemicelluloses and not of cellulose. In Fig 1.2 Areca fibers is shown along with the fiber plant.

(a) (b)

Fig.1 a. Areca Tree b. Areca Fibre

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2.1 Sisal Fibre

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 Nearly 4.5 million tons of sisal fibre are produced every year throughout the world. Tanzania and Brazil are the two main producing countries Sisal fibre is a hard fibre extracted from the leaves 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 A sketch of a sisal plant is shown in and sisal fibers are extracted from the leaves.

(a) (b)

Fig.2 (a) Sisal Plant (b) Sisal Fibre

3. METHODOLOGY

The methodology to prepare the natural fibre reinforced composite materials are fibre extraction from areca husk and sisal plant then cleaning the fibre and preparation of fibre as per our requirement and fabrication of polymer composites based on weight percentage and aspect ratio are prepared. The specimen are prepared according to the require size then testing the mechanical propensities and delamination factor for fabricated composites are tested.

3.1 General chemical properties of Areca and Sisal

Table.1 Chemical Properties of Different Fibers compared with Areca and Sisal

Properties	**Areca Fiber**	**Sisal Fiber**
Cellulose (%)	_	65
Hemicelluloses (%)	35-64.8	12
Lignin (%)	13-24.8	9.9
Moisture content (%)	11	10
Ash(%)	4.4	0.9
Pectin(%)	-	10
Density (g/m^3)	1050-1250	1450
Diameter (µm)	28-89	121-156
Tensile strength (Gpa)	72	68
Young's modulus (Gpa)	3.8	3.774
Properties	Areca Fiber	Sisal Fiber

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Table.2 Properties of Area and Sisal

Fiber	Cellulose (%)	Hemi cellulose (%)	Lignin (%)	Ash (%)	Wax (%)
Jute	61-71	13.6-20.4	12-13	-	0.5
Flax	71-78	18.6-20.6	2.2	1.5	1.7
Hemp	70.2-74.4	17.9-22.4	3.7-5.7	2.6	0.8
Kenaf	53-57	15-19	5.9-9.3	4.7	-
Sisal	67-78	10-14.2	8-11	1	2.0
Areca	-	35-64.8	13-24.8	-	4.4

3.2 Fabrication process of composite material

Fig.3 Fabrication of Composite material

As shown in Fig 3. a mould cavity of 200x150x10 mm was fabricate using teak wood as molding box material and the surfaces of the mould was pasted with mica sheets. The fibre is cut down the required length and spread over the mould uniformly, polyester resin mixed with 1.5% by wt. ofaccelerator and 1.5%by wt. of catalyst were then poured in side the mould.

The fibre volume fraction of fibre to matrix was fixed as 40:60 the mould is allowed for a Curing time of about 8 hours and then separated to obtain the composite plate.

4. RESULTS AND DISCUSSION

4.1 Tensile test

A standard test piece is gripped at either end by suitable apparatus in a testing machine which slowly exerts an axial pull so that the material is stretched until it breaks.

Figure.4 Tensile test Rig and Specimens

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The Fig 4.shows the view of autograph tensile testing machine and The tensile test was performed on autograph tensile tester available at Micro lab engineering and testing , Coimbatore. Tensile test was conducted in according to the ASTM D 3039 method. The Fig 2.4 shows the Tensile test specimen and the specimen.

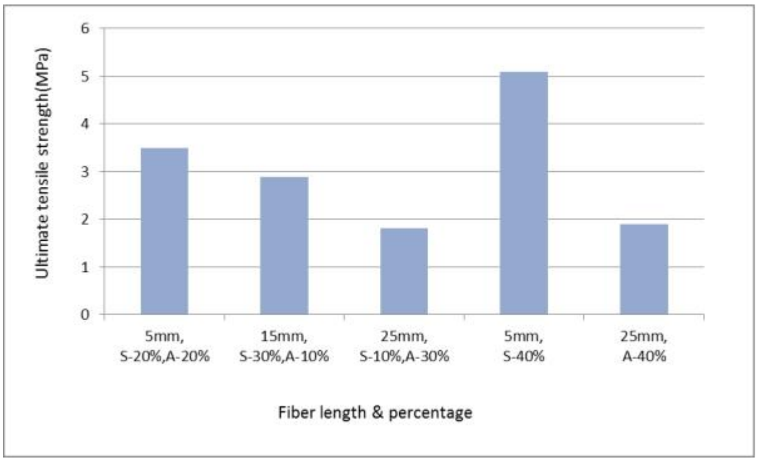
The properties of the composites are strongly influenced by the fibre length. The effect of the fibre ends plays an important role in the fracture of the short fibre composites. To achieve the maximum level of stress in the fibre, the fibre length (lf) must be at least equal to critical fibre length (lc), the minimum length of fibre required for the stress to reach the fracture stress of the fibre.

Tensile test results

Table .3 Tensile test result

Fibre Length (mm)	Weight percentage (%)	Area (mm2)	Ultimate load (KN)	Ultimate Tensile strength (Mpa)
S and A= 5 mm	S-20% , A-20%	544.05	1.90	3.49
S and A= 15 mm	S-30% , A-10%	491.66	1.42	2.89
S and A= 25 mm	S-10% , A-30%	593.45	1.08	1.82
S= 5 mm	S-40%	471.24	2.40	5.09
A=25 mm	A-40%	546.00	1.04	1.90

The following figure shows the graph of Tensile strength and modulus for various fibre length.



Figre 5. Graph for Tensile strength and modulus

4.2 Flexural test

The Fig 2.6 shows the three points bending flexural test and the test was conducted on Areca and Sisal fibre composites. The main advantage of a three point flexural test is the ease of the specimen preparation and testing of composites.

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Fig.5 Flexural Test & Specimens

The Fig 5.shows the Flexural tested specimen used for testing ,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. Flexural testing is often done on relatively flexible materials such as polymers, wood and composites. There are two test types; 3-point flexural and 4-point flexural test. In a 3-point test the area of Uniform stress is quite small and concentrated under the center loading point. In a 4-point test, the area of uniform stress exists between the inner span loading points (typically half the outer span length) the 4-point flexure test is common for wood and composites. The 4-point test requires a deflecto meter to accurately measure specimen deflection at the center of the support span.

Shows the stress–strain behavior of short Areca and Sisal fibre composites under flexural loading. The Areca and Sisal fibre composite introduces a plasticizing effect on the brittle polyester matrix. The Table 2.4 shows the variation of flexural strength with the Areca and Sisal fibre composites with different fibre lengths. The flexural strength values of short Areca and Sisal fibre composites increased with increasing fibre length, and the maximum value was obtained for the fibre S and A= 5 mm with S-20% , A-20% composites.

Flexural test results

Table .4 Flexural Test Result

Fibre Length (mm)	Weight percentage (%)	Flexural strength (MPa)
S and A= 5 mm	S-20% , A-20%	28.89
S and A= 15 mm	S-30% , A-10%	14.14
S and A= 25 mm	S-10% , A-30%	18.02
S= 5 mm	S-40%	19.29
A=25 mm	A-40%	10.90

The following Fig shows the graph of flexural strength and modulus for various fibre length.

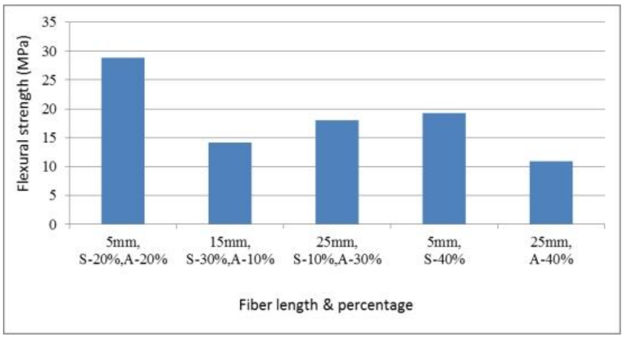

Figure 6. Graph for flexural strength and modulus

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4.3 Impact test

In mechanics, an impact is a high force or shock applied over a short time period when two or more bodies collide. Such a force or acceleration usually has a greater effect than a lower force applied over a proportionally longer time period of time. The effect depends critically on the relative velocity of the bodies to one another. At normal speeds, during a perfectly inelastic collision, an object struck by a projectile will deform, and this deformation will absorb most, or even all, of the force of the collision. And the fig 7 shows the view of Tinius Oisen impact testing machine

Fig7, Impact test

Different materials can behave in quite different ways in impact when compared with static loading conditions. Ductile materials like steel tend to become more brittle at high loading rates, and spalling may occur on the reverse side to the impact if penetration doesn't occur. The dependence of impact strength of short Areca and Sisal fibrecomposites on fibre length can be obtained from

Izod and Charpy Impact test results

Table.5 Izod and Charpy Impact test results

Fibre Length (mm)	Weight percentage (%)	IZOD	Charpy
		Joules	Joules
S and A= 5 mm	S-20% , A-20%	1	1
S and A= 15 mm	S-30% , A-10%	1.5	1
S and A= 25 mm	S-10% , A-30%	1	2
S= 5 mm	S-40%	2	2
A=25 mm	A-40%	1	1

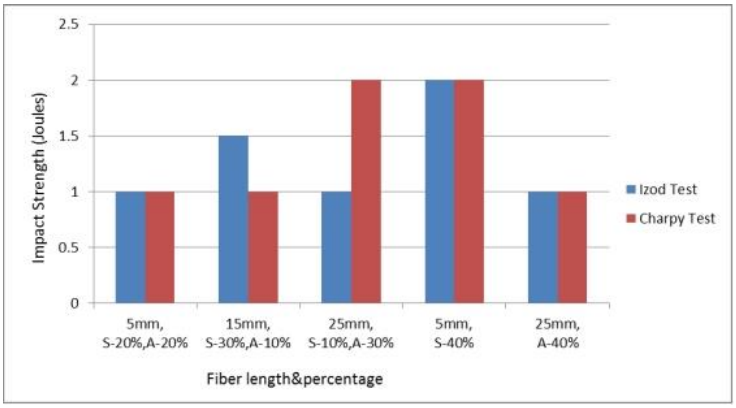

Figure 8. Graph for impact strength

4.4 Delamination

Delamination is the damage occurring in composite materials in drilling, and is to be controlled. The damage around the holes has been measured by using radical tool maker's microscope. The delamination factor was determined by the

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ratio of the maximum diameter (Dmax) of the delamination zone to the hole diameter (D). The value of delamination factor $F_d$can be expressed as follows

$$F_{d= D\ max/D}$$

The Fig 9.shows the drilled plate of composite materials plate to find out the delamination factor of the drilled hole of various diameters with various feed rate and at various speed, and the Fig 10.shows the Elimination effect.

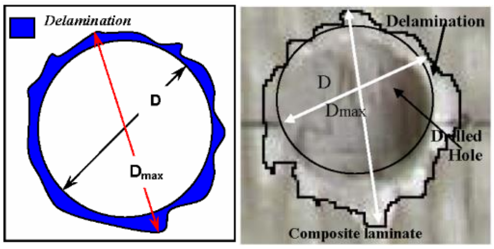

Fig.9.Drilled plate composite material

Fig.10. Delamination effect

5.0 Design of Experiments

The design of experiment used a statistical technique to investigate the effects of various parameters included in experimental study and to determine their optimal combination. The design of the experiment via the Taguchi method uses a set of orthogonal arrays for performing of the fewest experiments. That is, the Taguchi method involves the determination of a large number of experimental situations, described as orthogonal arrays, to reduce errors and enhance the efficiency and reproducibility of the experiments. Orthogonal arrays are a set of tables of numbers.which can be used to efficiently accomplish optimal experimental designs by considering a number of experimental situations. The Table 2.6 shows the Design experiments, with three parameters at three-level. Design experiments, with three parameters at three-level to determine Delamination Experiments

Table.6. Design of experiment

Parameter/Levels	Diameter in mm	Speed rpm	Feed rate in rev/min
1	5	175	0.2
2	7	365	0.4
3	9	685	0.6

An experimental design methodology adopting the Taguchi approach was employed in this study, with the orthogonal array design used to screen the effects of three parameters. And the Table 8 shows the results L-9 Orthogonal array.

Table.7. Orthogonal array

Experiments	P1	P2	P3
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

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The Table 8.shows the Experimental results of Delamination Factor for various diameter, speed, and feed rate to find out the maximum delamination and the delamination factor.

Experimental results of Delamination Factor

Table.8.Delamination Factor

S.No	Diameter in mm	Speed rpm	Feed rate in rev/min	Maximum Delamination	Delamination Factor
1	6	170	0.1	6.58	1.097
2	8	170	0.1	8.91	1.114
3	10	170	0.1	10.88	1.088
4	6	360	0.1	6.66	1.110
5	8	360	0.1	8.97	1.121
6	10	360	0.1	10.87	1.087
7	6	680	0.1	6.55	1.092
8	8	680	0.1	8.54	1.068
9	10	680	0.1	10.87	1.087
10	6	170	0.2	6.98	1.163
11	8	170	0.2	8.57	1.071
12	10	170	0.2	10.59	1.059
13	6	360	0.2	6.55	1.092
14	8	360	0.2	8.69	1.086
15	10	360	0.2	10.66	1.066
16	6	680	0.2	6.58	1.097
17	8	680	0.2	8.91	1.114
18	10	680	0.2	10.73	1.073
19	6	170	0.3	6.59	1.098
20	8	170	0.3	8.77	1.096
21	10	170	0.3	10.81	1.081
22	6	360	0.3	6.85	1.142
23	8	360	0.3	8.87	1.109
24	10	360	0.3	10.72	1.072
25	6	680	0.3	6.59	1.098
26	8	680	0.3	8.75	1.094
27	10	680	0.3	10.69	1.069

Delamination for the nine sets of experiments

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Table 9 Delamination Experiments

Experiments	Diameter in mm	Speed rpm	Feed rate in rev/min	Trial 1	Trial 2	Trial 3	Mean
1	7	180	0.1	1.099	1.097	1.098	1.10
2	7	370	0.2	1.093	1.092	1.092	1.09
3	7	670	0.3	1.099	1.098	1.097	1.10
4	9	180	0.2	1.073	1.071	1.074	1.07
5	9	350	0.3	1.11	1.109	1.109	1.11
6	9	670	0.1	1.067	1.068	1.069	1.07
7	11	180	0.3	1.083	1.081	1.082	1.08
8	11	360	0.1	1.089	1.087	1.088	1.09
9	11	670	0.2	1.074	1.073	1.075	1.07

The Table.9.shows the Delamination for the nine sets of experiments with different diameter, speed and feed rate to find out the mean value for the sets of experiments.In Taguchi method, the signal-to-noise (S/N) ratio is used to measure the quality characteristics deviating from the desired value. The S/N ratios are different in terms of their characteristics, of which there are generally three types, i.e. smaller-the-better; larger-the-better and nominal-the-better According to the analysis for the case of 'larger-the-better', the mean squared deviations (MSD) of each experiment were evaluated using the following equation:

$$\mathrm{MSD} = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{1}{y_i}\right)^2$$

Where n is the number of repetitions of each experiment and $y_i$the yield of rapeseed methyl ester. Then, the S/N ratio was evaluated using the following equation:

$$\frac{S}{N}\ \mathrm{ratio} = -10\log(\mathrm{MSD})$$

The S/N ratios for the nine sets of experiments are also shown in Table.10. The mean S/N ratio, which was calculated from the effect of the parameters and the interactions at assigned levels, was the average of all the S/N ratios of a set of control parameters at a given level

Table.10. S/N ratio for nine sets of experiments

Experiments	Diameter in mm	Speed rpm	Feed rate in rev/min	Mean	S/N ratio
1	5	180	0.2	1.10	3.947
2	5	360	0.3	1.09	4.027
3	5	670	0.4	1.10	3.947
4	7	180	0.3	1.07	4.187
5	7	370	0.2	1.11	3.869
6	7	690	0.2	1.07	4.187
7	9	180	0.4	1.08	4.107
8	9	350	0.2	1.09	4.021
9	9	670	0.3	1.07	4.187

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5.1 De-lamination test results,

Taguchi Design

Taguchi Orthogonal Array Design
L9(3**3)
Factors: 3
Runs: 9
Columns of L9(3**4) Array
1 2 3

5.2. Taguchi Analysis: DELAMINATION FACTOR Vs DRILL DIAMETER, SPEED, FEED

Response Table for Signal to Noise RatiosSmaller is better
S/N Result

Table.11. Delamination factor

Level	DRILL DIAMETER	SPEED	FEED
1	-0.725	-0.7248	-0.6
2	-0.7337	-0.7744	-0.7563
3	-0.6273	-0.5868	-0.7297
Delta	0.1065	0.1876	0.2562
Rank	3	1	2

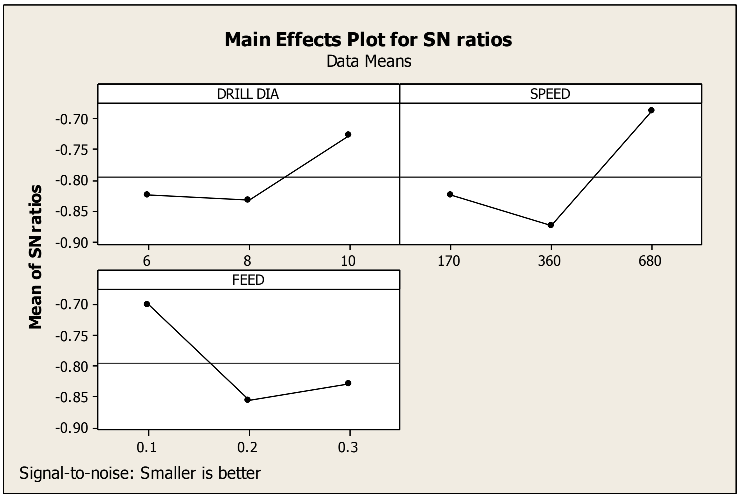

Fig.9. Graphical representation of SN ratio

The optimum conditions to achieve effective performance to minimize the delamination factor is shown in Table 11.The optimum result of delamination is 6mm diameter,170rpm and 0.3 rev/min feed rate. It can also be seen that in delamination factor the largest effect gives feed rate and diameter has the smallest effect on natural composite fibre.

5. CONCLUSION

The Areca and Sisal fibre have been excerption and cleaned. Thetensile, flexural and impact strengths of arbitrarily oriented fibre composites were dictated. The maximum tensile strength of the composite was found to be 6.09 MPa and the flexural and Impact strength was found to be 27.89 MPa and 0.3 J/mm^2 respectively.The various test results shows that the Sisal fibre is suitable to prepare composite material than Areca and Sisal-areca hybrid natural fibre composite. The mechanical properties of Areca and Sisal fibre reinforced polyester composites were recovered to be

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higher than that of real resin. The test results appearance that the presence of sisal fibre composite gives the maximum result comparing with other length of Areca and Sisal-areca hybrid composites.It can also be seen that delamination factor has the largest effect on feed rate and diameter has the smallest effect on natural composite fibre.

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