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OPTIMIZATION OF MACHINING PARAMETERS INDRILLING HYBRID FIBER REINFORCED COMPOSITES ON VMC

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ABSTRACT: In the highly competitive manufacturing world, the ultimate goals of the manufacturer are to produce high quality products at minimum cost and in less time. While focusing on the composite materials, the main points to be considered are environment friendliness and light weight, with high specific properties. To fulfill these requirements, the natural fibers are incorporated into manmade fibers, and partially eco friendly hybrid composites have been developed by using Bamboo, E-Glass and Sisal fibers as reinforcing material in the epoxy resin matrix and their mechanical properties such as tensile strength, flexural strength and impact strength are evaluated. Drilling operations were carried out on the composite laminate in order to optimize the process parameters viz., cutting speed, feed and Point angle for obtaining the optimal values of surface roughness using HSS twist drill. Experiments were carried out as per Taguchi experimental design (L_{16}) are conducted using BFW AGNI BMV 45++TC24 machining center and results were analyzed to study the influence of various combinations of process parameters on the quality of holes produced and a set of optimum values of process parameters to be obtained.

Keywords: *Quality, Cost, Time, Composite, Light weight, drilling, etc..,*

1. INTRODUCTION

Taguchi methods are statistical methods or robust design methods, developed by Genichi Taguchi to improve the quality of manufactured goods, and more recently also applied to engineering, biotechnology, marketing and advertising. Taguchi has envisaged a new method of conducting the design of experiments which are based on well defined guide lines. This method uses a special set of arrays called orthogonal arrays. These standard arrays stipulate the way of conducting the minimal number of experiments which could give the full informationof all the factors that affect the performance parameter.

1.1 Orthogonal array

While there are many standard orthogonal arrays available, each of the arrays is meant for a specific number of independent design variables and levels. For example, if one wants to conduct an experiment to understand the influence of 4 different independent variables with each variable having 3 set values (level values), then an L9 orthogonal array might be the right choice.

The orthogonal arrays have the following special properties that reduce the number of experiments to be conducted.

The vertical column under each independent variables of the above table has a special combination of level settings.

All the level settings appear an equal number of times. This is called the balancing property of orthogonal arrays.
All the level values of independent variables are used for conducting the experiments.

The sequence of level values for conducting the experiments shall not be changed. Thereason for this is that the array of each factor columns is mutually orthogonal to any other column of level values. The inner product of vectors corresponding to weights is zero.

1.2 Design of experiments

A well planned set of experiments, in which all parameters of interest arevaried over a specified range, is a much better approach to obtain systematic data. Mathematically speaking, such a complete set of experiments ought to give desired results. Taguchi Methodtreats optimization problems in two categories**,**

1. Static Problem
2. Dynamic Problem

1.2.1 Static Problems:

Generally, a process to be optimized has several control factors which directly decide the target or desired value of the output. The optimization then involves determining the best control factor levels so that the output is at the target value. Such a problem is called as a "STATIC PROBLEM".

This is best explained using a P-Diagram which is shown below ("P" stands for Process or Product. This is the primary aim of the Taguchi experiments - to minimize variations in output even though noise is present in the process. The process is then said to have become ROBUST. There are 3 Signal-to-Noise ratios of common interest for optimization of Static Problems;

1.2.2 Smaller-the-Better

n = -10 Log_{10} [mean of sum of squares of measured data]

This is usually the chosen S/N ratio for all undesirable characteristics like "defects "etc. for which the ideal value is zero. Also, when an ideal value is finite and its maximum or minimum value is defined (like maximum purity is 100% or maximum Tc is 92K or minimum time for making a telephone connection is 1 sec) then the difference between measured data and ideal value is expected to be as small as possible. The generic form of S/N ratio then becomes,

n = -10 Log_{10} [mean of sum of squares of {measured - ideal}]

1.3 Larger-the-Better

n = -10 Log_{10} [mean of sum squares of reciprocal of measured data]

This case has been converted to SMALLER-THE-BETTER by taking the reciprocals ofmeasured data and then taking the S/N ratio as in the smaller-the-better case.

1.3.1 Nominal-the-Best

mean = $10\mathrm{Log}_{10}$Squareof/variance

This case arises when a specified value is most desired, meaning that neither asmaller nor a larger value is desirable.

1.3.2 Analysis of Variance (ANOVA)

The Analysis Of Variance (ANOVA) is a powerful and common statistical procedure in the social sciences. It is the application to identify the effect of individual factors. In statistics, ANOVA is a collection of statistical models, and their associated procedures, in which the observed variance is partitioned into components due to different explanatory variables. In its simplest form ANOVA gives a statistical test of whether the means of several groups are all equal, and therefore generalizes.

1.4 OBJECTIVE OF THE PRESENT WORK

Keeping in view the above mentioned knowledge gaps, the following objectives were chosenfor the present research project work.

Fabrication of a new class of epoxy based hybrid composites reinforced withoriented glass fiber, bamboo fiber and silk fiber.

Evaluation of mechanical properties such as tensile strength, flexural strength andimpact for these composites.To study the influence of fiber parameters such as fiber and fiber loading on themechanical behavior of the composites.

To study the optimization of process parameters on drilling of hybrid

Table 3.1Properties of Fibers and Resin

Fiber	Density (kg/m^3)	Young's Modulus (N/mm^2)	Tensile Strength (N/mm^2)	Elongation and Break (mm)
Bamboo	**0.6 – 1.1**	**11 – 17**	**140 – 230**	**~ 2**
Sisal	**1.20 –1.40**	**9.40 - 22.0**	**511 - 635**	**~ 2.0 – 2.5**
E-Glass	**2.55**	**80**	**2000**	**~ 2.5**
Epoxy	**1.1-1.45**	**1.5-3.5**	**35-100**	**-**

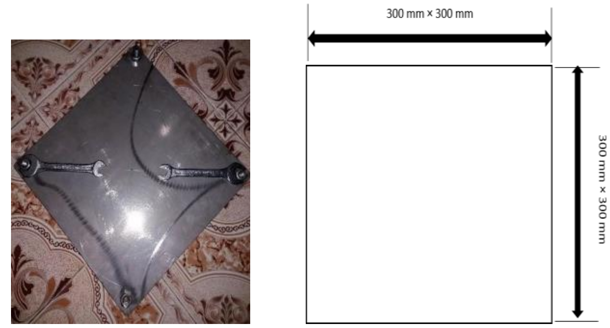


Figure 3.1 Preparation of die

Material	Mild Steel
Dimension	300 mm × 300 mm x 5 mm
Fitted with 4 bolds at corners for applying load	

1.4.1 Weight Calculation of Fiber and Resin

Weight of the fiber(W) = Density of the fiber(ρ) × Volume of the mould (V).Weight ofBamboo

(W_b) = Density of Bamboo (ρ_b) × Volume of mold (V)1.48 × 30 × 30 × 0.5 =Wb= 666 g.

Weight of Sisal (W_s) = Density of Sisal(ρ_s) × Volume of mold(V) = 1.4 × 30 × 30 × 0.5

W_S = 630 g.

Weight of E-glass (W_g)
= Density of E-glass(ρ_g) × Volume of mold(V)
=2.5 × 30 × 30 × 0.5

W_S = 1125 g.

Weight of Epoxy (W_R)= Density of Epoxy(ρ_R) × Volume of mold(V)=1.45 × 30 × 30 × 0.5

W_R = 652.5 g.

1.5 SAMPLE COMPOSITION

The samples are made as per the ASTM International Standards of size 300 mm × 300 mm × 5 mm. Here we change the composition of fibers based on the weightratio. For our study we take 30% composition of fibers for the samples

Table 3.2 Composition of Fibers

Control factors	Noise factors
Cutting speed	Vibration
Feed rate	Raw material variation
Tool angle	Temperature

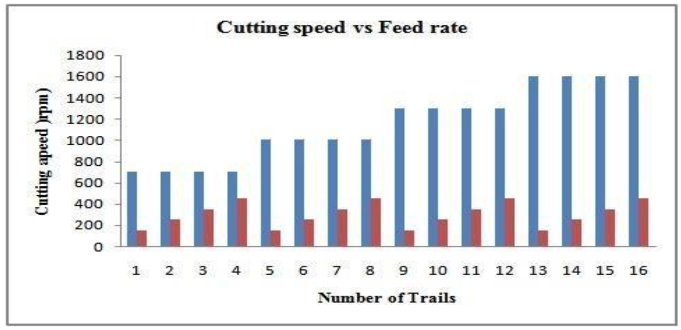
Table 3.4 Selected Factors and their Levels

Symbol	Factors	Units	Lev el 1	Leve l 2	Leve l 3	Leve l 4
A	Cutting Speed	rpm	1	2	3	4
B	Feed Rate	mm/ min	1	2	3	4
C	Point Angle	Degree	1	2	3	4

Table

3.5 Orthogonal Array (OA) L16

Experiment No.	Control Factors		
	Cutting speed (rpm)	Feed rate (mm/rev)	Point angle (degree)
1	1	1	1
2	1	2	2
3	1	3	3
4	1	4	4
5	2	1	2
6	2	2	1
7	2	3	4
8	2	4	3
9	3	1	3
10	3	2	4
11	3	3	1
12	3	4	2
13	4	1	4
14	4	2	3
15	4	3	2



Cutting speed vs Speed Rate

1.9 EXPERIMENTAL TESTING

1.9.1 DETERMINATION OF TENSILE STRENGTH

A tensile test, also known as tension test, is probably the most fundamental type of mechanical test you can perform on material. Tensile tests are simple, relatively inexpensive, and fully standardized.

Figure4 .1 Universal Testing Machines

We can learn a lot about a substance from tensile testing. As you continue to pull on the material until it breaks, you will obtain a good, complete tensile profile. The force measurement is used to calculate the engineering stress, σ, using the following equation

$$\sigma = F/A$$

1.9.2 DETERMINATION OF FLEXURAL STRENGTH

Flexural strength, also known as modulus of rupture, or bend strength, or transverse rupture strength is a material property, defined as the stress in a material just before it yields in a flexure test. . The transverse bending test is most frequently employed, in which a specimen having either a circular or rectangular cross-section is bent until fracture or yieldingusing a three point flexural test technique.

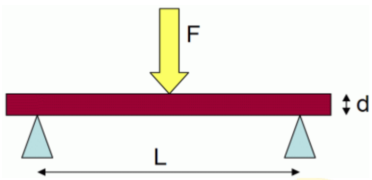


Figure 4.2 Flexural testing

For a rectangular sample under a load in a three-point bending setup:

$$\sigma = 3FL / 2bd^2$$

F is the load (force) at the fracture point (N)

L is the length of the support span, *b* is width and *d* is thickness.

1.9.3 DETERMINATION OF IMPACT STRENGTH

At the point of impact, the striker has a known amount of kinetic energy. The impact energy is calculated based on the height to which the striker would have risen, if no test specimen was in place and this compared to the height to which the striker actually rises.

1.9.4 SPECIMEN PREPARATION AS PER ASTM STANDARDS

The samples to be tested should be in specific standards for the testing. For that we are using ASTM international (American Society for Testing and Materials International).

Tensile Test Specimen (ASTM D638-01)

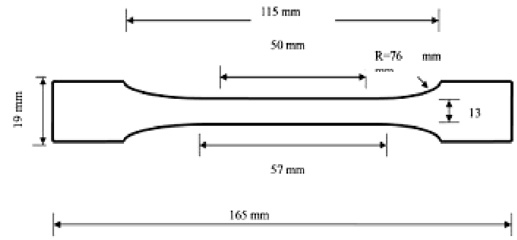


Figure 4.3 Tensile testing specimen dimensions

Flexural Test Specimen (ASTM D790)

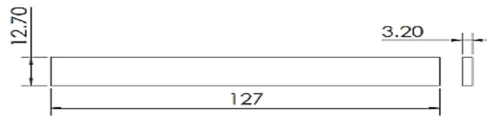


Fig 4.5 Flexural testing specimen dimension **Impact Test**

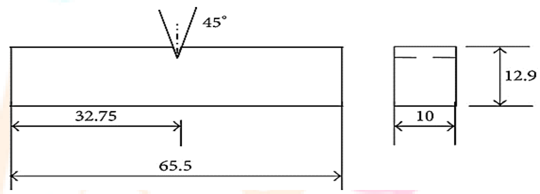


Fig 4.4 Impact testing specimen dimension

1.10 PICTOGRAPHY OF TESTING SPECIMEN

Figure 4.5 Sample Testing Preparation

Table 4.1 Mechanical Properties Testing Result

Sample	Tensile strength (Mpa)	Flextural strength (Mpa)	Impact strength (joules)
SI	30	12	3.8

1.11 DRILLING EXPERIMENTS

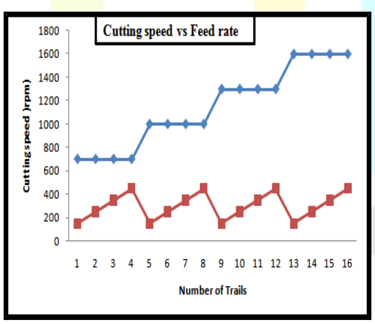
Drilling is the manufacturing process where a round hole is created within a work piece or enlarged by rotating an end cutting tool, a drill. Reaming is a similar process where a hole feature is enlarged to a very specific or accurate size y introducing a rotating end and side cutting tool called a reamer.

The drilling experiments are carried out as per the taguchi method L16 orthogonal array in sample size 300 × 100 × 10 mm, in the VMC machining centre by using HSS drill tool having 10 mm diameter with 2 flutes. Here there are 9 trails are performed by varying the input factor like cutting speed, feed rate, point angle. The trail details are given in the table 4.1 and L9 array as per taguchi in table 4.3

Taguchi Array L16 (3^3), Factors: 3, Runs: 9, Columns of L16 (3^4) and Array: 1 2 3

Table 4.2 Control factors levels

Symbol	Factors	Units	Level 1	Level 2	Level 3	Level 4
A	Cutting Speed	rpm	700	1000	1300	1600
B	Feed Rate	mm/min	150	250	350	450
C	Point Angle	Degree	103°	108°	113°	118°



Cutting speed vs Speed Rate

Table 4.3 Trail details

Trail	Cutting Speed (rpm)	Feed Rate (mm/min)	Point Angle (degree)
1	700	150	103°
2	700	250	108°
3	700	350	113°
4	700	450	118°
5	1000	150	108°
6	1000	250	103°
7	1000	350	118°
8	1000	450	113°
9	1300	150	113°
10	1300	250	118°
11	1300	350	103°
12	1300	450	108°
13	1600	150	118°
14	1600	250	113°
15	1600	350	108°
16	1600	450	103°

1.11.1 Drilling Program

CAD/CAM Software is used to generate part designs and then CNC machining programs corresponding to part designs. Short for “computer-aided design/computer-aided manufacturing,” these systems create these programs for CNC machine tools. In general, CAM development has proceeded along two different tracks. Geometry-based CAM systems used in die/mold machining and other applications focus on complex milled geometries. Algorithms provide specific and efficient ways for machining complex geometries with both high precision and long tool life. By contrast, feature-based CAM systems are generally used in the production machining of geometrically simpler components. Here we used work NC is a Computer aided manufacturing (CAM) software, Work NC CAM software is the premier automatic CNC software for surface or solid models in mold, die and tooling businesses for 2 to 5-axis CNC programming. The program for above trail mentioned data figure as shown below.

Figure 4.6 Program encoded in a machine

1.11.2 Drilling operation

As per the computer data, the operation was performed on the composite material as step by step procedure as shown in below. Figure 4.8 shows hold the work piece in machining for drilling operation. In this work, the depth of cut of 30 mm was kept constant for drill diameter.

Figure 4.7 Hold the Workpiece inside the machining table.

Figure 4.8 Coolant used during drilling operation

1.12 DETERMINATION OF SURFACE ROUGHNESS (RA)

After completing Drilling operations the surface roughness was tested by using the surface

roughness tester model SJ 201, Environment condition room temperature 20°C, Humidity 50% Most surface finish requirements are noted in Ra as opposed to an RMS value Ra is calculated as the Roughness Average of a surfaces measured microscopic peaks and valleys.

1.12.1 Features of SJ-201

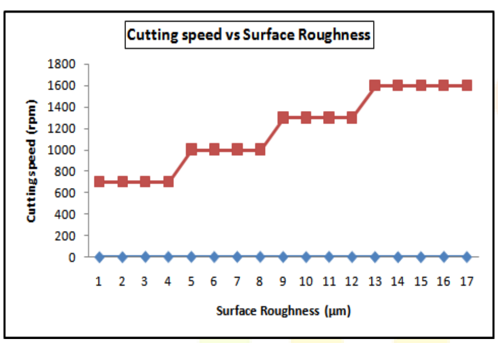
- The display unit demonstrates IP53 protection level and is proof against dripping water and dust.
- The built-in battery, if fully charged, allows approximately 450measurements to be taken even on a site with no access to mains power.
- A convenient carrying case is supplied as standard for protecting the instrument in the field.
- Up to 10 measurement results can be saved in the built-in memory.
- Measurement results appear in large characters on the large LCD screen. Results can be confirmed at a glance.

- The SPC connector for Digimatic output and the RS-232C output connector are provided on the rear panel of the display unit for data output to external devices.

Figure 4.11 Surface roughness testers SJ 201

1.12.2 Surface roughness result.

The surface roughness for 16 drilled surfaces was measured by using surface roughness tester model SJ 201, the result is given below table 4.4



Cutting speed vs Surface Roughness

Table 4.4 Surface Roughness result

Trail	Cutting Speed (rpm)	Feed Rate (mm/min)	Point Angle (degree)	Surface roughness (µm)
1	700	150	103^0	0.45
2	700	250	108^0	3.43
3	700	350	113^0	2.51
4	700	450	118^0	3.40
5	1000	150	108^0	2.42
6	1000	250	103^0	3.04
7	1000	350	118^0	3.32
8	1000	450	113^0	1.94
9	1300	150	113^0	2.12
10	1300	250	118^0	3.23
11	1300	350	103^0	2.24
12	1300	450	108^0	2.12
13	1600	150	118^0	0.80
14	1600	250	113^0	0.94
15	1600	350	108^0	3.24
16	1600	450	103^0	1.83

1.13 RESULT AND DISCUSSION

1.13.1 TAGUCHI RESULT

In accordance with the steps that are involved in Taguchi's Method, a series of experiments are to be conducted by the use of MINITAB 18 software. Here, milling operation on sample components using a vertical milling centre VMC has been carried out as a case study. The Taguchi 3 factor and 4 levels design was performed, the S/N ratio for surface roughness. Here we select the Smaller-the-Better function because we need theminimum surface roughness.

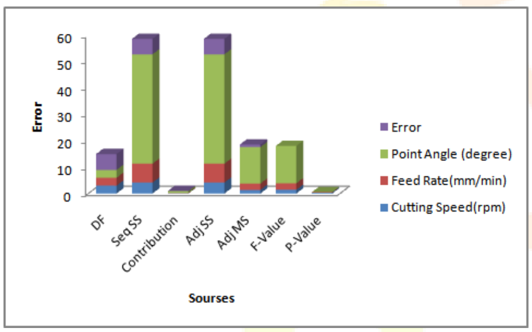
1.13.2 ANOVA TEST RESULT

Analysis of variance (ANOVA) is used to evaluate the response magnitude in (%) of each parameter in the orthogonal experiment. It is used to identify and quantify the sources ofdifferent trial results from different trial runs (i.e. different cutting parameters). Here we use multi factor anova by using software MINITAB 18. The basic property of ANOVA is that the total sums of the squares (total variation) is equal to the sum of the SS (sums of the squares ofthe deviations) of all the condition parameters and the error components, i.e., adding the variations of each factors

The ANOVA test details are given below

- MINITAB 18
- Multi factor ANOVA
- Significance level 95
- Control factors 3

RESULTS FOR SURFACE ROUGHNESS



Errors vs Sources

In this experiment, the surface roughness for each hole was measured and noted as response. The result of the surface roughness (Ra) is represented along with parameters in the given table 5.1. S/N (Ra) represents the signal-to-noise ratio for surface roughness.

Table 5.1 S/N ratio for each trail based on Ra

Trail	Cutting Speed (rpm)	Feed Rate (mm /min)	Point angle (degree)	Surface roughness (µm)	S/N (Ra)
1	700	150	103^0	0.45	6.9357
2	700	250	108^0	3.43	-10.7058
3	700	350	113^0	2.51	-7.9934
4	700	450	118^0	3.40	-10.6295
5	1000	150	108^0	2.42	-7.6763
6	1000	250	103^0	3.04	-9.6574
7	1000	350	118^0	3.32	-10.4227
8	1000	450	113^0	1.94	-5.7560
9	1300	150	113^0	2.12	-6.5267
10	1300	250	118^0	3.23	-10.1840
11	1300	350	113^0	2.24	-7.0049
12	1300	450	108^0	2.12	-6.52671
13	1600	150	118^0	0.80	1.9382
14	1600	250	113^0	0.94	0.5374
15	1600	350	108^0	34	-10.219
16	1600	450	103^0	.83	-5.2490

1.13.3 ANOVA Test for Surface roughness

The ANOVA test is conducted by using MINITAB18 software for with95%significance level,

General Linear Model : Surface Roughness Ra Vs Cutting Speed, Feed Rate and point angle.

Method Factor coding (-1, 0, +1)

Factor Information

Table 5.2 Factor Information for Ra

Factor	Type	Levels	Values
Cutting speed (rpm)	Fixed	4	700, 1000, 1300, 1600
Feed rate (mm/min)	Fixed	4	150, 250, 350, 450,
Point angle (degree)	Fixed	4	103°, 108°, 113°, 118°

Table 5.3 Analysis of Variance Ra

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Cutting Speed(rpm)	3	4.180	7.11%	4.180	1.3934	1.43	0.325
Feed Rate(mm/min)	3	7.170	12.19%	7.170	2.3900	2.45	0.162
Point Angle (degree)	3	41.617	70.74%	41.617	13.8724	14.20	0.004
Error	6	5.862	9.96%	5.862	0.9769	-	-
Total	15	58.829	100.00%	-	-	-	-

In this study of ANOVA test for Ra, the contribution of each of the machining parameters and their interaction was determined. The analysis of the F-ratio values reveals that the most important factors are drill diameter and the Feed rate result on the minimization surface roughness .

These have contributions of about 70.74% and 12.19%from Table 5.3.

1.13.4 Response Table for S/N Ratios (Ra)

The given table 5.4 shows the response and their significance in the variation in response which is surface roughness at the moment. It is clear from the table that the Drill diameter is most effective of them and cutting speed is the least effective on the response, while the feed rate is second to the most significant.

From main effects plot of S/N ratio for, the optimum parameters combination of surface roughness is A4 B1 C1 corresponding to the largest values of S/N ratio for all control parameters.

Table 5.4 Response Table for S/N Ratios for Ra

Level	Cutting Speed (rpm)	Feed Rate (mm/Min)	Point angle (degree)
1	-13.270	-10.559	-8.853
2	-13.893	-13.989	-13.312
3	-12.273	-12.917	-12.162
4	-12.123	-14.095	-17.231
Delta	1.770	3.536	8.378

1.14 CONCLUSION

This work shows that the successful fabrication and optimization of drilling parameters of a useful hybrid reinforced composites (Bamboo + Silk + E-Glass) using polyester resin. Based upon the design of experiments, we done drilling experiments conducted on hybrid composite material using L16 orthogonal array , the following conclusions are made:

1. In this work, to optimize the three process parameters like cutting speed, feed rate, point angle and their interactions on hybrid reinforced composites are evaluated using ANOVA.

2. Through ANOVA. It is found that the point angle is optimized parameter to control the surface roughness on composite material during drilling process.

3. This project concludes with information on engineering properties of hybrid reinforcement of concrete beams, plane truss and columns.

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