

## **A Study of Proper Conditions in Face Milling Palmyra Palm Wood by Computer Numerical Controlled Milling Machine**

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### **Abstract**

The purpose of this research was to investigate the effects of main factors on the surface roughness in milling process of Palmyra Palm wood face by computer numerical controlled milling machine and using shell end mill cutting tools 6 edges. The main factors including speed, feed rate, depth of cut and angle of cut were investigated for the optimum surface roughness. Generally, acceptable surface roughness was between 3.0-9.0  $\mu\text{m}$  before sanding process. In the experiment, Palmyra Palm wood of 11-13% humidity was used at 800-1200 rpm in cutting speed and feed rate at 0.03-0.05 mm/tooth. The result of preliminary trial showed that the depth of cut and the angle of the cut had no effect on surface roughness. It was found from the experiment that the factors affecting surface roughness were feed and speed, with tendency for reduction of roughness value at a lower feed rate and greater cutting speed. Therefore, in the facing process for Palmyra Palm wood it was possible to determine a face milling condition by means of the equation  $R_a = 0.954 + 20.4 \text{ feed} + 0.00126 \text{ speed}$ . This equation was employed at a limited speed of 800-1200 rpm, and the feed rate of 0.03-0.05 mm/tooth. The result from the experiment of the mean absolute percentage error of the equation of surface roughness is 6.10% which is less than the margin of error, and is acceptable.

**Keywords:** Design of Experiment; Computer Numerical Controlled Milling Machine; Palmyra Palm Wood; Surface Roughness

### **Introduction**

*Borassu flabellifer* Linn is a scientific name of Palmyra Palm which is a tropical plant from Africa. Later, Palmyra Palm was grown throughout in the south India and then Thailand lastly (Thalabnark, 2000). Every part of Palmyra Palm is useful for human beings. For instance, its young leaves are made for child toy handicrafts, its elder leaves can be used for making a roof, and its peeled stems can be made as a rope. Moreover, both young male and

female Palmyra Palm can produce palm sugar and their fruits are major ingredient of Thai dessert which has very nice smell. The peeled palm fruits also can be used as a kind of fuel which energizes a high energy. In addition, the palm stems can be used to make practical device and furniture including blackboards, desks, chairs, house posts or even beds. Apart from the mentioned usefulness, some souvenirs are created from Palmyra Palm woods such as spoons, dishes, vases, bracelets and candle plates.

Nowadays Palmyra Palm wood products are most popular and wanted in furniture markets because they have a unique texture with their rings, strength, durable and low prices. However, Palmyra Palm wood has a drawback point, in that its thorns in the texture cause the problems in production process. Therefore, the main challenge in using Palmyra Palm products is surface roughness in the production process. These include planning, turning or cutting processes. The surface roughness is not appropriate for target market need, thus it consumes much more time in decorating the Palmyra Palm wood products. The other factors that cause to surface roughness can be identified as cutting speed, feed rate, depth of cut and angle of cut (Bagci and Aykut, 2006; Rawangwong and Chatthong, 2007; Rawangwong and Chatthong, 2008; Routara et al. 2009; Yang et al., 2009; Rawangwong et al., 2010; Rawangwong et al., 2011). Last but not least, skillful and experienced workers are one of the important factors.

The cause mentioned above can motivate the researchers in investigating the optimum surface roughness for furniture industrial manufacturers to make use of Palmyra Palm wood in the production process. In addition, a reduction of time-consumption during cutting process can increase the quantity of production and it decreases the production cost. The finding would also become a data base for further research.

### Equipment and Tools

This research study aimed to investigate the effect of main factor on the surface roughness of Palmyra Palm wood in the face milling process by computer numerical controlled milling machine and using shell end mill cutting tools of 6 edges. The following equipment and instrument were used.

1) Computer numerical controlled (CNC) milling machine of model EMCO PC Mill 50 with basic technical specifications including a maximum stable round of speed of 2500 rpm, feed rate of 0-75 mm/min as shown in Figure 1.



**Figure 1** CNC milling machine

2) Wood piece Samples: Palmyra Palm wood fumigated planks with 50×50 mm in a cross section and 300 mm in a length of 11-13% with humidity in wood as shown in Figure 2.



**Figure 2** Palmyra palm wood work-piece

3) Cutting tools: A high speed steel (HSS) model Co 8% with 40 millimeter diameter of 6 edges, as shown in Figure 3.



**Figure 3** Shell end mill

4) A surface roughness measuring device of model Mitutoyo Surf Test 301 as shown in Figure 4.



**Figure 4** Surface roughness tester

5) Humidity measuring instrument: Model DT-129

6) Digital vernier caliper

**Methodology**

There were four main procedures that served the purposes of conducting this research study. First, it was to investigate the sample size for designing the Palmyra Palm milling machine. Second, it was to study the factors expected to make an effect on surface roughness in the Palmyra Palm wood milling

process. Third, it was a pilot treatment to examine the optimum surface roughness and last procedure was to take the real treatment in order to confirm the results. These were detailed in the following.

Procedures no. 1: To investigate the sample size for designing the Palmyra Palm milling machine by using Minitab R.15 with statistic reliability and significance at 95% and 5% respectively

Procedures no. 2: To study the factors affecting surface roughness in the Palmyra Palm wood milling process by using Completely Randomized Factorial Designs with 3 repeated treatments for reducing the variation of sampling. Minitab R.15 was employed to calculate statistic values and to analyze the 2<sup>4</sup> Factorial Design (Ploypanichjaroen, 2003), (Montgomery, 2005), (Sudasna Na Ayuthaya and Luangpaiboon, 2008). The 4 factors and the responsive surface roughness value as shown in Table 1.

**Table 1** The allocated variation in procedure no.2

Factor	High	Low
Speed (rpm)	1000	800
Feed (mm/tooth)	0.05	0.03
Depth (mm)	3	1
Angle (degree)	90	0

Procedures no. 3: As General Factorial Design was used for identifying the optimum surface roughness with the allocated speed of 3 levels: 800, 1000 and 1200 rpm; the allocated feed classified into 3 levels; 0.03, 0.04 and 0.05 mm/tooth; but the direction of cutting was stable at 0 degree. Further, the depth of cutting was stable at 1 mm which did not affect the surface roughness from the first treatment. The findings were shown in Table 2.

**Table 2** The allocated variation in procedure no.3

Factor	Level 1	Level 2	Level 3
Speed (rpm)	1200	1000	800
Feed (mm/tooth)	0.05	0.04	0.03
Depth (mm)	1	1	1
Angle (degree)	0	0	0

Procedure no. 4: To take the real treatment in order to confirm the results. This treatment was tried out to confirm the conformation of each treatment by using a linear equation of procedure no.3 to predict the surface roughness. Condition was sampling selected with 6 times of a replication without margin errors lower than 10%.

**Results**

Results of sampling sizes. The statistic values used in data analysis were reliability at 95% or significance at 5%. The feed was at 0.03 mm/tooth; the speed was 1000 rpm; the depth of cut was at 2 mm; and the direction of cutting was at 0 degree. The twelve repeated treatments revealed that the mean average of surface roughness was at 2.75  $\mu\text{m}$  and the standard deviation was 0.732  $\mu\text{m}$ . Furthermore, the result of sample size investigation was a 5-sampled size.

According to procedure no.2, the analysis of the variance of surface roughness  $R^2$  was of 67.71 % and the Adjust  $R^2$  was of 59.10 %. This meant that the data variance value was at 100  $\mu\text{m}^2$ . For the variance value at 67.71  $\mu\text{m}^2$  could be explained with regression model and the remaining value was not explainable due to the uncontrollable variables.

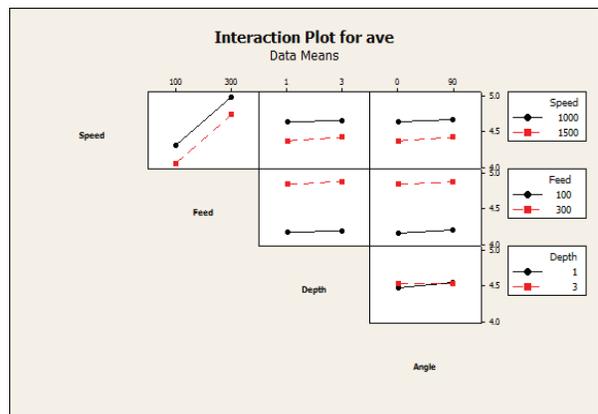
The details are as follows: it is obviously seen that the most variance of surface roughness is implied as a regression model. This can be said that the design of each treatment is appropriate and accurate as shown in Figure 5.

Analysis of Variance for RA, using Adjusted SS for Tests

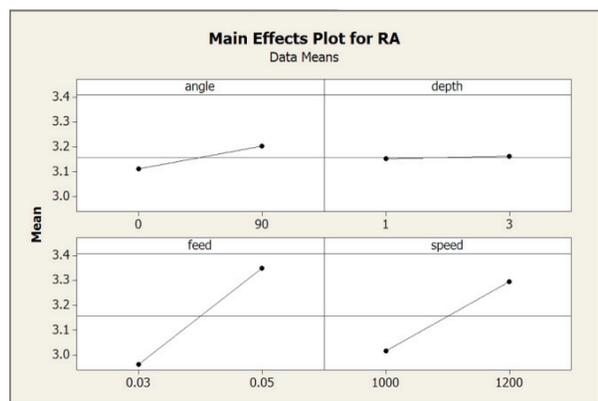
Source	DF	Seq SS	Adj SS	Adj MS	F	P
Blocks	5	0.10242	0.10242	0.02048	0.37	0.868
speed	1	1.85185	1.85185	1.85185	33.41	0.000
feed	1	3.58827	3.58827	3.58827	64.74	0.000
depth	1	0.00267	0.00267	0.00267	0.05	0.827
angle	1	0.20720	0.20720	0.20720	3.74	0.057
speed*feed	1	2.56324	2.56324	2.56324	46.25	0.000
speed*depth	1	0.05510	0.05510	0.05510	0.99	0.322
speed*angle	1	0.06970	0.06970	0.06970	1.26	0.266
feed*depth	1	0.08441	0.08441	0.08441	1.52	0.221
feed*angle	1	0.03527	0.03527	0.03527	0.64	0.428
depth*angle	1	0.04111	0.04111	0.04111	0.74	0.392
speed*feed*depth	1	0.03734	0.03734	0.03734	0.67	0.414
speed*feed*angle	1	0.04194	0.04194	0.04194	0.76	0.387
speed*depth*angle	1	0.00260	0.00260	0.00260	0.05	0.829
feed*depth*angle	1	0.02470	0.02470	0.02470	0.45	0.506
speed*feed*depth*angle	1	0.00831	0.00831	0.00831	0.15	0.700
Error	75	4.15672	4.15672	0.05542		
Total	95	12.87288				

S = 0.235421 R-Sq = 67.71% R-Sq(adj) = 59.10%

**Figure 5** Analyzed results of surface roughness values



**Figure 6** The interaction effects plot of surface roughness



**Figure 7** The main effects plot of surface roughness

Figure 5 and Figure 7 reveal that the main factors affecting the surface roughness of Palmyra Palm are feed and speed with tendency of higher surface roughness when feed and speed increase from 0.03 to 0.05 mm/tooth and 1000 to 1200 rpm respectively. The surface roughness reduced when the feed decreases and the decreased speed decreases the surface roughness of Palmyra Palm as shown in Figure 6 and Figure 7. shows that no other factors affect the surface roughness.

Based on procedure no. 3 and data analysis in order to identify the variation of surface roughness of Palmyra Palm and adjust for variance analysis. The findings revealed that the designing surface roughness measurement was decision making coefficient of 64.23 % and Adjust R<sup>2</sup> was of 54.25%. This meant that the variance value was at 100 μm<sup>2</sup> and 64.23 μm<sup>2</sup> was implied by the regression model and the rest of data could not be interpreted because of the uncontrolled variable.

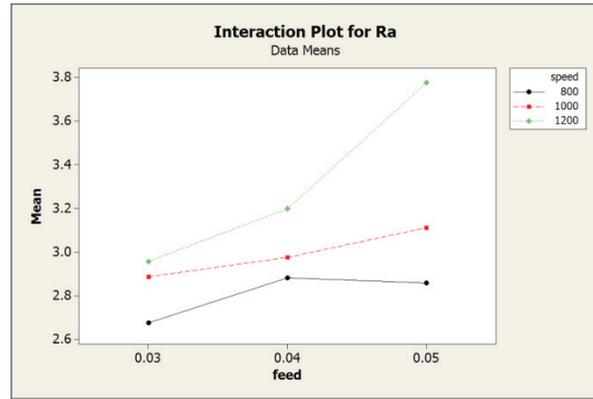
Therefore, the data variance to measure the surface roughness could be implied from the feed and speed. These brought about the accurate designing treatment and appropriate for data analysis. The analysis of variance for R<sub>a</sub> is shown in Figure 8.

Analysis of Variance for Ra, using Adjusted SS for Tests

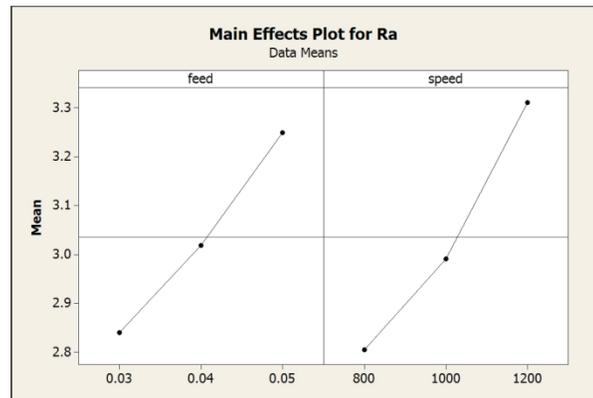
Source	DF	Seq SS	Adj SS	Adj MS	F	P
speed	2	3.13840	3.13840	1.56920	23.42	0.000
feed	2	2.01645	2.01645	1.00823	15.04	0.000
speed*feed	4	1.22737	1.22737	0.30684	4.58	0.003
Error	56	3.75285	3.75285	0.06702		
Total	71	10.49084				

S = 0.258873 R-Sq = 64.23% R-Sq(adj) = 54.65%

**Figure 8** Analyzed results of surface roughness values



**Figure 9** The interaction effects plot of surface roughness

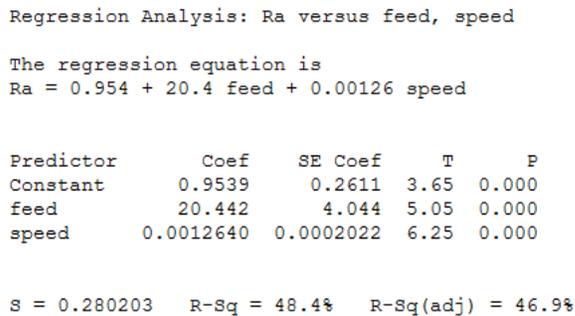


**Figure 10** The main effects plot of surface roughness

The basic treatment shown in Figure 8, Figure 9 and Figure 10 presents that the main factors influencing the surface roughness of Palmyra Palm are feed and speed. The surface roughness reduces when the feed decreases and the decreased speed decreases the surface roughness of Palmyra Palm as shown in Figure 10 and Figure 11. The other factors do not have effects on the surface roughness.

The regression analysis of the surface roughness of Palmyra Palm wood, and feed and speed by adjusting the variation. The ratio of feed is classified into 3 levels: 0.03, 0.04 and 0.05 mm/tooth; the speed is set into 3 levels: 800, 1000 and 1200 rpm. Further, the depth of measurement is stable at 1 mm and direction of cutting is at 0 degree

stability. The recessive test is Minitab R.15. The findings are shown in Figure 11.



**Figure 11** Regression analysis: surface roughness values, speed and feed

The analysis of regression model can be related to the main factors and the surface roughness ( $R_a$ ) as shown in this linear equation:

$$R_a = 0.954 + 20.4 \text{ feed} + 0.00126 \text{ speed} \quad (1)$$

The result of procedure no.4 is confirming all treatments by using an algebraic equation to predict the surface roughness of Palmyra Palm. The sampling of cutting process within the limited area can be compared to the real means. The deviation lessens than 10 % but it is just 6.10%. This is acceptable.

**Conclusion**

The study of investigating the surface roughness in Palmyra Palm wood face milling process by CNC milling machine and using shell end mill cutting tools of 6 edges in order to identify the means of the surface roughness of Palmyra Palm wood face milling process in furniture production. The completely randomized block factorial design was applied to the research. The main factors including speed, feed, depth of cut and angle of cut were investigated for the optimum surface roughness. It could be concluded as following;

1) Cutting speed significantly effects the surface roughness of Palmyra Palm wood followed by feed rate. The result also indicates that lower value of speed and lower feed tended to decrease the surface roughness.

2) The linear equation in this research was as follows:

$$R_a = 0.954 + 20.4 \text{ feed} + 0.00126 \text{ speed}$$

This equation could be applied with shell end mill tool and high speed steel with mill cutting tools 6 edges speed was at 800-1200 rpm and the feed rate at 0.03-0.05 mm/tooth.

3) When comparing the treatment for confirming the results to the findings using the formulation displayed, the measurement was 10 % of errors. The percentage of average error was of 6.10% fewer than the margin of error that could be acceptable.

**Suggestions**

1) The measurement for piece of work revealed that the Palmyra Palm wood had much vary which affected on the surface roughness measurement. This is an uncontrolled factor and time-consuming for the treatment. It is better to avoid measuring roughness of the core texture.

2) This research limitation is that the CNC milling machine used is of a small size that enables to produce a few power in milling.

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