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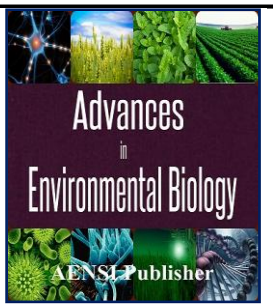

Study the Effect of Milling Parameters on Surface Roughness During Milling Kenaf Fibre Reinforced Plastic

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ABSTRACT

Background: Natural fibre is a hairy like raw material which comes from natural sources such as animal, plant and mineral fibres. Kenaf fibre is one of natural fibres which becoming popular as a reinforced for plastic composite material in the industrial application such as aircraft, automotive, sporting goods, and marine engineering. The objectives of this research are to study the effect of milling parameters on the surface roughness in milling kenaf fibre reinforced plastic composite using Taguchi Method. Later the optimization is carried out to determine the optimum condition for the range of milling parameters under investigation in order to minimize the surface roughness (R_a). In this study, Taguchi Method L_8 (2^3) design is used to conduct a non-sequential experiment. The milling parameters were cutting speed in the range of (V): 500rpm – 1000rpm, feed rate (F): 200mm/mim – 1200mm/mim, and depth of cut (DOC): 1.00mm – 2.00mm. The experimental results were analysed using the Minitab 16 software. It was found that, the optimum parameters for the minimum surface roughness were the cutting speed at 1000 rpm, feed rate at 200mm/min and the depth of cut 1.0 mm. The feed rate and the cutting speed are the main factors that influence the effect of surface roughness in milling kenaf fibre reinforced composite. High cutting speed and low feed rate resulted and low surface roughness for milling kenaf fibre reinforced composite.

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INTRODUCTION

Natural fiber is a hairy like raw material that comes from the natural resources such as animal, mineral and plant fibers. Besides, natural fiber is sustainable as well as eco-efficient therefore it has been used to replace glass fiber as well as other synthetic polymer fibers that have various kind of application in engineering[1]. Natural fibers are famous for its flexibility for processing because of it is not much delicate to the health hazards as well as damage in machine tool when manufacturing and etc. Furthermore, natural fibers have lot of beneficial characteristics, for example considerably high tensile, satisfying aspect ratio of fiber and low density but due to nature of the composite, machining of composite material becomes a major cause of concern in the industry[1]. In addition, natural fiber is a renewable source so its cost is very low if compared to man-made fiber. Furthermore, natural fiber is a biodegradable material, in other words, it is an environmentally friendly fiber which is not harmful to the environment. Therefore, it can be used to substitute non-biodegradable material in product development.

Kenaf is known as its scientific name of *Hibiscus cannabinus* that is similar to jute and cotton which is also warm season yearly fiber crop. In the past, to manufacture rope, sackcloth and twine, kenaf is used as cordage crop[2]. Recently, kenaf is widely used in various type industries due to increasing demand for green and clean industrial products. Besides, kenaf plant fiber can be processed to produce paper pulp, building material, construction material, automotive materials and biofuel because the properties of low weight, high specific properties and renewability. This indicated that kenaf act as good potential natural fiber to be used in the automotive and construction industry.

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Machining processes such as turning and milling has widely been used in manufacturing field or company. The machine surface's quality normally depends on machine component's reliability in the service application. Machining process causes changes in the mechanical and chemical properties of individual constituents used in the composite. Therefore, the performance of a composite material is minutely depending on the surface condition produce by machining. The quality of a product normally closely related to the surface finishing. In reality, surface finish is commonly expected as a major manufacturing goal in the milling process during edge trimming operation. Good surface produces not only ensure product quality, but also minimize manufacturing cost. The surface quality decrease will lead to decrease in product quality. The surface finish quality can be a considerable as an important aspect in the field of manufacture, especially in engineering, which can affect the functioning of a component. Surface roughness act as the importance, crucial constraints in cutting parameters and machine selection during the planning process.

1. Methodology:

2.1 Taguchi Method:

Taguchi methods comprise to cut down the differentiation of process by robust design[3]. The main purpose of this method was to manufacture good quality product in minimize cost to the investigator manufacturer. Dr. Genichi Taguchi from Japan was the developer for Taguchi method or a method based on orthogonal array (OA) experiments. This gave much reduced variance for the experiment with optimum setting of control parameters. Hence, bad quality of the process not only would influence society but as well as manufacturer.

1.2 Design Parameters:

The factors for kenaf fiber reinforced plastic are selected based on the research paper by G.Dilli Badu *et.al* which had published in the year 2013. The three main factors that were selected would examine at two levels, which were shown in Table 1. The OA L_8 has been selected for the experiment due to the experiment composed of three factors and two levels and also can be written in the form of L_8 (2^3). Meanwhile, the OA L_8 (2^3) in experimental form is indicated in Table 2.

Table 1: Levels of the parameter used in the experiment.

Process Parameter	Low (1)	High (2)
A – Spindle Speed (rpm)	500	1000
B – Feed Rate (mm/min)	200	1200
C – Depth of Cut (mm)	1.0	2.0

Table 2: Orthogonal array L_8 (2^3) in Experiment form.

L_8 (2^3) test	A	B	C
1	500	200	1.0
2	500	200	2.0
3	500	1200	1.0
4	500	1200	2.0
5	1000	200	1.0
6	1000	200	2.0
7	1000	1200	1.0
8	1000	1200	2.0

2.3 Materials use for experiments:

The workpiece materials use for this experiment is kenaf fiber reinforced plastic. the mixtures of the kenaf fiber reinforced plastic was equal to= unsaturated polyester (reversal 9565 from Synthomer Sdn. Bhd.): methyl ethyl ketone (from Merck): 6% cobalt napthalane (from sigma Aldrich) and has the ratio of 98:1:1.The kenaf fiber reinforced plastic have the dimension of 75 mm length, 52 mm width and 10 mm height or thickness.

2.4 Cutting tools:

The cutting tool that had been chosen for this experiment is 4 flute end mill. This is because the number of flute increase will decrease the chip load as well as to improve the surface while the feed rate remains unchanged. The materials of the cutting tool are made of High speed steel (HSS) which has 10mm as it diameter, length of the cutter is 30 mm while total length is 75 mm. HSS end mill is chosen because of its ability to be machining parts to the closest tolerance[4].

2.5 Regions for Surface roughness test:

Before starting machining operation, a simple NC program was written with different conditions specified to have machine on the top surface of 75 mm x 10 mm x 6 mm of the Specimen A (kenaf fiber reinforced plastic) or in order words, this mean that the surface of specimen A has been mill with length of 75 mm and wide of 10 mm and 6 mm for the depth that has been shown in Figure 1. Besides, for specimen B, it has undergone machining twice with same parameter on the top surface too, but with different dimension with the

Advances in Environmental Biology, 9(13) Special 2015, Pages: 46-52

specimen A which is 52 mm x 10 mm x 6 mm which been display in Figure 2. Other than that, the bottom mill surface and side mill surface would be written in term of R_a Horizontal A and R_a Vertical A respectively while the bottom mill surface and side mill surface for specimen B in Figure 2 were be recorded as R_a Horizontal B and R_a Vertical B.

Fig. 1: Regions for taking Surface Roughness Measurements for specimen A.

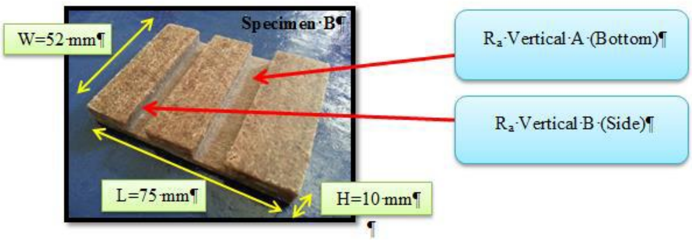

Fig. 2: Regions for taking Surface Roughness Measurements for specimen B.

RESULTS AND DISCUSSION

3.1 Surface roughness:

Table 3 illustrated the summary responses for all the values of surface roughness. The highlight values have shown that the value of the surface roughness is the lowest. The lowest value for among Ra 1, Ra 2, R_a 3 and R_a 4 are 1.328 µm (Sample 1), 1.837 µm (Sample 2), 1.249 µm (Sample 5) and 1.630 µm (Sample 7). Therefore, the lowest value of surface roughness has led to better quality of surface and vice versa. The values takes from surface roughness tester are not consistence due to some of the specimen has defect or crack after milling operation. This also influences the result for the surface roughness.

Table 3: The summary of Responses for Surface Roughness.

Sample	A	B	C	R_a 1	R_a 2	R_a 3	R_a 4
1	500	200	1.0	1.318	2.053	1.915	1.743
2	500	200	2.0	1.784	1.837	2.137	2.341
3	500	1200	1.0	3.349	2.855	2.389	2.383
4	500	1200	2.0	2.382	2.178	2.401	2.393
5	1000	200	1.0	1.453	2.440	1.249	2.131
6	1000	200	2.0	2.003	2.446	1.565	2.139
7	1000	1200	1.0	3.034	1.948	1.990	1.630
8	1000	1200	2.0	2.854	3.154	2.735	2.747

*Note: The highlight values illustrated the smallest values for surface roughness

3.2 Analysis of S/N ratio for surface roughness:

The analysis of signal-to-noise (S/N) ratio for this experiment are uses smaller is better approach. The S/N ratio represents as the response of the experiment. Its measure of variation of noise factors and it contributes to reduction of variation. Smaller is better focused on reduce variation when minimizing the response. In S/N ratio "signal" represent as the desirable value and "noise" represents the undesirable value for output characteristic. Table 4 has displayed the combination responses for values of surface roughness. Smaller is better can be determined using equation below:

$$\frac{S}{N} = -10log\frac{1}{n}(\sum y^2) \quad (1)$$

Where,

S/N = S/N ratio

y =value of the quality characteristic

n = Total number of trial runs.

Table 4: The summary of S/N Ratio for Surface roughness.

Sample	A	B	C	R_a 1	R_a 2	R_a 3	R_a 4
1	500	200	1.0	-2.3983	-6.24778	-5.64338	-4.82595
2	500	200	2.0	-5.0279	-5.28218	-6.59609	-7.38803
3	500	1200	1.0	-10.4983	-9.11212	-7.56432	-7.54248
4	500	1200	2.0	-7.5388	-6.76116	-7.60784	-7.57885
5	1000	200	1.0	-3.2453	-7.74780	-1.93125	-6.57167
6	1000	200	2.0	-6.0336	-7.76913	-3.89029	-6.60422
7	1000	1200	1.0	-9.6403	-5.79178	-5.97706	-4.24375
8	1000	1200	2.0	-9.1091	-9.97723	-8.73915	-8.77717

Labels:

A = Spindle Speed, rpm
B = Feed Rate, mm/min
C = Depth of Cut, mm
R_a 1= R_a Horizontal A (Bottom), µm
R_a 2 = R_a Horizontal B (Bottom), µm
R_a 3 = R_a Vertical A (Side), µm
R_a 4 = R_a Vertical B (Side), µm

Meanwhile, for this research study, smaller is better is use to determine the minimum surface roughness. Other than that, the S/N ratio of the surface roughness which shown in Table 4 that has the biggest or nearest to the value of zero is -2.3983 for R_a 1(R_a Horizontal A-Bottom) in sample 1, -5.28218for R_a 2(R_a Horizontal B-Side) in sample 2, -1.93125for R_a 3 (R_a Vertical A-Bottom) in sample 5 and -4.24375 for R_a 4 (R_a Vertical B-Side) in sample 7. However, the highness range from zero for R_a 1 is -10.4983, R_a 2 (-9.97723), R_a 3 (-8.73915) and R_a 4 (-8.77717). As a result, the S/N ratios which are closest to zero value means it has minimize surface roughness values or better surface quality. Therefore, the sample 1 for R_a 1, sample 3 for R_a 2, sample 5 for R_a 3 and sample 7 for R_a 4 has the lowest S/N ratio so these also indicate that these samples have the minimum surface roughness value.

There are 3 types of S/N ratios; nominal-the-best, smaller-the-better and larger-the-better. Smaller is better focused on reduce variation when minimizing the response. In S/N ratio “signal” represent as the desirable value and “noise” represents the undesirable value for output characteristic. Smaller is better can be determined using equation 1. From the S/N ratio analysis the optimum milling operation for surface roughness is R_a 3 [The most effective cutting parameters in reducing surface roughness] is cutting speed at 1000 rpm (Level 2), Feed rate at 200mm/min (Level 1) and Depth of cut at 1.0mm (level 1) which has shown in Figure 3(c). The different between R_a 1 to R_a 4 can be shown in Figure 3 (a-d). These findings are similar with G. Dilli. 2013, reported about the high cutting speed and low feed rate have the largest contribution to the surface. Besides, based on the research by K. S. Narayana [6] has investigated the same conclusion with this research study which is the most contributions to the surface roughness are in following order: feed rate, cutting speed and then the depth of cut.

3.3 Analysis of Variance (ANOVA) for surface roughness:

The experimental results are analyzed by analysis of variance (ANOVA), which is used for identifying the factors significantly affecting the performance measures. The results of ANOVA with surface roughness of R_a 1, R_a 2, R_a 3 and R_a 4 are shown in Table 5 (a –d). This analysis was carried out for significance level of $\alpha = 0.05$ or for a confidence level of 95%. The sources with P-value that less than 0.05 are considered to have a statistically significant contribution to the performance measures[8].

The sum of squares (SS) column of the table shows the relative contribution of each factor to the total variance of the factor. Degree of Freedom (DOF) shows the indication of the amount of the information contained in a data set. It is observed from the ANOVA in Table 5 (a) that B-Feed Rate (79.70%) is the most significant parameter followed by A-Spindle Speed (1.30%) and C-Depth of Cut (0.73%). This means that feed rate has given a larger contribution for surface roughness of R_a 1. Besides that, it is also found that feed rate be significant because the P-value of R_a 1 (0.014) is less than 0.05. The residual error or percentage error occurs from the ANOVA analysis for R_a 1 is 18.27%. Furthermore, ANOVA analysis for Table 5 (b) also shows that the B - Feed rate (14.19%) the most significant parameter, then is A-Spindle speed (10.13%) and lastly C-Depth of cut (0.53%). The P-values for all the factors are not statistically significant contribution to the performance measure because all are more than 0.05. Hence, the residual error for R_a 3 is 75.15%.

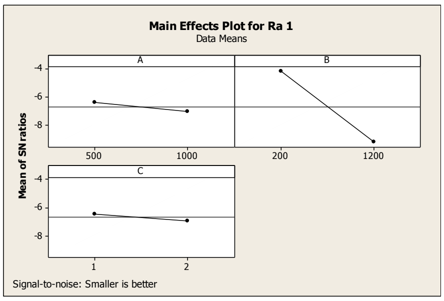

Figure 3 (b): Graph of main effects plots for R_a 1.

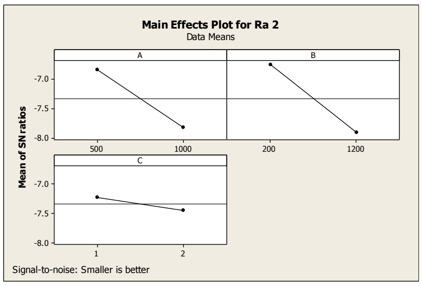

Figure 3 (b): Graph of main effects plots for R_a 2.

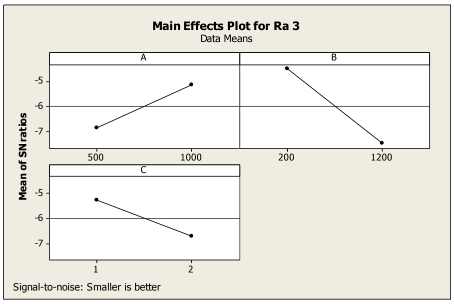

Figure 3 (c): Graph of main effects plots for R_a 3.

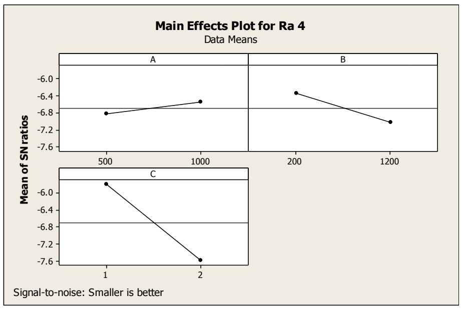

Figure 3 (d): Graph of main effects plots for R_a 4.

Based on the ANOVA analysis in Table 5 (c), the B-feed rate has given bigger contribution to R_a 2 which is 51.39% and then A-spindle speed (17.36%) followed by the C-depth of cut (12.01%). For R_a 2, only feed rate is statistically significant which has the p-value of 0.031. The percentage error for R_a 2 is 19.24%. Thus, C-Depth of cut has a larger contribution for R_a 4 (Table 5 (d)) which is 40.50%, follow by B-Feed Rate (5.98%) and A-spindle speed (1.02%). All the factors in this ANOVA analysis are not significant because all the P-values are more than 0.05. The percentage error is 52.50%.

In conclusion, a higher percentage contribution gives a significant impact on the surface roughness. The residual error or percentage error is the error that may occur during the measurement of the surface roughness. Besides, the error also gives a significant impact for the measurement of R_a value. The error of measurement occurs because of the composition of the material is not in uniform condition. Other than that, it also due to the resin exists on the machined surface because increasing temperature when the tool is contact the workpiece or specimen surface in the condition of high spindle speed and feed rate.

Table 5 (a): Analysis of Variance for R_a 1.

Source	DOF	SS	MS	F-value	P-value	C (%)
A	1	0.8224	0.8224	0.28	0.622	1.30
B	1	50.4078	50.4078	17.44	0.014	79.70
C	1	0.4643	0.4643	0.16	0.709	0.73
Residual Error	4	11.5643	2.8908	-	-	18.27
Total	7	63.2578	-	-	-	100.00
DOF = Degree of Freedom, SS=Sum of squares, MS= Mean squares, C=Contribution						

3.4 Prediction for the Optimal Condition for surface roughness:

The optimal conditions of the cutting parameter which can minimize the value of surface roughness for each cutting surface were identified based on the main effect plots in Figure 3 (a-d). Consequently, prediction for optimal condition for the surface roughness of each cutting surface by using Minitab 16 software and recorded in Table 6.

Table 5 (b): Analysis of Variance for R_a 2.

Source	DOF	SS	MS	F-value	P-value	C (%)
A	1	1.8844	1.88442	0.54	0.504	10.13
B	1	2.6397	2.63972	0.76	0.434	14.19
C	1	0.0991	0.09906	0.03	0.874	0.53
Residual Error	4	13.9822	3.49554	-	-	75.15
Total	7	18.6054	-	-	-	100.00
DOF = Degree of Freedom, SS=Sum of squares, MS= Mean squares, C=Contribution						

Table 5 (c): Analysis of Variance for R_a 3.

Source	DOF	SS	MS	F-value	P-value	C (%)
A	1	5.906	5.906	3.61	0.130	17.36
B	1	17.486	17.486	10.69	0.031	51.39
C	1	4.086	4.086	2.50	0.189	12.01
Residual Error	4	6.545	1.636	-	-	19.24
Total	7	34.024	-	-	-	100.00
DOF = Degree of Freedom, SS=Sum of squares, MS= Mean squares, C=Contribution						

Table 5 (d): Analysis of Variance for R_a 4.

Source	DOF	SS	MS	F-value	P-value	C (%)
A	1	0.1620	0.1620	0.08	0.794	1.02
B	1	0.9470	0.9470	0.46	0.537	5.98
C	1	6.4161	6.4161	3.09	0.154	40.50
Residual Error	4	8.3154	2.0788	-	-	52.50
Total	7	15.8405	-	-	-	100.00
DOF = Degree of Freedom, SS=Sum of squares, MS= Mean squares, C=Contribution						

The predicted surface roughness for R_a 1 (surface roughness A at bottom) is 1.592 µm when conducting milling operation at optimal condition for confirmation tests. The expected surface roughness values for R_a 2 which estimate by Minitab 16 software is 2.021 µm. Other than that, R_a 3 and R_a 4 have predicted surface roughness for confirmation test of 1.392 µm and 1.845 µm respectively. Based on the prediction, the optimize condition fall on R_a 3 (R_a Vertical A-Bottom) because it has the lowest value for surface roughness among other prediction. Besides, this also means that R_a 3 has the best surface quality and has the optimum parameters.

Table 6: Prediction for Optimize Condition for surface roughness.

Cutting Surface	Spindle Speed (rpm)	Feed rate(mm/min)	Depth of Cut (mm)	Predicted Surface roughness(µm)
Ra 1	500	200	1.0	1.592
Ra 2	500	200	1.0	2.021
Ra 3	1000	200	1.0	1.392
Ra 4	1000	200	1.0	1.845

3.5 The Confirmation Test for Surface Roughness:

After the optimum cutting condition is determined and the predicted surface roughness values at the optimum condition has been estimate by the use of Minitab software. A confirmation test must be conducted to verify the predictions of the surface roughness are correct or not. The average experimental results for each cutting surfaces were recorded in Table 7. Then, the predicted theoretical values for surface roughness which have been obtained via Minitab 16 in Table 6 have been used to compare with the average experimental results of surface roughness to obtain percentage error. The formula of percentage of error is determined by using equation (2). The percentage error obtained must be between 10% so that the results obtained are reliable.

$$Percentage\ of\ Error = \frac{|Theoretical\ Result - Experimental\ Result|}{Theoretical\ Result} \times 100\% \quad (2)$$

Last but not least, the percentage errors for all the cutting surfaces are less than 10% as shown in Table 7 which represented that the results obtained are concerned. A conclusion can be drawn from the confirmation test which is R_a 2 (R_a Horizontal B-side) has the lowest percentage error that represent that this result has the minimum error.

Table 7: Percentage Error for Experimental and Theoretical Results of surface roughness.

Cutting Surface	Theoretical Result(µm)	Reading for Experimental Results(µm)				Percentage error (%)
		1	2	3	Average	
Ra 1	1.592	1.558	1.612	1.819	1.663	4.46
Ra 2	2.021	1.765	2.158	2.068	1.997	1.19
Ra 3	1.392	1.528	1.373	1.579	1.493	7.26
Ra 4	1.845	1.496	2.422	1.977	1.965	5.50

4. *Conclusion:*

In conclusion, the objective of the research study has been achieved. During the experimentation the effect of difference machining parameters on surface roughness are study with the help of Taguchi Method and the best combination of machining parameters such as spindle speed, fee rate and depth of cut. Other than that, this research study was carried out via using kenaf fiber composite with dimension of75 mm x 52 mm x 10 mm. The specimens (Kenaf fiber composite) are than machine by using High Speed Steel (HSS) end mill with different cutting parameter so that the machinability can be improve when carry out milling operation. In addition, Taguchi Method was used throughout the experiment study to obtain analysis and experiment runs with the help of Minitab 16 software to identify the machinability with different cutting parameters such as spindle speed, feed rate and depth of cut.

The research study was carrying out using L_8 orthogonal arrays for Taguchi Method to analyze the surface roughness factor. There were total of eight experiments to be runs with two levels (low and high levels) and three factors (spindle speed, feed rate and depth of cut) which can be simplified by written in L_8 (2^3) orthogonal arrays. It is observed from the ANOVA for surface roughness of R_a1, R_a 2 and R_a 3, the feed rate is the most significant parameter which contributed of 79.70% (R_a 1), 51.39%(R_a 2) and 14.19%(R_a 3). The second significant parameter for R_a 1, R_a 2 and R_a 3 were spindle speed with the 1.30%, 17.36% and 10.13% as the overall contribution. The least significant parameter contributed to surface roughness for R_a 1, R_a 2 and R_a 3 were depth of cut with the percentage of 0.73%, 12.01% and 0.53%. In contrast, the most significant parameter for R_a 4 was depth of cut (40.50%) followed by feed rate (5.98%) and then spindle speed (1.02%). Based on the results obtain, the feed rate and spindle speed have the biggest contribution to the surface roughness (R_a). Therefore, the use of high spindle speed and low feed rate will lead to minimum surface roughness. Other than that, the confirmation tests were carrying out to compare the predicted values of surface roughness. There are good agreement between the experimental and theoretical results was observed. Based on the experiments, it was found that the optimum parameters for the minimum surface roughness was with the spindle speed of 1000rpm, feed rate of 200mm/min and depth of cut of 1.0mm.

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