ANALYSIS OF SURFACE ROUGHNESS AND WEAR BY TURNING OF FIBER PARTICULATE REINFORCED POLYMER COMPOSITE

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Abstract

This Paper presents a study of surface roughness and wear analysis by CNC turning process in the use of TNMG 16 04 08 carbide inserts on Fiber Particle Reinforced Polymer composites (FPRP). The primary problem that has been encountered in the development of machining operation is tool wear. Tool wear in machining is defined as the amount of volume loss of tool material on the contact surface due to interaction between the tool and the work piece. Tool wear is an important factor directly affecting the surface quality of the machined products. Recent mathematical and computational advances have fashioned a number of researches focusing on several aspects of modelling and analysis of tool wear. Many literatures indicate that in the turning process, cutting speed, feed rate and depth of cut are the major influential parameters which affect the tool wear. Hence it is essential to evaluate the effect of various processing parameters on the tool wear.With this overall view, the present work is about to study the surface finish and tool wear with different parameters viz. speed, feed, depth of cut, fiber orientation and diameter of fiber, which will be a scope in Industrial purpose.

Keywords: FPRP , TNMG 16 04 08, Surface roughness, Tool wear, Taguchi.

1. Introduction

Fiber reinforced polymer composites are used extensively used in automobile, aerospace and marine applications because of their high specific strength, high specific stiffness, better impact characteristics, corrosion resistance and design flexibility. Fiber and particulate reinforced composites are an economic alternative to stainless steel and other materials in highly corrosive industrial applications. In recent years, fiber/particle reinforced polymers (FPRP) have been extensively used in variety of engineering applications in different fields such as aerospace, oil, gas and process industries. FPRP composite components are normally fabricated by processes such as filament winding, hand lay-up, etc. After fabrication, they require further machining to facilitate dimensional control for easy assembly and for functional aspects. The machining of FPRP composites is different from conventional materials. The behavior of composites is anisotropic. The quality of machined products depends upon the fibers, matrix materials used, bond strength between fiber and matrix, type of weave, etc., The mechanism of material removal is also different from that of single-phased material, such as metals. De-lamination, fiber pull-out, fiber fragmentation, burring, and fuzzing are some of the types of damage caused by machining FPRP, as reported by suleymanneseli [1]. H.M.Somashekara et al. [2] suggested that surface roughness in turning operation using Taguchi technique for cemented carbide tools to improve the machinability of composites. Poornima et al. [3] studied the Optimization of machining parameters in CNC turning of martensitic stainless steel using RSM and GA. B. Sidda Reddy et al. [4] carried out study on machining of polymer composites. They concluded that higher cutting speeds give better surface finish. S. Rajesh [5] studied the Multi-response optimization of machining parameters surface. Pankaj Sharma. [6] attempted a Investigation Of Machining Parameters In CNC Turning By Taguchi Based Grey Relational Analysis. Compared to conventional drilling, this method has resulted in reduced cutting forces, less damage, and reduced tool wear. Show-ShyanLin et al. [7] reported that the Optimization of 6061T6 CNC Boring Process Using the Taguchi Method and Grey Relational Analysis. Muhammad AL Firdausi bin johari [8] Optimize the cutting parameters for turning operation based on taguchi method. Anil Gupta [9] reported that in high speed CNC turning of AISI P-20 tool steel .Machining of FPRP material is difficult to carry out due to the non-homogenous structure of material. Several authors studied the effect of process parameters on tool wear for different work materials. However, studies on tool wear in FPRP are not widely available in literature. Most of the researches have been carried out on the characterization of natural fiber composites but the prediction of mechanical properties is found to be limited in literature[10,11]. Some of the manufacturing studies on roselle fiber/particle reinforced polymer composites have been carried out using taguchi method and ANOVA techniques.[12]

2. Material and Methods

Roselle fiber and coconut shell particles reinforced Polymer (FPRP) is a composite material, which consist of vinylester thermosetting resin as matrix and fiber/particle as reinforcement. Pultrusion technique is used to fabricate FPRP products in various continuous forms of structural sections such as box, I-, H-, and plates, which are similar as steel sections. Pultrusion is the process of "pulling" raw composites through a heated die creating a continuous composite profile. The term pultrusion combines the words, "pull" and "extrusion". Extrusion is the pushing of material, such as a billet of aluminum, through a shaped die. Whereas pultrusion, is the pulling of material, such as fiberglass and resin, through a shaped die.

The pultrusion process starts with racks or creels holding rolls of fiber mat or doffs of fiber roving. Most often the Reinforcement is fiberglass, but it can be carbon, aramid, or a mixture. This raw fiber is pulled off the racks and guided through a resin bath or resin impregnation system. Resin can also be injected directly into the die in some pultrusion systems. The experimental work was carried out on the Galaxy- Midas 6 CNC turning machine. FPRP rod (Ø 45x100 mm) was used for the present work. Its composition is 82.27% of Fiber/particle and 17.73% of Vinylester resin. The TNMG 16 04 08 carbide inserts were selected as cutting tool. The experimental conditions are given in Table 2. After machining, the surface roughness values Ra were measured by a Mitutoyo SJ-201 Surface roughness tester. Also tool wear was measured by Tool maker microscope. Using L9 Taguchi standard orthogonal array, the experimental results are carried out. This plan was developed for establishing the quadratic model for surface roughness and tool wear by using Taguchi Method.

2.1 Design of Experiment

Design of experiments is a standard tool to conduct the experiment in an optimum way to investigate the effects of process parameters on the response or output parameter. The design matrix for three blocks, in which each of two factors are varied through the four possible combinations of higher and lower limits. In each block a certain number of factors are put through all combinations for the three factorial designs, while the other factors are kept at central values. Accordance with literature survey identified the turning parameters and their levels for the experiment are cutting speed, feed and depth of cut are given in Table.1.

Table 1: Process Parameters and their Levels

2.2 Taguchi's Method

The Taguchi method for robust design is a powerful tool. Two major tools used in robust design are S/N ratio and orthogonal array. Robust design is an important method for improving product or manufacturing process design by making the output response insensitive (robust) to difficult to control variations (noise). There are several types of quality characteristics, such as the lower-the-better, the higher-the-better and the nominal-the-better. In this study, since surface roughness should be a minimum and tool wear also minimum the smaller-the-better type of the S/N ratio has been used and is defined as follows:

$$S/N= -10 \log[1/n \, (y1^2+ y2^2+.... yn^2)] \quad (1)$$

Where ($y1^2+ y2^2+.... yn^2$) are the responses of the machining characteristic, for a trial condition repeated times. The negative sign in Eq. (1) is for showing the smaller-the better quality characteristic. The S/N ratios were computed using Eq. (1) for each of the 9 trials, and the values are re-ported with their experimentally measured values. For this purpose, the first step in the optimization process is to determine the S/N ratio for all the experimental tests using the Taguchi method. The next step is to find out the objective function. The three machining performance characteristics are to be optimized to meet the objective of the study. According to the literature review, the following summaries can be made: (OA) to examine the quality characteristics through a minimum number of experiments. The experimental results based on the OA are then transformed into S/N ratios to evaluate the performance characteristics. Therefore, the Taguchi method concentrates on the effects of variations on quality characteristics, rather than on the averages. That is, the Taguchi method makes the process performance insensitive to the variations of uncontrollable noise factors [1].

3. Experimental Details

This experiment works are planned using Taguchi,s orthogonal array in the design of experiments (DOE), Which helps in reducing the number of experiments. The number of three cutting parameters is selected for the present investigation is cutting speed (v), feed (f), and depth of cut (d). previous studies on the effect of machining parameters on FPRP composites indicate that higher cutting speeds were found to cause a large deformation range of fiber/particle, Taguchis orthogonal array L9 is most suitable for this experiment. This needs 9 runs and has 8 degree of freedoms.

Table 2: L9 Orthogonal Array with Observations

Table 3: Parameters Value Setup

4. Results and Discussion

Study of the surface roughness characteristics of FPRP composites require more analysis due to the presence of abrasive phase in the reinforcing fiber/particles, the main effects plot for means and S/N ratios. The minimum values in the graph of main effect plot for means or maximum values in the graph of main effect plot for S/N ratio is selected as the optimum values. Therefore the optimum value of cutting speed is 75m/min, feed rate 0.10mm/rev and depth of cut 0.4 mm**.**

Table 4: Anova Table for Surface Roughness

The table 4 shows the ANOVA for Penetration. The last column of the table indicates that all have Contribution values for Cutting Speed (v = 79.20%), Feed (f = 5.65%), Depth of cut (d =4.73 %),e-pool (p= 10.41%) have great influence on penetration.

The contributions of the parameters are as follows:

1. The maximum percentage of contribution is cutting speed (v=79.20%).
2. The percentage of contribution in E-pool is (p=10.41%).
3. The cutting speed is the dominant parameter for surface roughness followed by the feed.
4. Depth of cut shows minimal effect on surface roughness compared to other parameters.

Interaction plot of cutting speed x feed rate shows that at middle level of feed rate (0.15mm/rev) the level1 and level 3 of cutting speed is highly interacting. interaction plot of cutting speed x depth of cut shows that at middle level of depth of cut (0.8mm) the level1 and level 3 of cutting speed is highly interacting. Interaction plot of feed rate x depth of cut shows that at middle level of depth of cut (0.8mm) the level2 and level 3 of feed rate are highly interacting**.**

Fig. 2: Main Effects plot for Means

Fig. 3: Main Effects plot for S/N ratios

Fig 3 shows main effects plot for means and S/N ratios. The minimum values in the graph of main effect plot for means or maximum values in the graph of main effect plot for S/N ratio is selected as the optimum values. Therefore the optimum value of cutting speed is 50m/min, feed rate 0.10mm/rev and depth of cut 0.4 mm.

Fig. 4: Main Effects plot for Means

Fig. 5: Main Effects plot for S/N ratios

Table 5: ANOVA Table for Flank Wear

Table: 5 shows the ANOVA for Penetration. The last column of the table indicates that all have very small p-values. Cutting speed (v= 25.74%), Feed (f = 48.44%), Depth of cut (d =21.73 %), Error is (p= 4.09%) have great influence on penetration.

The maximum percentage of contribution is Feed = 48.44%, the percentage of contribution in Error is = 4.09 %.

Interaction plot of cutting speed x feed rate shows that at middle level of feed rate (o.15mm/rev) the level 2 and level 3 of cutting speed is highly interacting. Interaction plot of cutting speed x depth of cut shows that at middle level of depth of cut (0.8mm) the level1 and level 2 of cutting speed is highly interacting. Also in which at first level of depth of cut (0.4mm) level 2 and level 3 of Wear feed rate are highly intractable. Interaction plot of feed rate x depth of cut shows that at middle level of depth of cut (0.8mm) level 1 and level 2 of feed rate are highly enterable.

Fig. 6: Interaction plot for Surface Roughness

Fig. 7: Interaction plot for Flank Wear

5. Conclusions

The surface finish decreases by 5.23% when cutting speed increases from 50m/min to 75m/min. Further increase in cutting speed to 100m/min will result in decrease in surface roughness by 13.15%. The surface finish decreases by 7.70% when feed rate increases from 0.10 to 0.15mm/rev. Further increase in feed rate to 0.20mm/rev will result in decrease in surface roughness by 15.58%. The surface finish decreases by 9.40% when depth of cut increases 0.4 to 0.8mm. Further increase in depth of cut to 0.20 mm/rev will result in decrease in surface roughness by 9.09%. The Flank wear decreases by 28.93% when cutting speed increases from 50m/min to 75m/min. Further increase in cutting speed to 100m/min will result in increase in flank wear by

34.13%. The Flank wear increases by 0.12% when feed rate increases from 0.10 to 0.15mm/rev. Further increase in feed rate to 0.20mm/rev will result in increase in Flank wear by 6.04%. The Flank wear increases by 2.43% when depth of cut increases 0.4 to 0.8mm. Further increase in depth of cut to 0.20mm/rev will result in increase in Flank wear by 4.28%.

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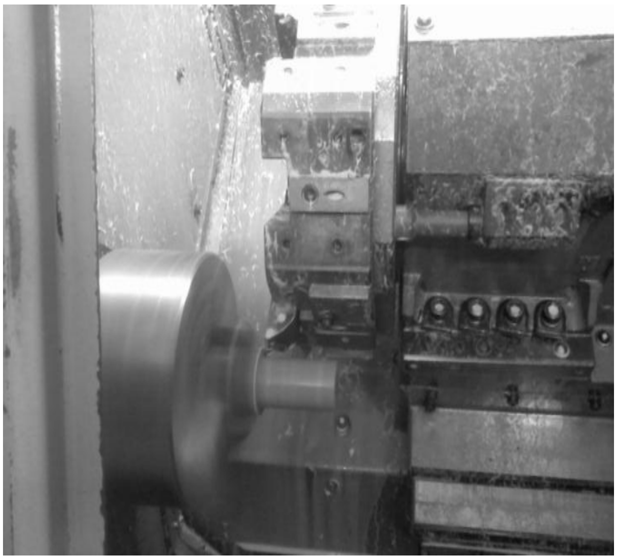

Fig.1. Turning machine (CNC)

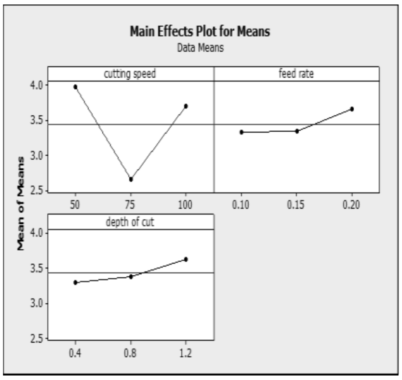

Fig. 2: Main Effects plot for Means

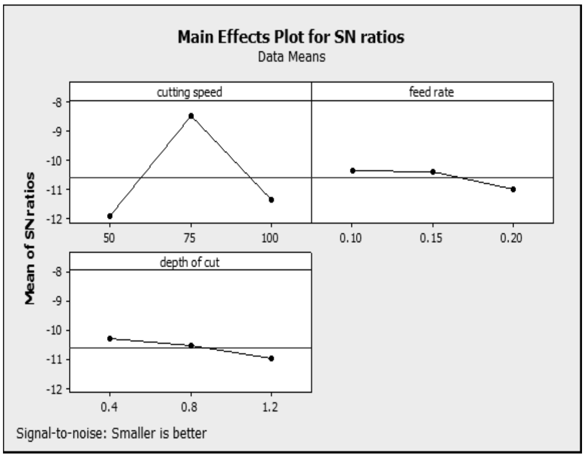

Fig. 3: Main Effects plot for SN ratios

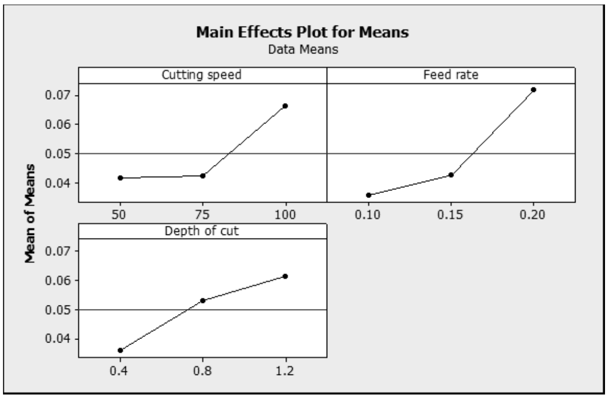

Fig. 4: Main Effects plot for Means

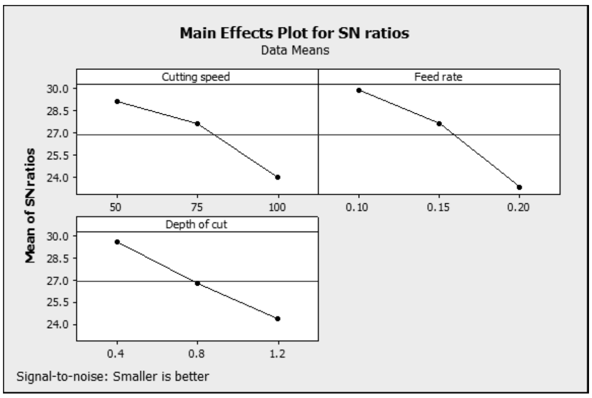

Fig. 5: Main Effects plot for SN ratios

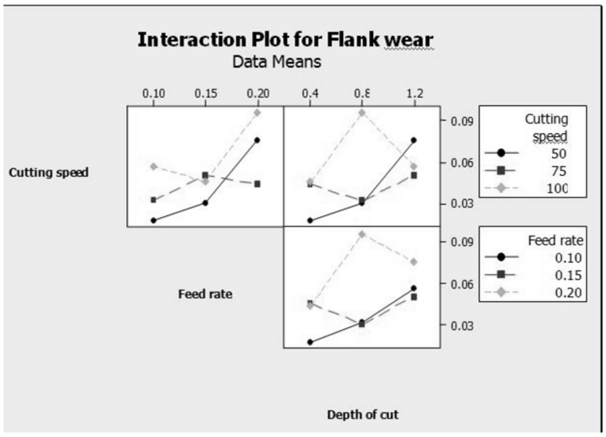

Fig.6. Interaction plot for Surface Roughness

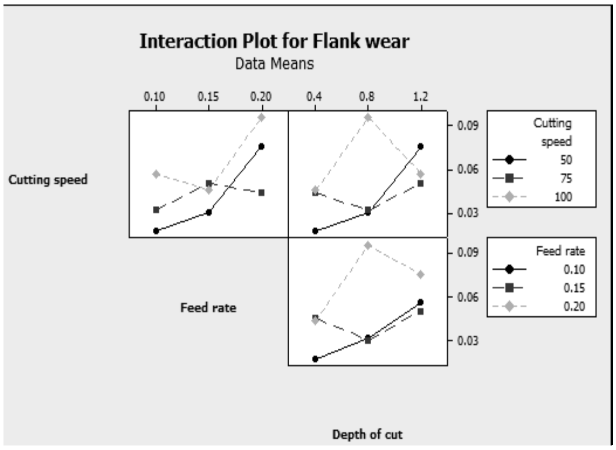

Fig.7. interaction plot for Flank Wear

Table 1: Process Parameters and their Levels

Control Parameters	Unit	Symbol	Level		
			Level 1	Level 2	Level 3
Cutting speed	m/min	V	50	75	100
Feed	mm/rev	F	0.10	0.15	0.20
Depth of cut	mm	D	0.40	0.80	1.20

Table 2: L9 Orthogonal Array with Observations

Trial no.	X1	X2	X3	Cutting speed (mm/min)	Feed rate (mm/rev)	Depth of Cut (mm)
1	1	1	1	50	0.1	0.4
2	1	2	2	50	0.15	0.8
3	1	3	3	50	0.2	1.2

Table 3: Parameters Value Setup

Exp. No	**Cutting Speed (V)**	**Feed (F)**	**Depth of Cut (D)**	**Surface Roughness (Ra)**	**Flank Wear (Fw)**
1.	50	0.10	0.40	3.59	0.018
2.	75	0.15	0.80	3.20	0.023
3.	100	0.20	1.20	3.70	0.039
4.	50	0.15	1.20	2.71	0.024
5.	75	0.20	0.40	3.66	0.031
6.	100	0.10	0.80	3.53	0.044
7.	50	0.20	0.80	2.94	0.033
8.	75	0.10	1.20	3.79	0.038
9.	100	0.15	0.40	4.67	0.072

Table 4: Anova Table for Surface Roughness

Source	**DOF**	**Seq SS**	**Adj SS**	**Adj MS**	**F**	**P**	**Contribution**
Cutting Speed	2	2.91	2.91	1.45	7.6	0.11	79.20%
Feed rate	2	0.20	0.20	0.10	0.54	0.64	5.65%
Depth of cut	2	0.17	0.17	0.08	0.45	0.68	4.73%
Error	2	0.38	0.38	0.19			10.41%
Total	**8**	**3.67**					**100.00%**

Table 5: ANOVA Table for Flank Wear

Source	**DF**	**Seq SS**	**Adj SS**	**Adj MS**	**F**	**P**	**Contribution**
Cutting Speed	2	0.0012	0.0012	0.00059	6.3	0.137	25.74%
Feed rate	2	0.0022	0.0022	0.00111	11.85	0.078	48.44%
Depth of cut	2	0.001	0.001	0.0005	5.31	0.158	21.73%
Error	2	0.0002	0.0002	9.4E-05			4.09%
Total	8	0.0046					100.00%