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Optimization of machining parameters on milling of GFRP composites by GREY Method

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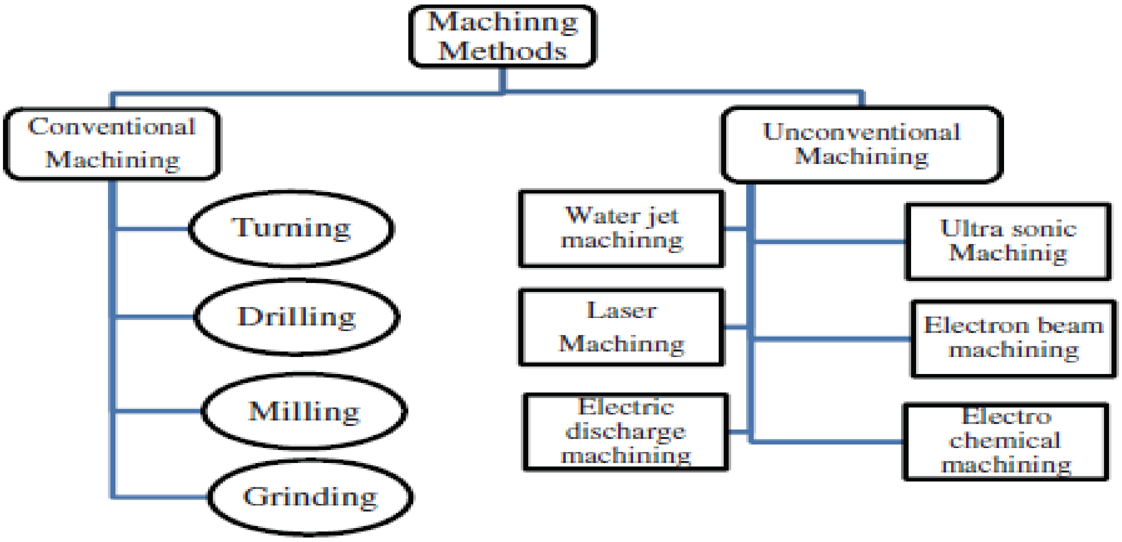
Abstract

Glass fiber reinforced polymer (GFRP) composite gear is used in a variety of applications that require precise motion transfer and quiet rotation. To broaden its application, the gear's quality must be improved. The analysis was carried out to assess the influences of the machining factors on the responses in order to determine the significant effect of the parameters on the quality characteristics of the test. This analysis was carried out with a level of significance of 5%, implying a level of confidence of 95%. Surface roughness ANOVA result It is discovered that the Cutting Tool (P=0.003) (47.73 percent) has the greatest influence on the machining force. Spindle speed (P= 0.048) (18.30 percent), Feed rate (0.098) (13.30 percent), and Depth of cut (0.136) (11.27 percent) were the next most significant. Surface roughness is a significant factor in the parameters of the current study.

1.1 INTRODUCTION:

The GRA-based Taguchi optimization technique with experimental design aids in the control/reduction of various errors during the fabrication of GFRP composite gear.(3) The response table was used to select various parameters for ranking. The p-value is less than 0.02 and thus all process parameters have a significant effect on the performance characteristics of GFRP. Rotary feed, cutting speed, cutting fluid ratio, and cutting fluid flow rate have been identified as key significant parameters of the gear shaper machine that control performance characteristics. The optimum machining parameters are 0.15 mm/stroke rotary feed, 240 strokes/min cutting speed, 12% cutting fluid ratio, and 30 ml/min cutting fluid flow rate. The significant parameters that influence performance characteristics have a 96% confidence level. According to a review of the existing literature, many studies have been conducted on polymer composite gears performance based on milling machine by varying reinforcement, process routes, and gear pair combinations of different materials, but no study is available on single optimization of milling machine cutting parameters for minimum variation/deviation of surface roughness of tooth, which affects noise, vibration, and load carrying capacity. The variation in root diameter affects the root fillet radius, which is responsible for tooth beam strength; the variation in tooth thickness controls the proper meshing of teeth, which is responsible for noise and vibration; and the variation in surface roughness affects the friction and life of teeth in wear.



2. METHODOLOGY

2.1 Materials and Methodology

A total of 25 tests were scheduled. The L25 orthogonal array architecture developed by Taguchi was used. Four critical parameters were considered when organizing the tests: spindle speed, feed rate, depth of cut, and type of milling tool used in the milling process; each parameter was adjusted at five levels. During the Taguchi study, the average value of experimental response and its related signal-to-noise (S/N) ratio for each run were obtained to investigate the effects of various machining process The S/N ratio was chosen for the Taguchi analysis because it aids in describing the trial data's average (mean) and variables (standard deviation). The goal of this study was to achieve the lowest machining force and surface roughness possible by optimizing the input process parameters. As a result, the S/N ratio will fall into the category of "lower is better." Experiments were carried out on a universal milling machine with a spindle power of 10 kW and a maximum speed of 3000 rpm. To keep the workpiece central and avoid vibrations, a specially designed fixture was used. [10]

2.2 Properties of GFRP Engineering polymer of DuPont make Zytel 70G33LN010 with 33% glass fibre reinforced polyamide 66 resin has been chosen for making gear blanks, and details of its properties are given in Table 1.

The Taguchi method is a technique for designing quality systems based on orthogonal arrays, which provides less variance for experiments with optimal parameter settings.

5. Optimization methodology using grey relational analysis

Step-1

The data is first to be normalized because of avoiding different units and to reduce the variability. It is essentially required since the variation of one data differs from other data. A suitable value is derived from the original value to make the array between 0 to 1 (NoorulHaq et al., 2008). In general, it is a method of converting the original data to a comparable data. If the response is to be minimized, then smaller-the-better characteristics is intended for normalization to scale it into an acceptable range by the following formula.

Equation is selected and it can be expressed as

$$.Y_i(k) = \frac{Y_i(k) - \min Y_i(k)}{\max Y_i(k) - \min Y_i(k)} \quad (1)$$

The first standardized formula is suitable for the benefit – type factor.

$$x_i(k) = \frac{\max x_i(k) - x_i(k)}{\max x_i(k) - \min x_i(k)} \quad (2)$$

The second standardized formula is suitable for defect – type factor.

$$x_i(k) = \frac{|x_i(k) - x_0(k)|}{\max x_i(k) - x_0(k)} \quad (3)$$

The third standardized formula is suitable for the medium – type factor.

The grey relation degree can be calculated by steps as follows:

a) The absolute difference of the compared series and the referential series should be obtained by using the following formula [15]:

$$\Delta x_i(k) = |x_0(k) - x_i(k)| \quad (4)$$

And the maximum and the minimum difference should be found.

b) The distinguishing coefficient *p* is between 0 and 1. Generally, the distinguishing coefficient *p* is set to 0.5.

c) Calculation of the relational coefficient and relational degree by (12) as follows.

In Grey relational analysis, Grey relational coefficient ξ can be expressed as follows [15]:

$$\xi_i(k) = \frac{\Delta \min + p\Delta \max}{\Delta x_i(k) + p\Delta \max} \qquad (5)$$

And then the relational degree follows as:

$$r_i = \sum \left[w(k)\xi(k) \right] \qquad (6)$$

In equation (13), ξ is the Grey relational coefficient, *w (k)* is the proportion of the number *k* influence factor to the total influence indicators. The sum of *w (k)* is 100%. The result obtained when using (12) can be applied to measure the quality of the listed software projects.

Step-6

After optimal combination of process parameters are found out, the next step is very the improvement of grey relational grade through conducting confirmatory experiment. The predicted value of grey relational grade for optimal level can be obtained as follows,

$$\widehat{\gamma} = \gamma_m + \sum_{i=1}^{0} \widehat{\gamma}_i - \gamma_m \qquad (7)$$

Where γ_m is the total mean grey relational grade, $\widehat{\gamma}_i$ is the mean grey relational grade at the optimal level of each parameter, and the number of the significant process parameters (Sahoo&Sahoo, 2013).

The predicted optimum values are listed in Table 5.9. The value of $\widehat{\gamma}$ is calculated 0.4413fromabove equation. To check the reliability of predicted GRG, Confidence Interval (CI) is also determined using Equation (7) (Çaydaş & Hasçalık, 2008; Ju-Long, 1982).

5.1. Implementation of methodology to find multi-response parametric optimization

Step-1

The experimental data have been normalized for Material removal rate (Gm. /Min), Total metal removed presented in Table 5.1 called grey relationalgenerations.Pre-processing is important in GRA because the data sequences that will be compared have different ranges and units. Therefore, all data sequences must be standardized between the same lower and upper limits. They are defined here as 0 and 1. For Larger the Better Characteristics (e.g. MRR), the input quantity is normalized using equation (1). For Larger the Better characteristics (MRR), equation (2) is used. These equations are taken from [3].

Table3.2 Details of input parameters and considered responses for all 25 experiments[10]

Exp. No.	**Cutting Tool**	**Spindle speed**	**Feed rate**	**Depth of cut**	**Machining force**	**Surface roughness “Ra**
1	1	690	0.6	0.5	23.3	4.11
2	1	960	0..8	1	23.5	4.07
3	1	1153	1	1.5	24.6	3.86
4	1	1950	1.2	2	24.1	3.66
5	1	2500	1.4	2.5	23.4	3.24
6	2	690	0.8	1.5	23.4	3.18
7	2	960	1	2	22.9	3.86
8	2	1153	1.2	2.5	23.5	3.26
9	2	1950	1.4	0.5	23.6	3.51
10	2	2500	0.6	1	23.3	3.13
11	3	690	1	2.5	23.7	2.83
12	3	960	1.2	0.5	23.7	3.87
13	3	1153	1.4	1	23.2	2.65
14	3	1950	0.6	1.5	23.2	3.84
15	3	2500	0.8	2	23.5	3.25
16	4	690	1.2	1	22.7	3.14
17	4	960	1.4	1.5	23.1	3.13
18	4	1153	0.6	2	22.4	3.52
19	4	1950	0.8	2.5	22.5	3.53
20	4	2500	1	0.5	22.8	3.39
21	5	690	1.4	2	22.2	2.75
22	5	960	0.6	2.5	21.2	3.1
23	5	1153	0.8	0.5	21.6	2.97
24	5	1950	1	1	20.6	2.88
25	5	2500	1.2	1.5	21.9	2.49

Table 4.3 Grey relation coefficient

Grey relation coefficient		GRG
Machining force	Surface roughness “Ra	
0.426	0.333	0.379
0.408	0.339	0.374
0.333	0.372	0.352
0.364	0.409	0.386
0.417	0.519	0.468
0.417	0.540	0.478
0.465	0.372	0.418
0.408	0.513	0.460
0.400	0.443	0.421
0.426	0.559	0.492
0.392	0.704	0.548
0.392	0.370	0.381
0.435	0.835	0.635
0.435	0.375	0.405
0.408	0.516	0.462
0.488	0.555	0.521
0.444	0.559	0.502
0.526	0.440	0.483
0.513	0.438	0.475
0.476	0.474	0.475
0.556	0.757	0.656
0.769	0.570	0.670
0.667	0.628	0.647
1.000	0.675	0.838
0.606	1.000	0.803

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Machining force	Surface roughness “Ra		
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0.417	0.540	0.478	7
0.465	0.372	0.418	15
0.408	0.513	0.460	14
0.400	0.443	0.421	16
0.426	0.559	0.492	9
0.392	0.704	0.548	7
0.392	0.370	0.381	19
0.435	0.835	0.635	6
0.435	0.375	0.405	16
0.408	0.516	0.462	14
0.488	0.555	0.521	8
0.444	0.559	0.502	8
0.526	0.440	0.483	9
0.513	0.438	0.475	9
0.476	0.474	0.475	10
0.556	0.757	0.656	4
0.769	0.570	0.670	3
0.667	0.628	0.647	5
1.000	0.675	0.838	1
0.606	1.000	0.803	2

Table 4.6. Experimental and predicted values of grey relational grade

Performance characteristics Optimal	**Initial machining parameters**	**Optimum process machining parameters**	
		Experimental value	**Predicted value**
	A1 B1 C1 D1	A5 B4 C3 D2	A5 B4 C3 D2
Cutting Tool (A)	**0.379**	**0.838**	**0.8431**
Spindle speed (B)			
Feed rate(C)			
Depth of cut(D)			
Grey relational grade			
Grey relational grade improvement	**0.0051**		

Hence the grey relational analysis based on taguchi method for the optimization of the A particularly important tool is multi-response problems. For predicting the Machining force and surface roughness.

The improvement of grey relational grade from initial parameter combination (A1–B1–C1 D1 to the optimal parameter combination (A5 B4 C3 D2) is found to be 0.0051

CONCLUSION

1. The spindle speed and feed rate have no effect on the SR and Machining force of CFRP composite laminates.

2. The Grey-Taguchi method can be used to simplify and improve the optimization of numerous common performance criteria. According to the response table, the maximum setting for the GRG for spindle speed is 4000 rpm, feed rate is 200 mm/min, and cut depth is 0.5mm (A5 B4 C3 D2).

3. The depth of cut is the most important factor influencing the SR and DLF. To determine the SR and DLF, cutting depth is a critical parameter that interacts heavily with spindle speed.

4. Machining force ANOVA result It is discovered that the Cutting Tool (P=0.003) (47.73 percent percent) has the greatest influence on the machining force. Spindle speed (P= 0.048) (18.30 percent), Feed rate (0.098) (13.30 percent), and Depth of cut (0.136) (11.27 percent) were the next most significant. In the current study, parameters have a significant impact on surface roughness.

5. The R –sq value is 91.51 percent, indicating good agreement between the input and output relationships. It demonstrates that the input and output variables have a strong relationship. Now, the R-Sq (adj) value is 74.52 percent, indicating that the data are well fitted for the new sets of variables.

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