Effect of Cutting Parameters On The Surface Roughness Of MWCNT Reinforced Epoxy Composite Using End-Milling Process

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ABSTRACT

This research reports the study on effect of cutting parameters using CNC Milling to obtain quality surface finish that is specified by customer for machined composite parts. In this research, an attempt has been made to study the effects of cutting parameter that influence the surface roughness quality. This research becomes part of major contribution for the manufacturing industry especially machining of MWCNT/epoxy composite materials using CNC milling process. Interestingly, this project can be regarded as an exclusive work because the information's and solutions achieved at the end of this research will be significant and can be implemented in future demanding CNC industries especially in carbon nanotube/ epoxy composites applications and also to future researches.

Keywords: MWCNT, epoxy composite, nanotechnology, cnc milling, manufacturing,.

1 INTRODUCTION

Surface finish is a quality that is specified by customer for machined parts[1-3]. In recent years, many advances have been made in the field of polymer matrix composites [4-7]. It has not yet been proven to industry that these advances have significantly affected the cost of machining this class of composites. Machining a composite is a most difficult process when compared to machining a monolithic material [8]. A cost effective machining of MWCNT/Epoxy Composites has not been proven so far. Capable machining practices established in the past decade have not been optimized for machining MWCNT/Epoxy composites. This may cause loss of materials and time. Optimized process parameter can cause effective machining and better surface finish[9,10]. Hence, an optimized technique is proposed in this study to overcome this problem. There are many parameters that have effect on surface roughness, but most are difficult to quantify adequately[11-13]. In milling operation, there are many parameters such as cutting speed, depth of cut and feed rate that have great impact on the surface finish. In order to maximize the gains from milling operation, an accurate model of process must be constructed. In this research, an attempt has been made to study the effects of cutting parameter that influence the surface roughness quality.

2 MATERIALS AND METHODOLOGY

2.1 Epoxy resin, Hardener and MWCNT

The epoxy resin consists of two components that are clear Epoxy resin 331 where its viscosity is 11,000 - 14,000 cps. Epichlorohydrin hardener consists of polyamine monomers, for example Triethylenetetramine (TETA) where its viscosity is 350 - 450 cps. Both chemicals are obtained from authorized chemical supplier placed in Puchong, Selangor. Multi-walled carbon nanotubes (MWCNT) supplied by School of Chemical Engineering, USM with specific surface area of 100 m^2/g and density of 2.6 g/cm^3. The MWCNT has purity percentage of 93%. The diameter of the carbon nanotubes are 10-20nm and the average length of the nanotube was 50 µm.

2.2 Preparation of MWCNT Reinforced epoxy composites

Epoxy resin 331 and hardener Epichlorohydrin in stoichiometric ratio of 100 : 50, with 0.3 wt% amount of the MWCNT require to prepare MWCNT reinforced composite block. Table-1 shows the mixing ratio for the composite casting.

Table-1: Composition of resin, hardener and MWCNT.

EPOXY				MWCNT	
Resin		Hardener			
wt %	grams	wt %	grams	wt %	grams
62.46	53.14	37.24	26.66	0.3	0.2
ARMWCNT 0.3					

2.3 Machining Parameter

To improve the quality of surface roughness of MWCNT epoxy composite and process with minimum cost and time constraints, the Taguchi parameter design techniques [15] are applied in design of experiment (DOE). Minimum surface roughness average (R_a) was carried out since the value represents better or improved surface roughness. The controllable parameters are selected because of their most potential effecting factor on surface roughness quality in end milling operation. The parameters are the depth of cut denoted as (A), the spindle speed denoted as (B) and the feed rate denoted as (C). Table 2 shows the input factors and the levels.

Table 2: Input factors and Levels

Factors	Levels		
	Level 1	Level 2	Level 3
Depth of cut, (A)	0.4	0.6	0.8
Spindle speed, (B)	1000	1250	1500
Feed rate, (C)	10	20	30
DOE based on interactions of factors (AB, AC, BC)			

As designed previously, the machining done for the composite material by CNC machine with G/M-code programming with auto parameter change in program line. Later, each line was studied with microscopy and surface roughness using perthometer.

2.4 Surface Roughness Evaluation

The average roughness (R_a), is the point of area between the roughness profile and its mean line, or the integral of absolute value of the roughness profile height over the evaluation length. The 'R_a' is specified by the following equation:

$$R_a = \frac{1}{L}\int_0^L |Y(x)|\, dx\ (\mu m) \text{ …………………(1)}$$

Where, R_a is the roughness,
x – distance along measurement
L – evaluation length
Y– height

The Scanning Electron Microscopy (SEM) was used to observe the tool and surface roughness feature of the machined sample. The surface roughness measured using perthometer [14] roughness profilometer and average measurement were taken from 5 different location in each machined line and recorded in MINITAB statistical software. Measurement values collected and saved for further analysis and discussion.

2.5 Taguchi Analysis Method

The mean response for each run in the orthogonal array is analyzed and the signal-to-noise ratio (SNR) is deployed to analyze the most dominant effect of parameters towards the surface roughness quality. The signal-to-noise ratios are determined using the equation 5. The smaller the better concept of Taguchi's method [15] is adopted to obtain the optimal performance as given below:

$$\text{SNR} = -10\log\left(\frac{1}{n}\sum_{i=1}^{n} y_i^2\right) \text{ ……….(2)}$$

The signal-to-noise ratio SNR_L will be utilized to target the largest response. However, in this study the smallest response is desired and the SNR_S will be selected and equation 5 will be used in Minitab software in order to obtain SNR output and linear model of means.

3 RESULTS AND DISCUSSION

3.1 Surface Roughness analysis

The main effect of cutting parameters are shown in Figure-1 which shows that each cutting parameter factors had different patterns of plots. From this result, it can be understood that the roughness value improves in increasing and decreasing of parameter values. The highest roughness obtained at 0.6 mm of depth of cut, spindle speed of 1500 rpm and feed rate of 10 mm/min shows the similar average roughness value. So, the optimum cutting conditions for surface roughness with high evidence should be set to lowest level of depth of cut which was dominant factor for the surface roughness, and lowest level of cutting speed and highest level of feed rate. Same interactions were found significant from Figure-1 we know that the signal to noise ratio follows significantly the response factor that were surface roughness.

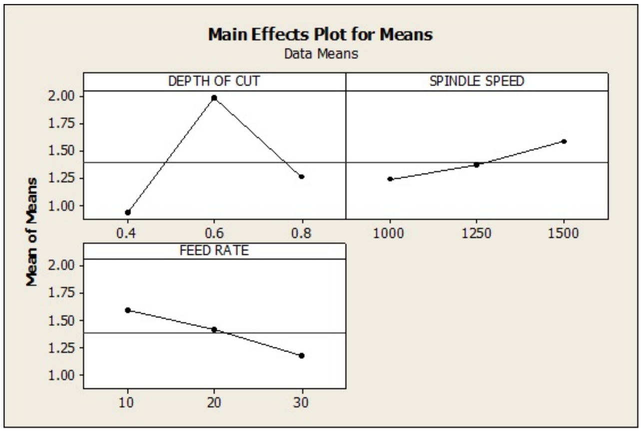

Figure 1: Main Effect plots for Means

Also the interaction plot describes the same manner as the main effect plots. From Figure-2 the significant interaction only can be seen between depth of cut * feed rate. The main significant interaction had pair of order for the plot. The red line in row 1 column 3 explains that as feed rate increases, the roughness decreases, while the other two line seems be same pattern and not significant changes while feed rate increasing. Same goes to row 3 and column 1 shows the black and red line increase and decreases as depth of cut increases. while green line not showing significant changes when depth of cut increases. Other interactions all are in same pattern which most of the lines are parallel to each other which is showing not significant effect for surface roughness quality.

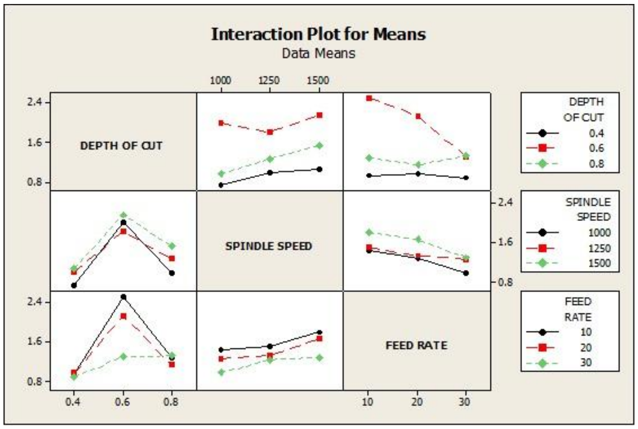

Figure 2: Interaction Plot for means

From the both plots, it can be concluded that the significant effects of cutting parameters and also the interaction of parameters shows major contribution for roughness performance.

3.2 Analysis of Average Mean Responses

From Table-3, it clearly explains that the depth of cut contributes the highest effect (Delta = 1.0511) on the surface roughness followed by feed rate (Delta = 0.4094) and spindle speed (Delta = 0.3511) respectively.

Table 3: Response table of Average Surface Roughness

Level	**Depth of cut (mm)**	**Spindle Speed (rpm)**	**Feed Rate (mm/min)**
1	0.9383	1.2356	1.5878
2	1.9894	1.3667	1.4228
3	1.2611	1.5867	1.1783
Delta	1.0511	0.3511	0.4094
Rank	1	3	2

Control parameters (A, B, and C) can be monitored using p-values from ANOVA analysis table which is fairly more accurate. So, from here it can be understood that depth of cut is far the most dominant factor affecting the surface roughness quality followed by feed rate and spindle speed. Table 4 shows optimized parameter values.

Table 4: Optimized cutting parameters

Factors	**Before Optimization**	**After Optimization**
Depth of Cut, mm	0.5	0.4
Spindle Speed, rpm	1250	1000
Feed Rate, mm/min	20	30
Roughness, R_a (μm)	1.375	*0.6524(Predicted value)*

From the above obtained results, it is a breakthrough for machining a nano-filled epoxy composite material after getting the optimized values since no researchers was proven on machining this type of composite materials.

3.3 Morphology of Machined Surface

In this study, some samples were studied under Scanning Electron Microscopy (SEM) to look more detailed surface roughness variation. Figure-3 shows the detailed SEM images obtained from table top SEM. Figure-4 explains that, the surface structure are clearly smooth and very minimal level of bright patches. This show at this cutting parameter level, the surface roughness can be achieved at minimum level.

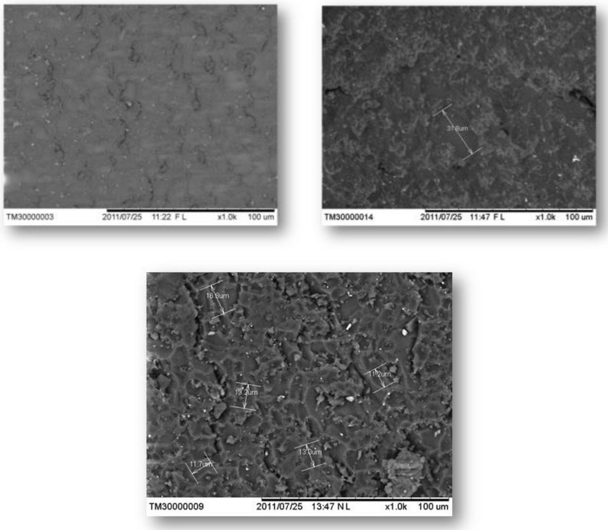

Figure 3: Sample SEM images

3.4 Effect of MWCNT on Surface roughness of MWCNT/Epoxy composites

An approach was made to study the differences in pure epoxy composites and with MWCNT filled epoxy composite. A breakthrough was identified where with adding MWCNT, actually it improves surface roughness from 0.76 to 0.66µm. The clear epoxy composites produces 0.76µm roughness while with the nanofilled epoxy composites produces only 0.66 µm. Figure 4 shows the differences between two different composites in bar chart form.

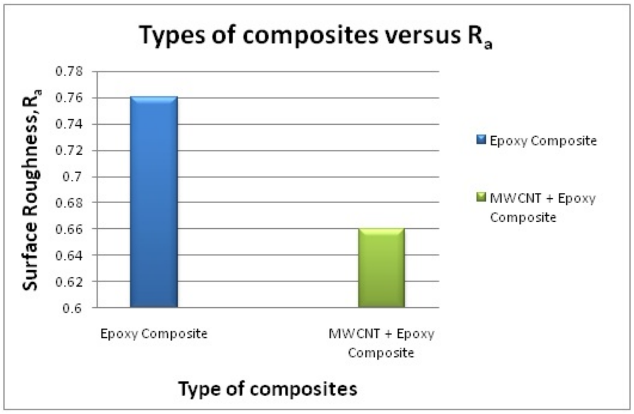

Figure 4: Effect of MWCNT on the surface roughness

4 CONCLUSIONS

The effects of the depth of cut, spindle speed and feed rate on surface roughness were studied using MINITAB analysis software. Taguchi used to design the experiments and optimization. The ANOVA shows that all three factors and interactions have significant effects on the response. Moreover, the mean average roughness indicates that depth of cut contributes highest effect on the surface roughness, followed by feed rate and depth of cut. From this research, following conclusion could be reached with fair amount of confidence. Finally, the study shows that depth of cut is the most dominant factor of those studied. The medium significant factor is feed rate and followed by spindle speed. The most important interactions that effect surface roughness of machined surfaces were between the feed rate and depth of cut for this particular type of MWCNT/epoxy composite. This research becomes part of major contribution for the manufacturing industry especially machining of MWCNT/epoxy composite materials using CNC milling process and for future researchers.

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