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STUDY AND ANALYSIS OF MECHANICAL PROPERTIES AND MACHINING PARAMETERS ON NATURAL FIBER HYBRID COMPOSITES

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ABSTRACT

Natural fiber reinforced polymer composites have played important role in variety of applications because of their light weight, recyclability, low cost of materials and production, high specific strength and modulus. Drilling is one of the important machining operations which are required to facilitate assembly of the component to get final product. Drilling in composite material may induce some problems like poor surface roughness and delamination. So the present work concentrates on jute and human hair as natural fibers which are reinforced with Epoxy resin to fabricate a series of composite. The effect of human hair in jute fiber reinforced composite are studied. And also the interfacial properties and internal structure of fractured surfaces are analyzed by using Scanning Electron Microscope. Drilling in hybrid fiber composites was performed and optimal machining parameters for surface roughness are analyzed by taguchi method.

Keywords: Hybrid Fiber, Mechanical properties, Scanning Electron Microscope, Drilling, surface roughness, Taguchi method.

1. INTRODUCTION

When two or more fiber materials are combined in a single matrix then it is called as Hybrid composites. It provides combination of properties. Jute fiber is falls into the bast fiber category and is an attractive natural fiber for use as reinforcement in composite because of its low cost, renewable nature and much lower energy requirement for processing. The jute composites may be used in everyday applications such as lampshades, suitcases, paperweights, helmets, shower and bath units.

Hair is creating an environmental problem so its use as a fiber reinforcing material can minimize the problem. It is also available in abundance and at a very low cost. Elasticity is one of the most important properties of hair. A lock of 100 hairs can withstand 12 tons [1]. Hair fiber is usually used in concrete applications.

The epoxy resins are being widely used for many advanced composites due to their excellent adhesion to wide variety of fibers, and good performance at elevated temperatures. Drilling is usually the final operation during the assembly of the structures. Twist drills are widely used in industry to produce holes rapidly and economically. Any defect that leads to the rejection of the parts represents an expensive loss. The variation of volume fraction of the fibers makes the drilling process more complex, as proper feed, and speed should be given particular volume fraction to produce a good hole.

Ramesh et al. [2] find out the Mechanical property of sisal–jute–glass fiber reinforced polyester composites. They have indicated that the addition of jute fiber with GFRP can improve the properties and used as an alternate material for glass fiber reinforced polymer composites. **Liu and Dai**. [3] Studied the Surface modification and micromechanical properties of jute fiber mat reinforced polypropylene composites. They have treated the Jute fiber using sodium hydroxide

(NaOH) and Maleic anhydride-grafted polypropylene (MPP) and result observed that the interfacial shear strength, flexural and tensile strength of the composites all increased, but the impact strength decreased slightly. **Salma et al.** [4] investigated the Physico Mechanical Properties of Jute-Coir Fiber Reinforced Hybrid Polypropylene Composites. Based on the fiber loading used in this study, 20% fiber reinforced composite resulted the best set of mechanical properties. **Miah et al.** [5] Characterized the Jute Fiber Reinforced Low Density Polyethylene Based Composites (LDPE). It is found that due to chemical treatment of the jute fibers, a significant improvement of the mechanical properties of the composites are happened (56% TS, 30% BS and 35% BE) compared to the LDPE.

Jain and Kothari [6] evaluated the Hair Fiber Reinforced Concrete. They were studied the effect of human hair on plain cement concrete on the basis of its compressive, crushing, flexural strength and cracking control. By testing of cubes and beams they found that there is an increment in the various properties and strength of concrete by the addition of human hair as fiber reinforcement. **Akhtar and Ahmad** [7] investigated the effect of randomly oriented hair fiber on mechanical properties of fly-ash based hollow block. The better results of mechanical properties are achieved in higher content of hair fiber reinforced hollow block. **Sanjay et al.** [8] studied the Mechanical Behavior of Polypropylene and Human Hair Fibers and Polypropylene Reinforced Polymeric Composites. Human hair fibers are mixed into polypropylene (PP) at 3,5,10 and 15 % by wt. It was concluded that Polypropylene and hair fiber polymer reinforced composite have better flexural and impact strength and lower the tensile strength than pure polypropylene composite.

Prakash and Mishra [9] Processed and optimized the Properties of Natural Fiber-Reinforced Polymer Composite. The three different composite materials are fabricated by pure epoxy, 10% grass fiber and 20% grass fiber. The result shown that the hardness of fiber reinforced polymer composite is more than that of the pure epoxy and also increases with the increase in amount of reinforcement. **Harish et al.** [10] perform work in coir fiber reinforced Epoxy composites and their mechanical properties are increased as fiber content increased. **Senthilkumar et al**. [11] studied the mechanical behavior in aluminium particulate epoxy composites. The various mechanical test and microstructure analysis were performed and it was concluded that epoxy based composite increases the fatigue life, thermal conductivity and hardness with increasing filler material. **Naveen et al.** [12] investigated the drilling parameters on composite materials. Three speeds, four feeds and three volume fraction of composites are used in this study. It is observed from this experiment high cutting speeds and lower feed rates are best suited for drilling FRP composite laminates. **DilliBabu et al.** [13] established the effects of drilling parameters on delamination of hemp fiber reinforced polyester composites. Taguchi and ANOVA methods established the result as optimum parameters of both minimum peel up delamination and minimum push down delamination are the feed rate at level 1 (100 mm/min), the cutting speed at level 3 (2000 rpm). **Jayabal and Natarajan** [14] investigated the Drilling analysis of coir fiber reinforced polyester composites. From these work it was observed that the drill bit diameter of 6 mm, spindle speed of 600 rpm and feed rate of 0·3 mm/rev gave the minimum value of thrust force, torque and tool wear by using Taguchi approach. **Murthy et al.** [15] optimized the Process Parameter in GFRP. In this work the process parameters such as spindle speed, feed and drill point angle is main contributing parameter for the variation in the thrust force.

2. MATERIALS AND METHODS

Materials Used

The present investigation employs jute and human hair as the reinforcement material and epoxy as the matrix material to fabricate a series of composites, which is shown in figure 1. The jute fiber in yarn types (2Kg) are purchased from National Jute Board (Ministry of Textiles, Govt. of India), Chennai in India. Human Hair is purchased from Om Balavinainayaga Enterprises, Chennai in India. The present work concentrates on the chopped type of fiber reinforcement as 20mm by length. The epoxy resin and the corresponding hardener HY-951 are purchased from Javanthee Enterprises, Chennai in India. The physical properties of raw material which is used for present work is shown in Table 1.

Figure 1 Raw materials used

Composite Fabrication

In the present work hand layup method is followed. Composites are fabricated in the size of 300 mm*300 mm square plate with 5 mm thickness. Five different types of composites have been fabricated. Each composite have 25% volume of fiber and 75% volume of resin. The fiber composition of the each composite prepared for this work is listed in Table 2. The cast of each composite is cured under a load of about 50 kg for 24 hours before it removed from the mold.

Mechanical Testing of Composites

Samples for mechanical testing are prepared from fabricated composite materials according to ASTM standard in vertical zigzag cutting machine. Three samples per test were prepared for each composite. The mechanical properties such as tensile test (ASTM D638), Flexural test (ASTM D790 and Impact test (ASTM D256) are performed in universal testing machine. And also the interfacial properties and internal structure of the fractured tensile specimens are analyzed by Scanning Electron Microscope (SEM).

Table 1 composition and designation of composites

Composite	Fiber Composition
A	100% jute + 0% human hair
B	75% jute + 25% human hair
C	50% jute + 50% human hair
D	25% jute + 75% human hair
E	0% jute + 100% human hair

Table 2 physical properties of raw material

Fiber	Density, g/cm³	Diameter µm	Tensile Strength, Mpa	Young's Modulus, GPa	Elongation at Break, %	Moisture Absorption, %
Jute	1.4	160-185	400-800	10-30	1.8	12
Human Hair	1.32	17-180	400	-	216.94	-
Epoxy	1.1-.14	-	35-100	3-6	1-6	0.1-0.4

Drilling of Composite

Experimental Setup

Drilling operation is performed in three different hybrid composites with three different machining parameters such as speed, feed and drill point angle with three levels. The cutting tool used for this work is carbide drill bit with 10 mm diameter. The drilling operation is performed in Hurco vm20 CNC vertical machining center. The machining parameter and their levels are described in Table 3. The drilled composite specimens are tested for surface roughness.

Experimental Design by Taguchi Method

The experimental design by taguchi method involves L9 orthogonal array to organize the 4 parameters with 3 levels that affecting the process. To determine the effect each variable has on the output, the signal-to-noise ratio or the SN number needs to be calculated for each experiment conducted. For the case of minimizing the performance characteristic, the following definition of the SN ratio should be calculated:

$$SN_i = -10 \log \{ \sum^{Ni} (\quad ^2 \quad i \}$$

Table 3 Machining parameters and their levels.

level	Speed (rpm)	Feed (mm/ min)	Drill point angle (Degree)	Composite type (Fiber composition)
	P_1	P_2	P_3	P_3
1	1000	100	90	B (75% jute +25%hair)
2	1500	200	110	C (50% jute +50%hair)
3	2000	300	130	D (25% jute +75%hair)

3. RESULT AND DISCUSSION

Mechanical Characterization

Tensile Properties

The tensile testing of composite samples is performed using universal testing machine. The maximum load observed at breaking point is obtained and corresponding tensile stress and tensile modulus values of each sample are evaluated. The figure 2 shows the average tensile strength of each composite. It is seen that while we are adding the human hair with jute fiber composite the tensile strength are increased as compared to 100% jute fiber reinforced epoxy composite.

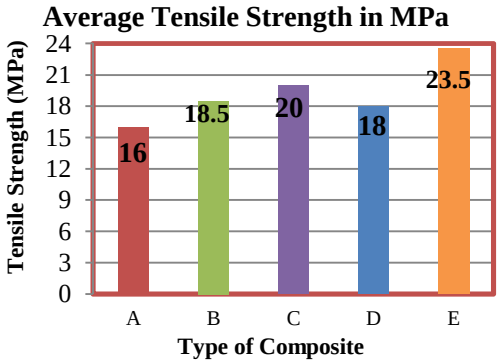

Figure 2 Tensile strength of the composites

The figure 3 shows the average tensile modulus or young's modulus of each composite. The young's

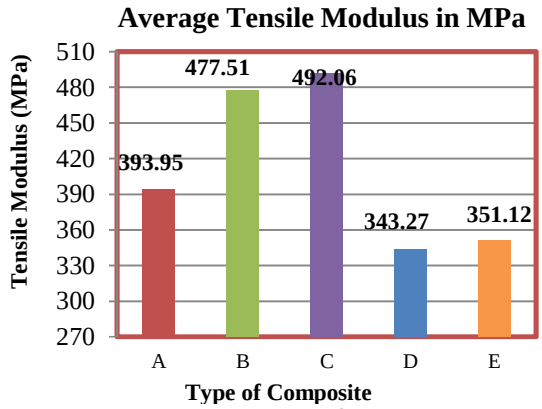

Figure 3 Tensile Modulus of the composites.

Modulus of composite are gradually increased in. Composite A, B and C and then modulus is decreased in composite D then further increased in composite E. This is due to their maximum elongation of material

Flexural Properties

The three point bending testing of composite samples are performed using universal testing machine. The figure 4 shows the average Flexural strength of each composite. The 25 % of human hair in jute fiber reinforced epoxy composite posses lower value of tensile strength than 50% and 75 % human hair added jute fiber reinforced composite. The 100 % human hair reinforced composite has higher value of flexural strength than 100 % jute fiber reinforced composite. The figure 5 shows the average flexural modulus of each composite. The 100 % of jute fiber reinforced epoxy composite posses lower flexural modulus values than other composites. The 100 % human hair reinforced composite has higher value of flexural modulus than other composites.

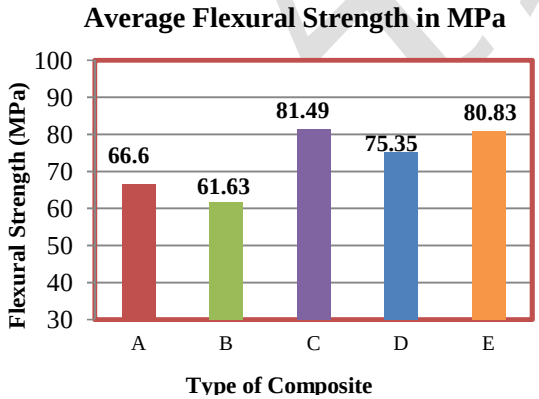

Figure 4 Flexural Strength of the composites

Impact Test

The impact test is performed in Krystal impact testing machine and the strength values are directly noted form the dial gauge. The figure 6 shows the average impact strength of each composite. The result shows that impact strength are increased as the human hair content in jute fiber composite increased.

Scanning Electron Microscope Analysis

The microstructure of fractured tensile specimens is analyzed by Scanning Electron Microscope. The figure 7 shows that the 100 % jute fiber reinforced composite has good bonding relationship between resin and fiber. And in the figure 8 shows that 25% jute and 75% human hair reinforced composite fibers are pulled out from resin during testing. So it has poor bonding between fiber and resin.

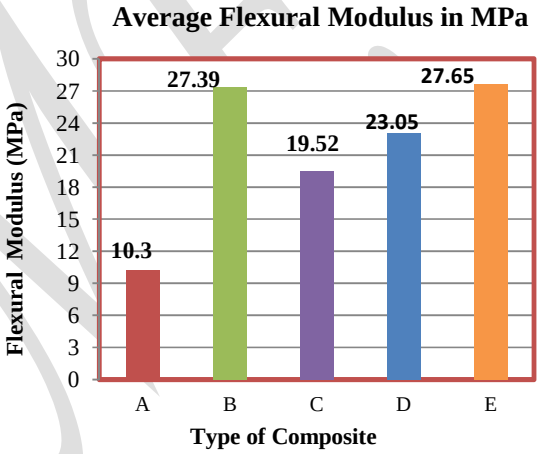

Figure 5 Flexural Modulus of the composites.

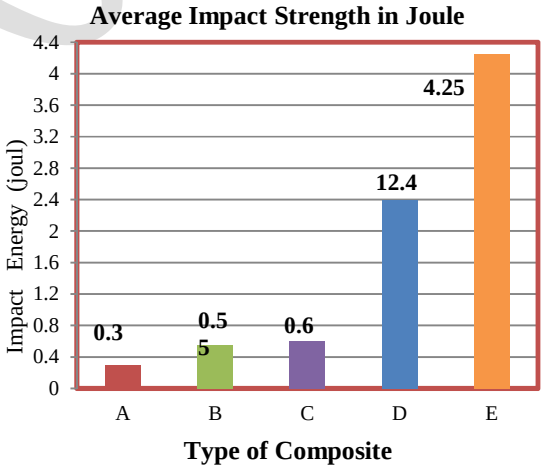

Figure 6 Impact Strength of the composites.

Table 4 Average values of mechanical properties for each composite

Composite	A	B	C	D	E
Tensile Strength (MPa)	16	18.5	20	18	23.5
Tensile Modulus (MPa)	393.95	477.05	492.06	343.27	351.12
Flexural Strength (MPa)	66.6	61.63	81.49	75.35	80.83
Flexural Modulus (MPa)	10.3	27.39	19.52	23.05	27.65
Impact Strength (MPa)	0.3	0.55	0.6	2.4	4.25

Observation from Results

From the mechanical characterization of composite, the result shows that, the mechanical strength are high in 100% human hair reinforced composite than100% jute fiber reinforced composite. And also the strength is gradually increased as hair content in jute fiber composites increased. From result the strength are suddenly decreased in composite D due to poor bonding between fibers and resin. The figure 8 indicates the fiber pull out during testing.

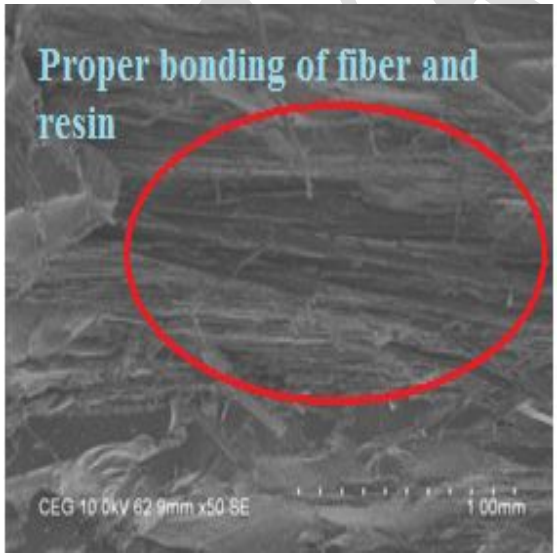

Figure 7 SEM image 100% jute fiber reinforced composite after tensile test

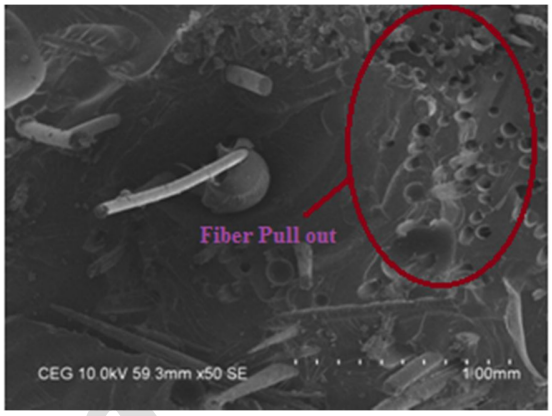

Figure 8 SEM image 25% jute fibers and 75 % human hair reinforced composite after tensile test

Drilling Effect Analyzing

Drilling is performed in composites by two trials per experiment. Totally of 18 holes are tested. The surface roughness of drilled hole is determined by Mitutoyo 5J201 surface roughness tester. The value of roughness (R_a) is directly noted from the display unit of instrument.

Analysis of SN Ratio and Mean:

The SN ratio and mean values of measured surface roughness are determined by using Minitab software. The Minitab software is Statistical Analysis software which is easily analyses the data. Output from Minitab, the Response Table for Signal to Noise Ratios and Means, Main Effects Plot for SN ratios and Means were obtained and it is ranked as for most contribution which affecting the process.

Taguchi Response Table and Graph for Surface Roughness:

Table 5 Response Table for Signal to Noise Ratio

Surface Roughness - SN ratio				
Level	**Speed (rpm)**	**Feed (mm/min)**	**Drill point angle (Degree)**	**Composite types**
1	35.18	35.09	32.90	35.02
2	35.25	35.25	35.50	33.10
3	33.14	33.23	35.17	35.45
Delta Δ	2.11	2.01	2.60	2.35
Rank	3	4	1	2

Table 6 Response Table for Means

Surface Roughness - Means				
Level	**Speed (rpm)**	**Feed (mm/min)**	**Drill point angle (Degree)**	**Composite types**
1	0.01717	0.01783	0.02150	0.01783
2	0.01700	0.01717	0.01700	0.02100
3	0.02167	0.02083	0.01733	0.01700
Delta Δ	0.00467	0.00367	0.00450	0.00400
Rank	1	4	2	3

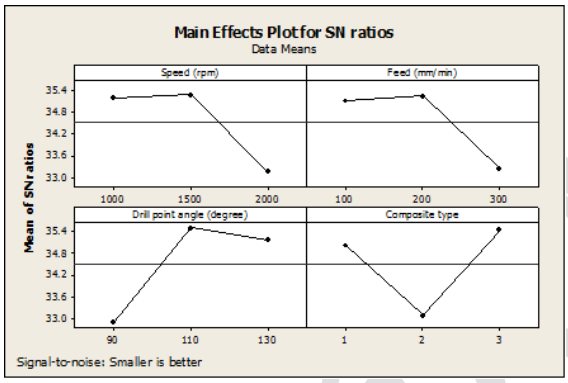

Figure 9 Plot for SN ratios of Surface Roughness

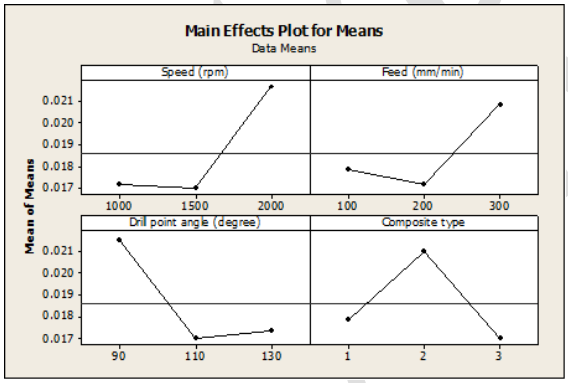

Figure 10 Plot for Means of Surface Roughness

Observation from Results

From response table the SN ratio and mean observed the most contributed parameters and their levels for surface roughness in the following order,

From SN Ratio,

- Drill point Angle at level 2 (110 degree),
- Composite type at level 3 (D),
- Speed at level 2 (1500rpm),
- Feed at level 2 (200mm/min)

From Mean,

- Speed at level 2 (1500rpm),
- Drill point Angle at level 2 (110 degree),
- Composite type at level 3 (D),
- Feed at level 2 (200mm/min)

4. CONCLUSION

The present work of analyzing the mechanical properties and machining parameters in jute and Human hair reinforced natural composite has observed the following results,

- Mechanical properties such as Tensile, Flexural and impact properties are increases with human hair content in jute fiber reinforced composite increased.
- The 100% jute fiber composite has lower strength values than the 100% Human hair composite.
- SEM image shows, the bonding between 25% jute and 75% hair composite has poor and it becomes the reason for decreased strength value.
- In this study Taguchi method provides the efficient method for optimizing the process parameters.
- Based on the SN ratio the surface roughness is mostly affected by drill point angle.
- Based on the Mean the surface roughness is mostly affected by Speed.
- The optimal parameters for surface roughness are same for both SN Ratio and Mean.
- From the result Drill point angle and Speed are the major contribution to affecting the quality of hole. So, it should be selected carefully to reduce the defects.

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