Tuijin Jishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol. 44 No. 6 (2023)

Investigation of Drilling Characteristics of Abaca-Neem Fiber Laminate Composite

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Abstract:- In this work, an epoxy resin combination is used as the bonding agent to create a composite made of abaca and neem fibre. The combination of abaca and neem fibre is used because it has outstanding tensile and flexural characteristics as well as salt water corrosion resistance. Using a vertical drilling machine with different spindle speeds, feed rates, and drill diameters, the abaca neem composite is put to the test. The Taguchi technique is used to generate factor combinations and is implemented in an L27 orthogonal array arrangement. The SN ratio is produced for test data acquired by combining parameters for metal removal rate, thrust force, torque, along with peel up delamination and push out delamination. To further enhance and provide a grey relational grade of the Taguchi technique results, grey relational analysis is used. The ANOVA table is generated in order to determine the significance and contribution percentage of each component. The spindle speed, followed by feed rate and drill bit diameter, was determined to have the greatest impact on the drilling process. The regression equation is produced for each of the influencing variables in order to forecast the future behaviour of the dependent and independent variables.

Keywords*: abaca and neem fibre, ANOVA, Grey relational grade (GRG), DOE method, Taguchi Method.*

1. Introduction

Natural fibres are one of the components that are most typically applied in the composite material production process because of their strength and structural integrity. They significantly improve the material's mechanical qualities whether employed alone or in a composite with other materials or natural fibres. The increased consciousness of environmental concerns throughout the world has persuaded businesses to use renewable resources, such as natural fibres, in a variety of engineering applications to lessen pollution in waste materials. The way natural fibre is treated has a significant impact on its characteristics and method of use in the field. It has been established that epoxy performs better than polyester in terms of drilling needs because of reduced shrinkage and better fibre bonding. When the orthogonal array L9 is used in conjunction with the DOE method and an ANOVA table is generated, the Taguchi method is used to incorporate responses in order to find the best testing inputs for thrust force, torque, and surface integrity. This method reveals that the feed rate is the primary cutting tool parameter.

Krishnaraj et al (2011) In order to find the best cutting conditions, a full factorial design experiment was conducted on thin CFRP laminates using a K20 carbide drill. The drilling parameters, such as spindle speed and feed rate, were varied in this experiment [1]. Mamun et al (2014) have studied about, the use of banana and abaca fibres as reinforcements in composites aims to implement fibres in all the manufacturing process by improving the mechanical characteristics of the natural fiber [3]. Ramkumar et al (2022) investigated composite reinforced with Abaca and Kenaffibres where Industries want environmentally acceptable materials that, due to their high strengthto-weight ratio, may replace traditional materials. And reported that the application of the hybrid composite can be implemented in the automobile industries where the natural fibres can be the alternative for the conventional materials [4]. ArjunNagaraj et al (2022) analysed the drilling of carbon fiber reinforced polymer composite material in various cooling and lubrication conditions. Investigated on drilling performance in various feed to the composite by noting the thrust force, torque, and diameter [6].Senthilbabu et al (2022) studied and analysed hybrid composites (Al/B4C/graphite) using grey relational and Taguchi techniques. They optimize the parameters involved in drilling of aluminium /boron carbide/ graphite hybrid composite materials to get good quality holes. The experimental results are collected individually on an L27 orthogonal array and analysed by Signal – Noise (S/N) quantitative relation and grey relational analysis [7].

Akash Sharma et al (2021) concludes different sort of approach that is followed by the various researcher and the problems they conquered while performing such experiments are seen here and they found that drill diameter is the one which has the most effective impact on the output characteristics and the mostly used methods for managing the machine specifications are the grey relation analysis and Taguchi's method [9]. T. sunny et al (2014) studied effect of Process Parameters on Delamination in Drilling where Taguchi method is implemented to find the combination of responses to be done to find the optimal testing inputs of thrust force, torque, surface roughness in which the L9 orthogonal array is used along with DOE method and ANOVA table is generated which reveals that the feed rate is the main cutter parameter [11]. R. Vinayagamoorthy et al (2019) given the various factors affecting the development of Natural Fiber Hybrid Plastics. And studied the various compositions for their tensile strength, compressive strength and flexural strength. Possible areas of application were detailed to be used in aircrafts, marine and automotive fields [12]. Reeghan Osmond et al (2021) done a case study on group multi criteria decision making with ANOVA to select optimum parameters of drilling. When the objective (entropy) weights are changed the alternative A6 is chosen for all the other three experts [14]. S. Sanman et al (2022) studied the abrasive wear properties in two bodies of a natural fiber composite. The analysis was carried out with taguchi technique [15]. Chongcong Tao et al (2022) learned about the delamination with a cyclic load on a composite that is he looked upon the fatigue delamination of the composite [16].

Ziang Jin et al (2022) have reviewed on how to improve the properties of the interlaminar properties of the thermoplastic composite made of resin and fiber and summarised that it can be used for nanotechnology and increase the interlaminar mechanical properties of the composite [17]. B. Ramesh et al (2022) conducted an experiment to determine the process parameter for glass fiber composite with nano granite particles. The experiment results were tabulated with the method of Taguchi L_9 rotational array and the statistical analysis is done [18]. RiteshBhat et al (2019) have performed the TOPSIS technique to know the drilling process parameters of the marine grade GFRP composite and analysis of variance where done [19]. Vijayaramnath et al experimentally investigated some of the natural fibers and found that there is an enormous change in mechanical characterization and found significant. [20-23]. MMC has been fabricated and their mechanical behavior were studied. It was concluded that hybrid composite shows better mechanical behavior than pure aluminum [24]. Fiber metal laminates (FML) with aluminum layer was fabricated. It was concluded that FML with aluminum inclined at 45 degree shows higher tensile strength [25]. Optimization FSW parameters and AWM process parameters were studied [26, 27]. Mechanical behavior of abaca and Kevlar fiber composite were studied and it was concluded that hybrid composite shows better mechanical behavior [28,29].

2. Materials and Methods

2.1 Material specimen Preparation

Utilizing epoxy resin, neem, and hardener, the abaca-neem composite is moulded by hand lay-up technique. The abaca fibre is commonly used for constructing ropes because it has strong tensile strength and is resistant to sea water.

2.2 Drilling characteristics

The abaca-neem composite is tested using a vertical drill machine with the drilling characteristics which are taken into consideration as shown in Table 1 respectively. The output parameters taken into consideration are Material Removal Rate (mm^3/min), Thrust Force (N), Torque (N-m), Peel Out Delamination (mm), Push Out Delamination (mm).

Table 1 Levels and process parameters

Drilling parameters	**Level 1**	**Level 2**	**Level 3**
Spindle speed (rpm)	**600**	**1200**	**1800**
Feed rate (mm/min)	**30**	**60**	**90**
Drill Diameter (mm)	**4**	**6**	**9**

Table 2 Generated L_{27} Orthogonal Array

Exp no	**Spindle Speed (rpm)**	**Feed Rate (mm/min)**	**Tool Diameter (mm)**	**Expt. No.**	**Spindle Speed (rpm)**	**Feed Rate (mm/min)**	**Tool Diameter (mm)**
1	600	30	4	15	1200	60	9
2	600	30	6	16	1200	90	4
3	600	30	9	17	1200	90	6
4	600	60	4	18	1200	90	9
5	600	60	6	19	1800	30	4
6	600	60	9	20	1800	30	6
7	600	90	4	21	1800	30	9
8	600	90	6	22	1800	60	4
9	600	90	9	23	1800	60	6
10	1200	30	4	24	1800	60	9
11	1200	30	6	25	1800	90	4
12	1200	30	9	26	1800	90	6
13	1200	60	4	27	1800	90	9
14	1200	60	6				

2.3 Taguchi Method

Taguchi method uses an orthogonal array in order to organize the parameters which affect the experiment without the need for a high amount of experimentation. With Taguchi optimization technique 27 experiments are done using L27 orthogonal arrays which are as shown in Table 2 respectively. Table 2.GeneratedL_{27}Orthogonal Array

3. Result and Discussion

3.1 Drilling test results

The experimental test results of metal removal rate, thrust force are furnished as shown in Fig. 1, 2 respectively. The Fig. 3 represents the torque, peel up delamination & push out delamination.

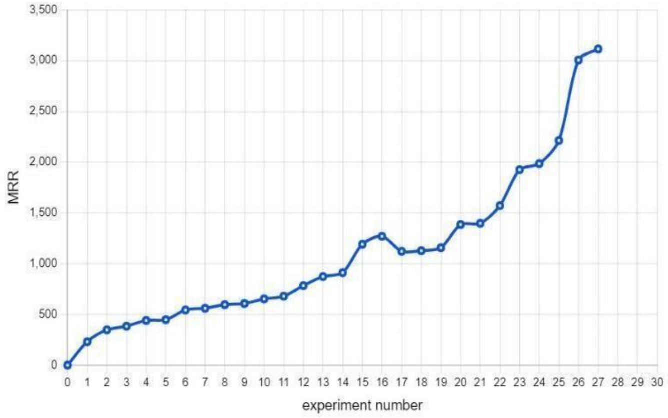

Figure1 MRR of Abaca neem Composite

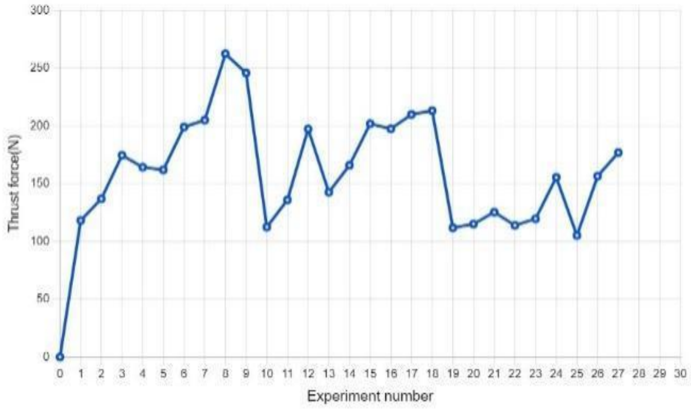

Figure 2 Thrust Force of Abaca neem composite

We may conclude that when the number of experiments increases, the MRR value rises as a result of changes in the spindle speed, feed rate, and tool diameter.

We could observe that while the spindle speed, feed rate, and tool diameter varied with regard to experiment number, the thrust force changed as well.

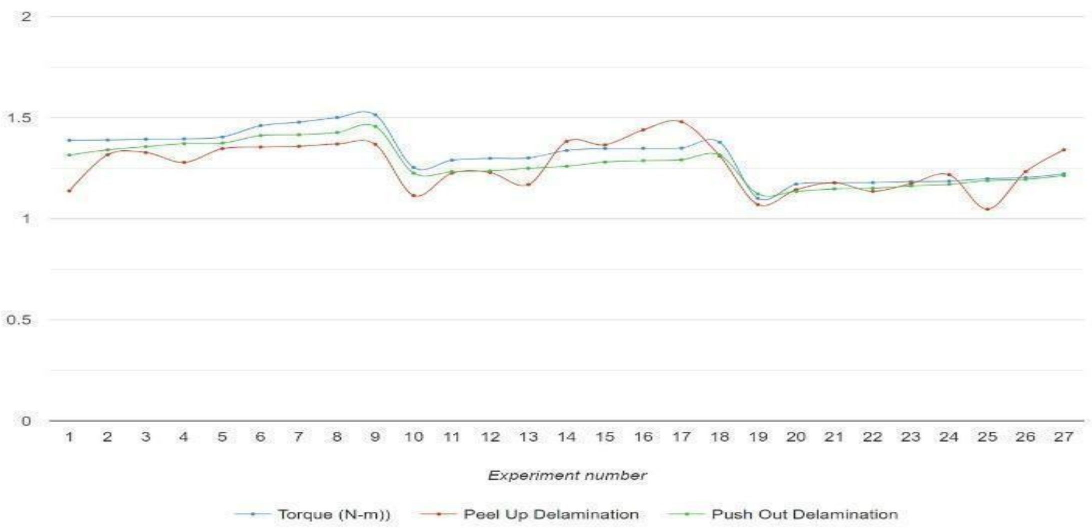

Figure 3 Torque, Peel Up Delamination, Push Out Delamination of Abaca neem Composite

The above graph shows the changes in the torque and delamination of the abaca – neem composite with respect to the changes made in spindle speed, feed rate and in the tool diameter.

3.2 Grey Relational Analysis

In this study, cutting speed, feed rate, and tool diameter were analysed as input parameters using Taguchi L_{27} orthogonal arrays and Grey relational analysis, respectively. For enhancing the complex and demanding inferences between the various response features, GRA is considered appropriate for this study. According to the created orthogonal array, which is displayed in Table 3, 27 tests were carried out.

Table 3 Grey Relational Grades Output Values

Expt. No	MRR (mm3/min)	Thrust Force (N)	Torque	Peel up Delamination (mm)	Push out Delamination (mm)	Grey Relation Grade	Rank	Expt NO	MRR (mm3/ Min)	Force (N)	Torque Thrust	Peel Up Dela Minatio n	Push Out Dela Minatio n	Grey Relatio n Grade	Rank
	Larger - Better	**Smaller - Better**	**Smaller - Better**						**Larger - Better**	**Smaller - Better**	**Smaller - Better**				
1	0.333	0.858	0.418	0.704	0.465	0.556	12	15	0.428	0.448	0.455	0.404	0.514	0.450	17
2	0.343	0.712	0.417	0.445	0.434	0.470	16	16	0.439	0.460	0.454	0.355	0.503	0.442	19
3	0.346	0.531	0.413	0.435	0.416	0.428	22	17	0.420	0.429	0.453	0.333	0.497	0.426	23
4	0.350	0.571	0.412	0.483	0.401	0.443	18	18	0.421	0.421	0.426	0.451	0.465	0.437	20
5	0.351	0.580	0.405	0.419	0.399	0.431	21	19	0.424	0.921	1.000	0.904	1.000	0.850	1
6	0.359	0.456	0.365	0.413	0.366	0.392	24	20	0.455	0.888	0.747	0.691	0.928	0.742	3
7	0.361	0.440	0.354	0.410	0.363	0.386	25	21	0.456	0.796	0.728	0.623	0.870	0.695	5
8	0.364	0.333	0.340	0.401	0.355	0.359	26	22	0.483	0.899	0.726	0.709	0.856	0.735	4
9	0.365	0.359	0.333	0.403	0.333	0.359	27	23	0.548	0.844	0.713	0.630	0.807	0.709	6
10	0.369	0.915	0.574	0.761	0.619	0.648	8	24	0.561	0.610	0.708	0.559	0.780	0.644	10
11	0.372	0.718	0.522	0.547	0.603	0.553	13	25	0.615	1.000	0.680	1.000	0.717	0.802	2
12	0.382	0.460	0.511	0.543	0.594	0.498	14	26	0.929	0.605	0.667	0.538	0.699	0.688	7
13	0.391	0.677	0.508	0.640	0.568	0.557	11	27	1.000	0.523	0.631	0.424	0.647	0.645	9
14	0.396	0.564	0.466	0.392	0.549	0.473	15								

Table 4 Optimized Value for Abaca-Neem Composite

Specimen	Expt. No.	Spindle Speed (rpm)	Feed Rate (mm/min)	Tool Diameter (mm)	MRR (mm^3/min)	Thrust Force (N)	Torque (N-m)	Peel Up Delamination (mm)	Push Out Delamination (mm)
Abaca-Neem	19	1800	30	4	0.424	0.921	1.000	0.904	1.000

Following drilling abaca composites, Table 4 depicts the primary impact on the outputs' Grey relationship grade. The goal of the GRG is to achieve the highest rate of material removal, lowest thrust force, torque, and push-out and peel-up delamination. At 1800 rpm for spindle speed, 30 mm/min for feed rate, and 4 mm for drill bit dimension, it is discovered that the Grey relational grade (GRG) is at its highest. The experimentally determined result is shown in Table 4, and the analysis of variance (ANOVA) for the GRG for the drilled abaca composites is shown in Table 5 for the same previous section circumstances where the GRG is high in the 19th experiment.

It can be deduced that the rotation speed contributes 79.784% of the total, while the feed rate contributes 9.412%. The GRG factor is significantly influenced by the feed rate, drill bit radius, squares of spindle speed and feed rate, as well as the product of feed rate and size. In order to anticipate the quantities with the required quantifiable input properties, the regression equation for the GRG of the drilled abaca composites is constructed. Since the R^2 proportion is more than 95%, the regression equation appears to be extremely accurate with few mistakes. According to equation (1), the regression equation is produced accordingly.

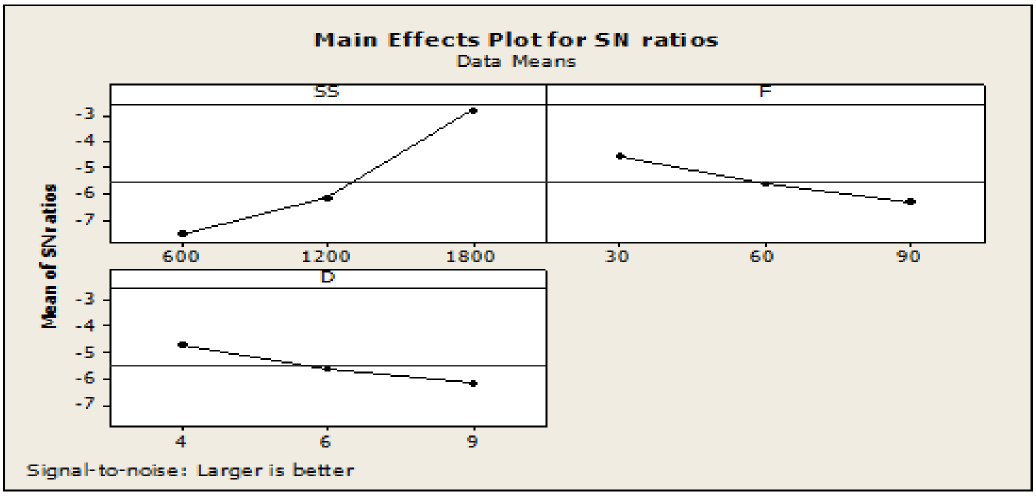

Figure 4 Main Effect Plots for Abaca-Neem Composite

Table 5 ANOVA for Abaca Neem Composite

Source	DF	Seq SS	Adj SS	Adj MS	F	P	% Contribution
SS	1	0.4008	0.0060	0.0060	9.1802	0.0076	73.191
F	1	0.0446	0.0116	0.0116	17.6096	0.0006	8.144
D	1	0.0399	0.0061	0.0061	9.3576	0.0071	7.290
SS*SS	1	0.0346	0.0346	0.0346	52.6233	0.0000	6.310
F*F	1	0.0018	0.0018	0.0018	2.8161	0.1116	0.338
D*D	1	0.0035	0.0035	0.0035	5.3685	0.0332	0.644
SS*F	1	0.0033	0.0033	0.0033	4.9753	0.0395	0.597
F*D	1	0.0048	0.0048	0.0048	7.3749	0.0147	0.884
SS*D	1	0.0031	0.0031	0.0031	4.7005	0.0446	0.564
Error	17	0.0112	0.0112	0.0007			2.038
Total	26	0.5476					100.00

GRG = 1.02491 - 0.000244954 SS - 0.00678519 F - 0.0754415 D + 2.10802e-007* SS*SS + 1.95062e-005 F*F +

0.00406667 D*D + 9.16667e-007 SS*F + 0.000266082 F*D - 1.06213e-005 SS*D(6.25)

S = 0.0256250 R-Sq = 97.96% R-Sq (adj) = 96.88%

4. Conclusion

In this study the abaca-neem fiber is moulded and checked for its machining parameters for spindle speed, feed rate and drill bit diameter. The interactions between the groups were analysed from the input parameters using Taguchi L_{27} orthogonal arrays and Grey relational analysis and concluded with Anova. The below observations are found in the study.

The contribution of the spindle speed was the most followed by the feed rate & drill bit diameter respectively

1. The material removal rate was found to be maximum at 1800 rpm spindle speed, 90mm/min feed rate and 9mm drill bit diameter. It is seen that the majority of the contribution is given by the spindle speed 67.77%, followed by feed rate 15.95%. The spindle speed, square of spindle speed and product of spindle speed and feed rate were significant inputs while affecting MRR of hybrid composite
2. The peel up delamination during drilling of hybrid composite was minimum at 1800 rpm spindle speed, 30mm/min feed rate and 4mm drill bit diameter. The spindle speed contributes about 27.85% and feed rate about 23.17% observed.
3. The push out delamination is minimum at 1800 rpm spindle speed, 30 mm/min feed rate and 4mm drill bit diameter. It is inferred that the spindle speed contributes 87.28%, followed by feed rate 10.27%. The spindle speed, feed rate, square of spindle speed and spindle speed and feed rate product are the significant factors that influence the push out delamination during drilling of abaca-neem composite.
4. The GRG was found to be maximum at 1800 rpm spindle speed, 30 mm/min feed rate and 4mm drill bit diameter. It is inferred that the spindle speed contributed highest 73.19% followed by feed rate 8.144% and drill bit diameter 7.29%. The spindle speed, feed rate, drill bit diameter, square of spindle speed, square of drill bit diameter, product of spindle speed and drill bit diameter were found to be significant that influence GRG.

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