OPTIMISING DRILLING PARAMETERS OF GFRP BY USING GREY RELATIONAL ANALYSIS

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Abstract

Glass fiber reinforced polymer (GFRP) composite constitutes the current trends in the composite technology and machining of these materials make a challenging task. Drilling of GRPF can cause many problems if not optimized. In this study, composite undergo drilling and L_{27} orthogonal array is used for determining delamination and surface roughness. Relationships are developed between parameters. In drilling, spindle speed, tool point angle and feed rate are combined to know the optimal parameters. Grey Relational Analysis was performed to observe the effect of parameters and its interaction. Experiment results reveal that spindle speed is the most significant factor while point angle contributes to the least.

Keywords: *GRPF, Drilling, Grey Relational Analysis, Optimization*

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1. INTRODUCTION

The glass fiber-reinforced polymer composite makes its way up in the engineering due its high strength to weight ratio. These composites are highly used in transportation and construction applications. BharathiRaja et al. found the optimal machining parameters for the surface roughness in machining. Experimental analysis were carried out on aluminium material and studied effect of machining parameters such as cutting speed, feed, and depth of cut on the surface roughness and to obtain the desired surface roughness on face milling process. Mathematical model for surface roughness prediction using Particle Swarm Optimization (PSO) was developed on the basis of experimental results [1].

Lu et al. examined optimization design of the cutting parameters for high-speed end drilling on SKD61 tool steel. The main features selected to estimate the processes are tool life and metal removal rate, and the corresponding cutting parameters were spindle speed, feed per tooth, radial depth of cut, and axial depth of cut. Grey Relational Analysis was the tool used for optimization [2].

Panneerselvam et al. studied the performance of cutting tool on Glass Fibre Reinforced Polymer (GFRP). Grey Relational Analysis approach was the tool used for the study and optimized the machining parameters such as Tool Condition, number of flutes, cutting speed and feed rate on milling of GFRP. The outputs measured were surface delamination, machining forces, cutting torque and surface roughness [3].

Baharudin et al. expanded the Taguchi technique to study the optimal surface roughness on material AL6061. The milling parameters were assessed based on various factors such as spindle speed, feed rate and axial rake angle. Analysis of Variance (ANOVA) was carried out by an orthogonal array L_9 and found out signal-to-noise (S/N) ratio and identifies the significant factors that are affecting to the surface roughness [4].Faria et al. (2008) studied machining parameters such as thrust force and tool wear on carbon fiber epoxy composite(CFRP) by using steel coated carbide drill. Testing was conducted in an industrial setting and drilled up to 24,000 holes. Output parameters reviewed was difference in the thrust force and in geometry [5].

MohamadSyahmiShahromet al. studied Minimum Quantity Lubricant (MQL) and wet machining in milling processes of AISI 1060 Aluminum work material with the main objective of determining the effect of lubrication conditions on the surface roughness. The other parameters considered in the study are feed rate (FR), depth of cut (DOC) and cutting speed (CS).There are four levels in each parameters. He used the Taguchi method was used to predict the surface roughness. He found that, MQL produced better surface finish as compared to wet machining [6].

AzlanMohdZain et al. observed best possible effect of the radial rake angle of the tool, speed and feed rate, cutting conditions in effecting the surface roughness. Surface roughness should be minimum for optimization technique. In the study, Grey Relational Analysis was done to find the optimal result of the cutting conditions and the study proved that the GRA is capable of estimating the optimal cutting conditions [7]. Davim et al. (2004) examined cutting speed and feed rate as input parameters and surface roughness and delamination as output parameters. K10 carbide tools were used for the milling process. Output parameters such as surface roughness and delamination were predicted using response surface method (RSM).

The main intentions behind is to study machinability features and applying GRA to find the optimum conditions. In the present study, K10 solid carbide drill is used for machining process and was machined under parameters, viz., spindle speed (A), point angle(B) and feedrate(C).

Table-1: Properties of the Laminate

Density (kg/m^3)	Weight (kg/m^2)	Tensile Strength (MPa)	Tensile Modulus (GPa)	Hardness (Hv)
1204	9.534	71	1.81	22

2. EXPERIMENTAL INVESTIGATION

Work piece used for the experiments is GFRP with epoxy resin composite. The size of the specimen used was 150 x150 x10 mm. The drilling process was carried out using TCA-70BV drilling Machine.The properties of the laminate are mentioned in Table 1. The cutting tool used for the machining was K10 solid carbide. The input parameters and their levels selected for the experimental design are listed below in Table 2.

Table-2: factors and levels

Symbol	Machining Parameters	Level 1	Level 2	Level 3
A	Speed (rpm)	1000	2000	3000
B	Point Angle(°)	100	118	135
C	Feed rate (m/min)	0.05	0.1	0.15

Fig-1: TCA-70BV Drilling Machine

3. GREY RELATIONAL ANALYSIS

In grey relational analysis, the level of similarity between elements touchstone the relative among elements. It finds out uncertain relation between one main factor and other factors given in a system. Black denotes zero information and white symbolize all information in grey relation technique. Grey is in between black and white. In the case that experiments are ambiguous or when the experimental method cannot be carried out exactly, grey analysis helps to compensate for the shortcoming in statistical regression.

4. MACHINING PERFORMANCE MEASURES

In this present study, Delamination Factor (DF) and Surface Roughness (Ra) were considered as the output parameter affecting the results of machining process by varying spindle speed, point angle and feed rate. Mitutoyo make Subsonic Surface Tester was used to find out the Surface Roughness. The Table 3 shows the orthogonal array (L_{27}) experimental design, input and output parameters.

Table-3: Orthogonal array (l27) experimental design, input and output parameters

	INPUT PARAMETERS			OUTPUT RESPONSES	
Sl. No	Speed, A (rpm)	Point Angle, B (°)	Feed, C (m/min)	Surface Roughness Ra (µm)	Delamination Factor, DF
1	1000	100	0.05	3.1621	1.1696
2	1000	100	0.1	3.515	1.24
3	1000	100	0.15	3.8857	1.281
4	1000	118	0.05	3.2101	1.194
5	1000	118	0.1	3.5613	1.275
6	1000	118	0.15	3.7295	1.317
7	1000	135	0.05	3.0113	1.1832
8	1000	135	0.1	3.4261	1.236
9	1000	135	0.15	3.7	1.288
10	2000	100	0.05	3.456	1.327
11	2000	100	0.1	3.544	1.3972
12	2000	100	0.15	3.966	1.4173
13	2000	118	0.05	3.412	1.3831
14	2000	118	0.1	3.58	1.4041
15	2000	118	0.15	4.07	1.4235
16	2000	135	0.05	3.271	1.3678
17	2000	135	0.1	3.524	1.3782
18	2000	135	0.15	3.852	1.4223
19	3000	100	0.05	3.87	1.384
20	3000	100	0.1	4.0132	1.4295
21	3000	100	0.15	4.477	1.46
22	3000	118	0.05	3.925	1.398
23	3000	118	0.1	3.998	1.435
24	3000	118	0.15	4.492	1.478
25	3000	135	0.05	3.7134	1.381
26	3000	135	0.1	3.969	1.444
27	3000	135	0.15	4.327	1.464

5. RESULTS AND DISCUSSUIONS

The experiments were carried out on the bases of L_{27} orthogonal array. Delamination factor and surface roughness were analysed on changing spindle speed, point angle and feed rate. The input parameters were optimized by using Grey Relational Analysis (GRA) for determining the optimal machining input parameters with the consideration of several performance features. Grey relational grade was found out and ranked for obtaining the optimal condition. Besides, this approach is feasible to obtain optimal machining parameters for a desired surface roughness and minimum delamination factor by GRA.

Table-4: Calculated Grey Relational Coefficient and Grey Relational Grade

Exp. No	**Experimental Design**			**Grey Relational Coefficient**		**Weighted Grey Relational Grade**
	Speed, A(rpm)	**Point Angle, B(°)**	**Feed, C(m/min)**	**Surface Roughness, Ra (μm)**	**Delamination Factor , DF**	
1	1000	100	0.05	0.831	1.000	0.915
2	1000	100	0.1	0.595	0.687	0.641
3	1000	100	0.15	0.458	0.581	0.520
4	1000	118	0.05	0.788	0.863	0.826
5	1000	118	0.1	0.574	0.594	0.584
6	1000	118	0.15	0.508	0.511	0.509
7	1000	135	0.05	1.000	0.919	0.959
8	1000	135	0.1	0.641	0.699	0.670
9	1000	135	0.15	0.518	0.566	0.542
10	2000	100	0.05	0.625	0.495	0.560
11	2000	100	0.1	0.582	0.404	0.493
12	2000	100	0.15	0.437	0.384	0.410
13	2000	118	0.05	0.649	0.419	0.534
14	2000	118	0.1	0.566	0.397	0.481
15	2000	118	0.15	0.412	0.378	0.395
16	2000	135	0.05	0.740	0.438	0.589
17	2000	135	0.1	0.591	0.425	0.508
18	2000	135	0.15	0.468	0.379	0.424
19	3000	100	0.05	0.463	0.418	0.441
20	3000	100	0.1	0.425	0.372	0.399
21	3000	100	0.15	0.336	0.347	0.341
22	3000	118	0.05	0.448	0.403	0.425
23	3000	118	0.1	0.429	0.367	0.398
24	3000	118	0.15	0.333	0.333	0.333
25	3000	135	0.05	0.513	0.422	0.468
26	3000	135	0.1	0.436	0.360	0.398
27	3000	135	0.15	0.360	0.344	0.352

Table-5: Response Table for Grey Relational Grade Level Factor

Sl No	Spindle Speed(A)	Point Angle(B)	Feed Rate(C)
1	**0.6851**	0.5243	**0.6352**
2	0.4881	0.4984	0.5079
3	0.3950	**0.5455**	0.4251

6. CONCLUSIONS

Grey relational Analysis was used to discover optimal machining parameter. With GRA, we determine found grey relational grade and finally ranked it. Since the minimum value of surface roughness and minimum delamination factor is ideal for the machining operation, the grey relational coefficients for the same given in table IV are obtained using the formula:

$$\text{Grey Relational Coefficient} = \frac{= (\max(x) - x)}{(\max(x) - \min(x))}$$

Machining Parameters namely Spindle Speed (A), Point Angle (B), Feed Rate(C) were optimized to meet the objective. From the study, the following conclusions are drawn:

- The observation result shows that the primary factor affecting the surface roughness is spindle speed, subsequently followed by feed rate and point angle. Also spindle speed is the major factor affecting the delamination factor.
- The optimized control factors for minimizing the Surface roughness Ra and delamination factor DF were Spindle speed A_1=1000rpm, Point Angle B_3=135°, Feed Rate C_1=0.5m/min.

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