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INVESTIGATION OF MECHANICAL PROPERTIES AND SURFACE ROUGHNESS OF BANANA AND SISAL FIBER REINFORCED POLYMER COMPOSITE BY ABRASIVE WATER JET MACHINING

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Abstract

A composite material is a material that has two or more constituents whose individual physical or chemical properties are significantly different than thatwhen combined. Natural fibers have been used in composite materials for a long time due to their availability in the environment.Some examples of natural fibers are hemp, jute, cotton, etc. These natural fiber reinforced composites have various advantages over other man made composites such as carbon fire or fiber glass. They are easier and cheaper to manufacture, biodegradable and the fibers are usually easily available. The aim of this study is to determine the mechanical properties of Sisal Banana reinforced epoxy composite.

Keywords: Composite, Banana, Sisal, Epoxy, Mechanical Properties

1. Introduction

A composite material is a material that has two or more constituents whose individual physical or chemical properties are significantly different that when combined. Composites generally have two main components, namely the matrix and the reinforcing fiber(s). Composites such as carbon fiber and fiber glass are expensive and require complex processes to manufacture. They are also non-biodegradable and are not eco-friendly. Natural fiber reinforced composites overcomes such problems while also having appreciable physical properties. .Natural fiber reinforced composites are replacing plastics in more and more everyday applications such as casings, interior panels for panels, primary structure support, etc. [1]. The type of composite used in this study was of a bidirectional fiber and polymer matrix. The research was divided into two parts. The first part was to understand the mechanical properties of fabricated composite. The second part was to analyze the effect of various abrasive water jet machining parameters on the surface roughness of the composite after cutting.

Materials

The reinforcing fibers used are sisal and banana. Sisalfibersand Banana fibers were stitched into sheets and were cut into the required dimensions.. Epoxy resin is used to from the matrix of the composite. It is combined with a hardener in the ratio 10:1. Five sheets of each, Banana fiber and Sisal fiber were used. The total weight of the reinforcing fibers was 200g and 300g of Epoxy resin was used.

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Banana Fibers

Banana fibers are extracted from the stem of the plant either manually or mechanically. Banana fiber was selected for the composite due to its easy availability and easy extraction process. The Banana sheet used in the composite contains a small amount of fibers (used to stitch the Banana fibers into a sheet). The sheet contains 74% Banana fibers and 26% Cotton fibers.

The two important mechanical properties (that were tested for) of Banana fibers are as follows:

- Tensile Strength : 28MPa
- Flexural Strength : 72MPa8

Fig 1. Banana Fiber

Sisal Fibers

Sisal is a natural fiber (Scientific name Agave Sisalana) of Agavaceae (Agave) family yields a stiff fiber traditionally used in making twine and rope. Sisal fiber made from the large spear shaped tropical leaves of the Agave Sisalana plant. Sisal fiber is exceptionally durable and a low maintenance with minimal wear and tear. Its fiber is too tough for textiles and fabrics.

The sisal fiber sheets used contained a certain amount of cotton fibers (used to stitch the sisal fibers into a sheet). The sheet consists of 57% Sisal fiber and 43% Cotton fibers.

The two important mechanical properties (that were tested for) of Sisal fibers are as follows:

- Tensile Strength : 800 –1500 MPa
- Flexural Strength : 8MPa

Fig 2. Sisal Fiber

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Epoxy Resin

Epoxy Resin was used as a matrix of the composite. It is a polyester polymer. Some of the main reasons this resin was chosen was because of its better mechanical properties and resistance to environmental degradation. Another major advantage of this polymer if that it undergoes very low shrinkage upon curing. The hardener used along with the epoxy resin is Amine. The ratio of Epoxy resin to hardener used is 10:1.

Fig 3. Epoxy Resin with Hardener

2. Experimental Procedure:

Layering

The sisal and banana fibers are woven into fabric layers of dimensions 200 X 200 mm. A weight ratio of 60:40 (Resin: Fiber) was used. This ratio of resin to fiber classifies the fabricated composite as a "Low volume" Polymer composite.The Banana and Sisal sheets were layered in alternating directions. This allowed for a bidirectional orientation of the fibers.

Compression Moulding

The compression moulding involves applying heat and pressure onto the composite so as to cure the resin faster and better. Resin was applied on one side of Aluminum 0.1mm thick foil sheet of 200x200mm placed on bottom and top mould frame. The Banana and Sisal Sheets were layered and another Aluminum foil (0.1mm thick) was placed on top. This was placed between two heavy metal plates before being placed in the oven. These plates help distribute the applied pressure uniformly across the composite. The pressure applied was 30kg/m^3 and a temperature of 130°C.

2.1 Testing

Flexural Testing

Three point flexural testing were conducted according to the ASTM D 790 standard [2]. A Universal Testing Machine of load capacity 500kg was used. The specimens were machined to the dimensions of 125 mm ×12 mm ×4 mm. The following results were obtained.

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Maximum Load	741.4289 N
Flexural Stress	30.8929 N/mm^2

Table 1. Results of Flexural Test

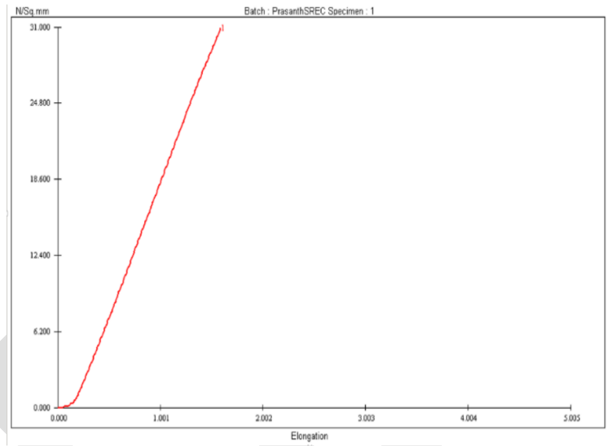

Fig 4. Flexural Test Fig 5. Stress .vs. Elongation

Tensile Testing

The tensile test was performed using a Universal Testing Machine of load capacity 500kg. The test specimen was prepared according to ASTM D 638 standard [4]. The dimension of the test specimen is 165mm x 13mm x 4mm. This standards was selected as it is used for plastics as well as low volume polymer composites. The following results were obtained from the test.

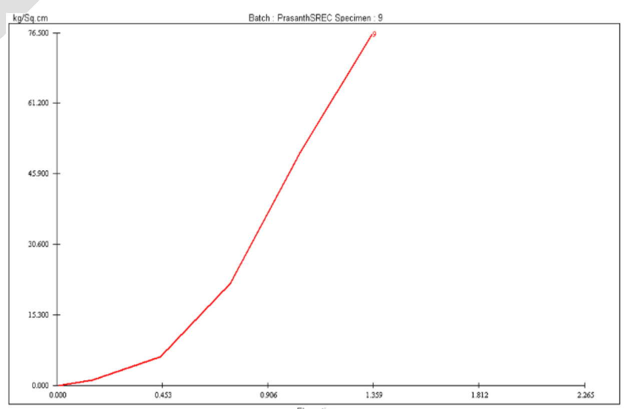

Fig 6. Tensile Test Fig 7. Stress .vs. Elongation

Table 2. Results of Tensile Test

Maximum Load at Breaking Point	118.8110 kg
Tensile Stress	*76.1609 kg/cm^2*
Elongation at Breaking Point	1.3546 %

2.2 Abrasive Water Jet Cutting

Cutting of Natural fiber reinforced samples are performed on the Abrasive water jet machine (Make: STREMLINE E3105, KMT Water jet systems, Model: JETLINE JL450).The machine is equipped to operate in the range pressure value of 1300 to 6200 bar with drive motor power of 40 HP pump. The material removal process is mainly by erosion. The AJM will chiefly be used to cut shapes in hard and brittle materials like glass, ceramics etc. the machine will be automated to have 3 axes travel.

Abrasive	: Sic, Al2O3,Garnet (of size 20µ to 80µ)
Flow rate of abrasive	: 500 – 600 g/min
Velocity	: 150 to 300 mm/min
Pressure	: 200 – 300 MPa
Nozzle size	: 0.4 to 1.5 mm
Material of nozzle	: WC, Sapphire, tungsten carbide
Nozzle life	: 12 to 300 hours
Standoff distance	: 0.25 to 15 mm (8mm generally)

Table 3. Abrasive Water jet Machine parameters

In the present study, pressure(MPa),transverse speed(mm/min), abrasive flow rate and S.O.D (mm) are considered as control parameters and depth of cut are measured on the work piece.

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Water Pressure

The pressure is the pressure of the water jet leaving the nozzle. The surface roughness of the machined work piece is related directly to the pressure of the water jet. The amount of variation differs for different material. For composite material it increases slightly with increase in pressure. The pressure used in this study are 200MPa, 250MPa and 300MPa.

Transverse Speed

Transverse Speed is the translational speed of the nozzle or cutting head about the work piece surface. Effect on surface roughness due to transverse is related to the depth off cut. As transverse speed increases, surface roughness also increases, that too greatly with greater depth of cut. The transverse speed is usually expressed as a percentage of the maximum transverse speed of the machine (in our case, a maximum of 300 mm/min). The various transverse speeds used were 60%, 70% and 80% of maximum transverse speed.

Stand-Off Distance

The standoff distance is the distance between the nozzle and the work piece. Since the standoff distance determines the mechanical force applied over the machined surface in abrasive water jet machining process, it has the most significant role on determining the surface roughness. If abrasive flow rate is higher than the optimized value, then the larger craters will be formed over the machined surface due to the higher mechanical energy happened between the abrasive and the work piece surface [3].

The Stand off Distance values for the study of their effect on the surface roughness of the machined composite are 2mm, 4mm and 6mm.

Surface Roughness Measurement

The composite was cut into cuboids of dimensions 20mm x 11mm x 10mm (length x breadth x depth). The surface roughness was measured along the depth of the piece in a direction perpendicular to the fibers. The surface roughens was measured using Surface Roughness Tester TR 100.

Fig 8. Surface Roughness Tester TR 100

Analysis

To analyze the effect of the three parameters on the surface roughens of the machined surface, Design of Experiments and Taguchi optimization method was used. The L9 Orthogonal Array was used to tabulate the experiments. The number of experiments conducted was calculated using the formula:

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$$\text{Number of Experiments} = 1+N(L-1)$$

where,

N = Number of parameters

L = Number of levels or settings

In our case, we have 4 variables (pressure, stand-off distance, transverse speed and surface roughness) and three different levels. So from the formula, we get 9 experiments.

Test Case	Parameter 1	Parameter 2	Parameter 3
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

Table 4. L9 Orthogonal Array Experiments

Pressure (MPa)	**Transverse Speed (%)**	**Stand Off Distance (mm)**	**Surface Roughness (µm)**	
			Trial 1	**Trial 2**
200	60	2	14.33	13.62
200	70	4	12.16	13.505
200	80	6	16.89	13.64
250	60	4	11.68	13.47
250	70	6	12.65	11.57
250	80	2	12.08	16.28
300	60	6	12.97	12.5
300	70	2	12.75	13.73
300	80	4	9.35	9.53

Table 5. L9 Orthogonal Array

Considering this process as a static problem and using “smaller-is-better” form of the Taguchi Optimization method, the signal to noise ratio was determined for each experiment. The signal to noise ratio is given by the formula:

n = -10 Log10 [mean of sum of squares of measured data]

The Response (Δ) of each parameter was calculated by subtracting the maximum and minimum signal to noise ratio values of each parameter. The responses of a parameter defines how it affects the output parameter. Larger response values signifies more influence on the output parameter. Level vs Signal-Noise Ration graphs were plotted for each parameter.

	Pressure	Transverse Speed	Stand Off Distance
1	-22.936	-22.341	-22.827
2	-22.270	-22.097	-21.230
3	-21.348	-22.116	-22.498
Δ	1.588	0.243	1.597
Rank	**2**	**3**	**1**

Table 6. Response Table

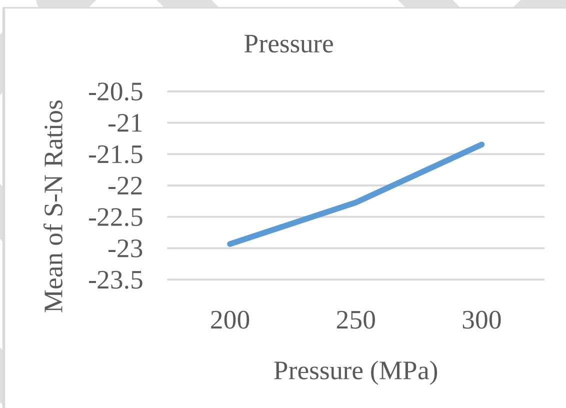

Fig 9. Mean 0f S-N Ratio .vs. Pressure

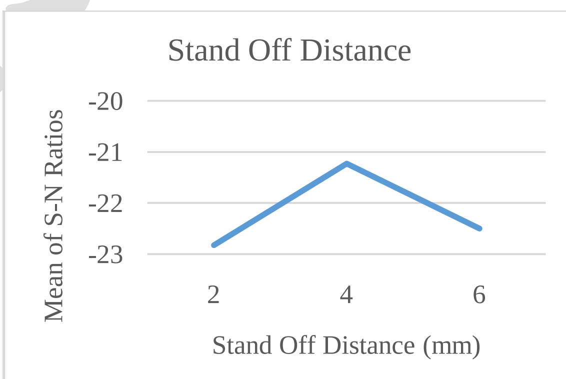

Fig 10. Mean 0f S-N Ratio .vs. Stand off Distance

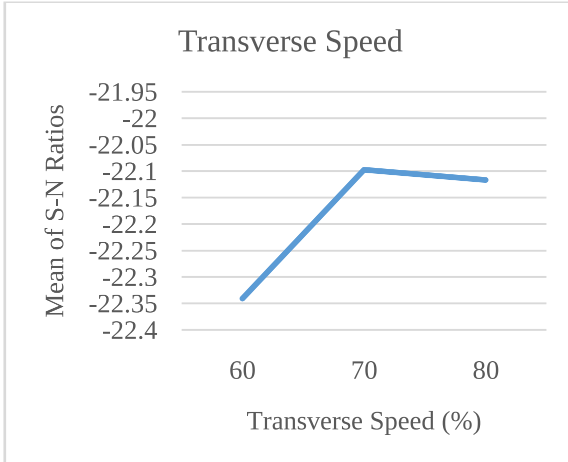

Fig 11. Mean 0f S-N Ratio .vs. Transverse Speed

3. Conclusion

The Banana and Sisal Fiber polymer composite was successfully fabricated and tested for its mechanical properties. The following results were obtained.

1. The 10mm thick fiber plate gives a maximum tensile strength of ***7.4688MPa***.
2. The 10mm thick fiber plate gives a maximum flexural strength of ***30.8929 MPa***.

The surface roughness was measured for a 10mm thick natural fiber reinforced composite by Abrasive Water Jet Cutting while varying the various cutting parameters such as pressure, stand-off distance and transverse speed. Using Taguchi's Method of Design of Experiments and optimization technique, it has been found that the ***standoff distance*** has the most influence on surface roughness out of the three measured parameters.

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