Thrust Force in Drilling of Abaca Composite Panel

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Abstract

In drilling of composite material, the thrust force is one of the main problems which affect the quality of the drilled hole. This paper reports the thrust force in drilling process of natural composite panel. The composite panel was made of abaca fiber and synthetic adhesive by using manual lying process. Epoxy and resin is used as adhesive in this process with the ratio of 30% abaca fiber and 70% adhesive. The drilling processes were conducted on vertical machining center by using High Speed Steel drill tool. Three drilling parameters were selected as independent variables with three levels of values respectively (spindle speed: 1000, 3000 and 5000 rpm, feed rate: 75, 150 and 225 mm/min and tool diameter: 8, 10 and 12 mm). The thrust force as the response of the experiments, were measured and analyzed. The result shows that the spindle speed, feed rate and tool diameter give significant effect to the thrust force in drilling process of abaca composite panel. Recommendations could be given for the best cutting condition to minimize the thrust force.

Keywords: abaca composite panel, drilling, thrust force

Introduction

The abaca fiber is a vegetable fiber from the family of the abaca-banana tree ‘‘musatextilis”. It growths rapidly in tropical forest of Philippine, Thailand and Indonesia. Philippine has been the leader of the world market of abaca fiber that manages more than 80% of the business share. Its ability to growth naturally gives abaca an economical benefit compares to other natural fiber. The abaca fibers are used in manytechnical applications [1, 2] mostly because of their high tensileproperties [3, 4, 5].

Composite panel requires machining processes to achieve final shape and dimension. Drilling and milling processes are mostly used in manufacturing of composite panel product. Milling is used to make side profiles. Drilling is used to make holes for assembly and fitting processes. The quality of machining product is determined by the surface characteristic and the precise of its dimension. Both of those quality characteristics depend on the thrust force developed during the machining process. Previous related research shows that the thrust force was influenced by the machining parameters [6].

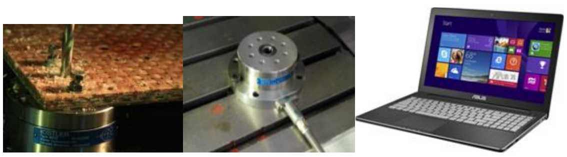
This paper reports the result of a research to investigate the effect of machining parameter to the thrust force in drilling process of abaca composite panel. Three drilling parameters were selected as independent variable: spindle speed, feed rate and tool diameter. The drilling processes were conducted at different cutting condition (3 levels of each machining parameters) by using High Speed Steel (HSS) drill tool. The thrust force of each drilling process was measured and the results were analyzed to study the effect of each drilling parameter to the thrust force and to predict the drilling condition that will minimize the thrust force.

Material and Method

The composite panel was made from 70 % of abaca fiber and 30% of epoxy resin by using manual hand laying process. The dimensions of the panel are 300 mm length, 260 mm widthand 14 mm thickness.

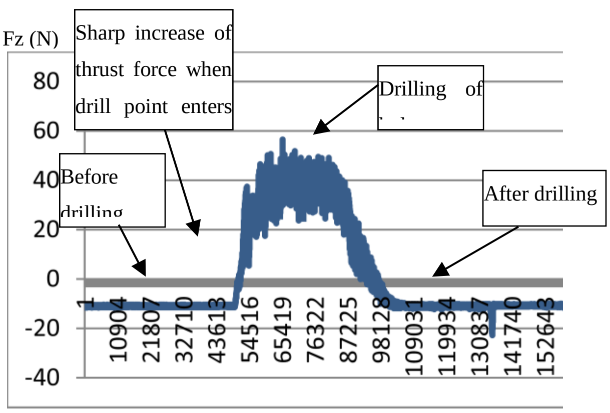
Table 1. The drilling parameters

Parameters	Level		
	1	2	3
Spindle speed (N, rpm)	1000	3000	5000
Feed (f, mm/min)	75	150	225
Diameter (D, mm)	8	10	12



(a) (b) (c)

Figure 1. Experimental setup (a) drilling



Drilling process was conducted on vertical CNC machining center Agma A-8 by using HSS drill tool. Spindle speed, feed rate and tool diameter were selected as independent variables and 3 levels of value were determined for each of the parameter as shown in Table 1. The design of experiment was developed by using Box Behnken of Response Surface Methodology [7]. Seventeen experiments were proposed by the said method as shown in Table 2. The drilling process was repeated 2 times for each of cutting condition and the average measure was taken as the result. The thrust force of each drilling process was measured by using Kistler 9272 vertical dynamometer.

The dynamometer was placed on machine table. The composite panel was clamped on the top surface of the dynamometer. Only one drill hole can be made at one position. Consequently, the new repositioning of the composite panel is required whenever new drill hole need to be made. The

Table 2. Result of the experiment

Std	Run	Block	Factor 1 A:N rpm	Factor 2 B:F mm/min	Factor 3 C:D mm	Response 1 Force N
8	1	Block 1	5000.00	150.00	12.00	7.23
13	2	Block 1	3000.00	150.00	10.00	10
2	3	Block 1	5000.00	75.00	10.00	2.28
15	4	Block 1	3000.00	150.00	10.00	11.9
10	5	Block 1	3000.00	225.00	8.00	25.8
14	6	Block 1	3000.00	150.00	10.00	11.1
4	7	Block 1	5000.00	225.00	10.00	11.3
12	8	Block 1	3000.00	225.00	12.00	6.04
5	9	Block 1	1000.00	150.00	8.00	13
9	10	Block 1	3000.00	75.00	8.00	4.11
3	11	Block 1	1000.00	225.00	10.00	25.8
17	12	Block 1	3000.00	150.00	10.00	9.36
6	13	Block 1	5000.00	150.00	8.00	6.86
11	14	Block 1	3000.00	75.00	12.00	2.3
7	15	Block 1	1000.00	150.00	12.00	13.9
1	16	Block 1	1000.00	75.00	10.00	10.2
16	17	Block 1	3000.00	150.00	10.00	11.2

Table 3. Analysis of varian

Transform | Fit Summary | Model | ANOVA | Diagnostics | Model Graphs

Use your mouse to right click on individual cells for definitions.

Response: Force

ANOVA for Response Surface 2FI Model

Analysis of variance table [Partial sum of squares]

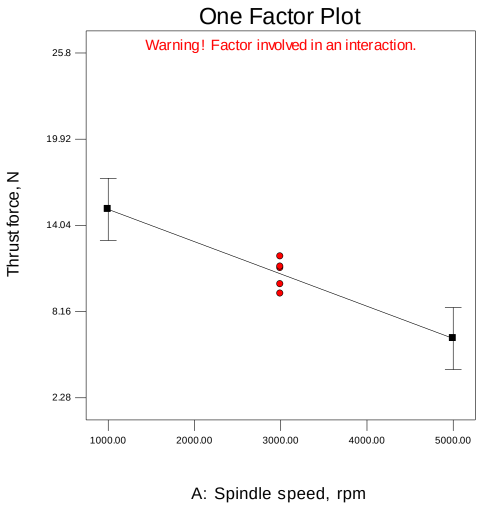
Source	Sum of Squares	DF	Mean Square	F Value	Prob > F
Model	611.23	6	101.87	10.35	0.0008
A	155.14	1	155.14	15.76	0.0026
B	313.13	1	313.13	31.81	0.0002
C	51.51	1	51.51	5.23	0.0452
AB	10.82	1	10.82	1.10	0.3191
AC	0.070	1	0.070	7.134E-003	0.9344
BC	80.55	1	80.55	8.18	0.0169
Residual	98.44	10	9.84		
Lack of Fit	94.31	6	15.72	15.21	0.0100
Pure Error	4.13	4	1.03		
Cor Total	709.67	16			

dynamometer is connected to a multi-channel amplifier and continues to a computer with the software. The experimental equipment and process are shown in Figure 1.

The result of the measurement was presented by the dynamometer in value and graph as shown in Figure 2. As the tool rotate and heading to the hole positon, the reading shows some small value of the force. As the drill point touch the composite panel, the thrust force increase sharply and become stable during the drilling process. The thrust force reduces rapidly as the drilling process come to the end. It was found that all of the drill process has the same trend of signal plot as described above.

Result and Discussion

The result of the experiment was statistical analyzed by using Design Expert Software Ver 6.0.8, as shown in Table 2. The analysis of variance (ANOVA) was carried out to identify the factors which are having more influence on the thrust force in drilling of abaca composite panel. The result of ANOVA (Table 2) shows that the model is significant with F-value of 10.35 and the probability of 0.0008. Values of Prob F less than 0.05



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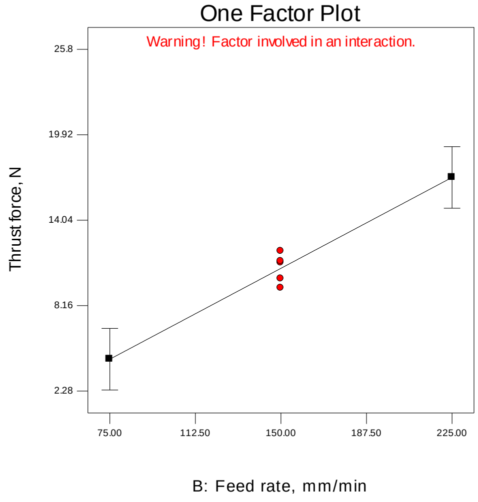

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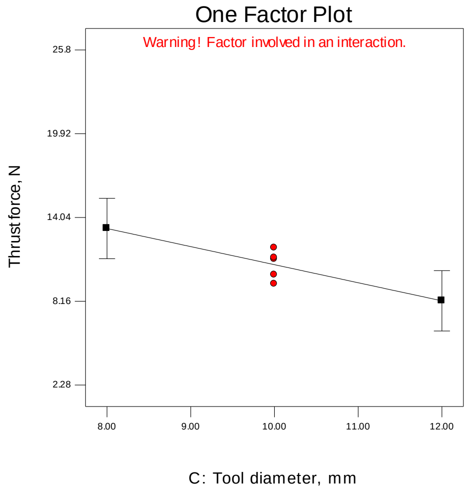


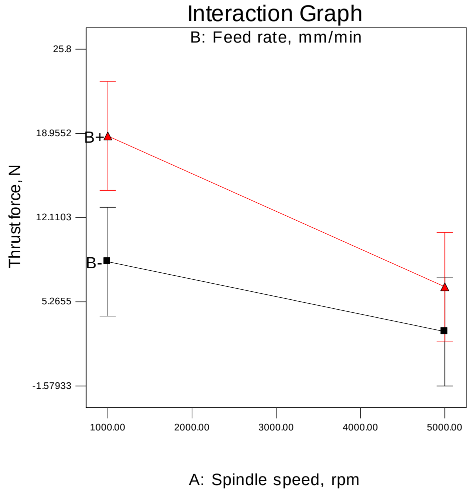
(c)

Fig. 3. Effect of drilling parameters on thrust force. (a) Spindle speed versus thrust force. (b) Feed rate versus thrust force. (c) Tool diameter versus thrust force.

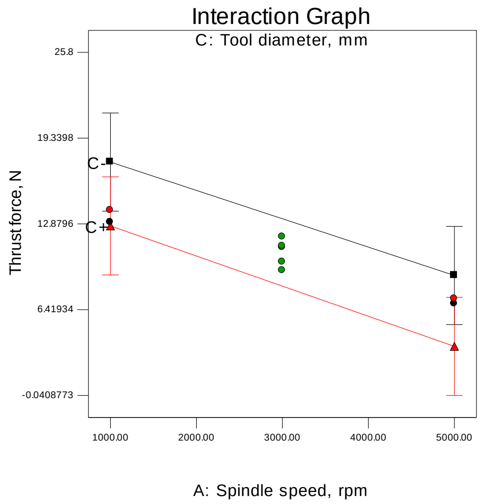
indicate that the model terms are significant. In this case N, f, D and f-d and are the significant model terms which influence the thrust force (with the value of ProbF are 0.0026, 0.0002, 0.0452 and 0.0169 respectively).

The effects plot for spindle speed, feed rate and depth of cut is presented in Fig. 3. From Fig. 3 (a), it is evident that the thrust force developed decreases with increase in spindle speed. Fig. 3 (b) shows that the increase of feed rate increases the thrust force. The increase of feed rate increases the contact area and load on the tool, which in turn increases the thrust force in drilling. Fig. 3 (c) indicated that higher tool diameter decreases the thrust force. From the results, it is revealed that the thrust force developed in drilling of abaca composite panel can be minimized with higher spindle speed and lower feed rate by using bigger tool diameter combination.

The interaction between the parameters also has effect on the drilling of abaca composite panel. The interaction plots for the thrust force are presented in Fig. 4. From Fig. 4 (a), it is observed that the thrust force decreases with the increasing of spindle speed at both low and high level of feed rate. However the thrust force decreases faster at the higher level of feed rate compare to the lower levelone. Figure 4 (b) indicates that increasing of the spindle speed will decrease the thrust force at both low and high level of tool diameter. Figure 4 (c) shows that the thrust force is increased with increase of feed rate. The graph indicated that it increases more at smaller tool diameter. Fig. 4 also indicates that the significant interaction is observed between feed rate and tool diameter. Un-significant interaction is found between spindle speed and feed rate and between spindle speed and tool diameter, in which the



(a)



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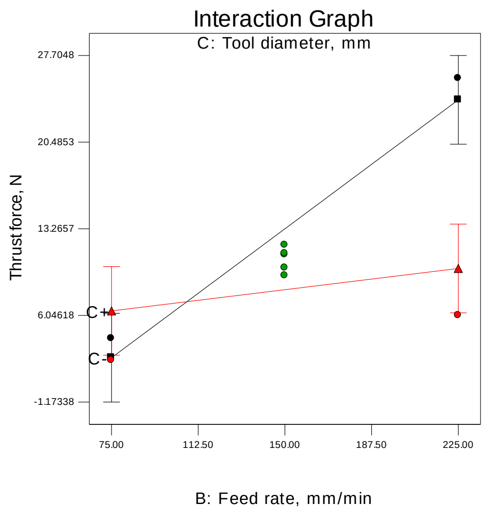


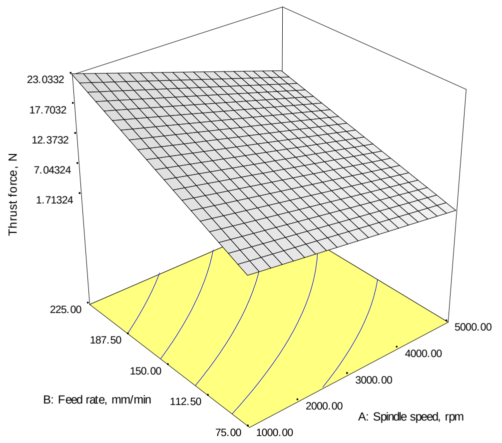
(c)

Fig 4.The interaction effect between drilling parameters. (a) Spindle speed versus feed rate. (bSpindle speed versus tool diameter (c) Feed rate versus tool diameter

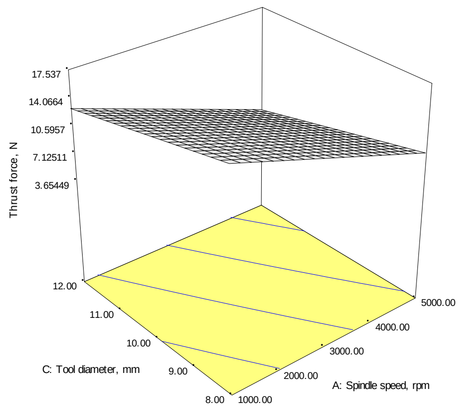
lines are almost parallel to each other. The similar result has been found in the result of analysis of variance.

Fig. 5 shows the three dimensional surface plots for thrust force developed in drilling of abaca composite panel with different cutting conditions. The surface plot can help to visualize the response surface. These are used to establish the desirable response values and operating conditions. The surface plots show how a thrust force relates to two factors based on model equation. The surface plots show only two variables, the third variable is kept as constant. For analyzing the thrust force, the third variable is kept at constant middle level. Fig. 5 (a) shows the relation between spindle speed and feed rate on thrust force. This plot shows how spindle speed and feed rate are related to thrust force. This plot reveals that for minimizing the thrust force, high spindle speed and low feed rate are preferred.

Fig. 5 (b) shows how spindle speed and tool diameter are related to thrust force in drilling of abaca composite panel. This graph indicates that maximum spindle speed and maximum tool diameter are preferred for drilling of abaca composite panel. Fig. 5 (c) shows how feed rate and tool diameter have influence the thrust force. The result indicated that for obtaining minimum thrust force, 75 mm/min feed rate and 12 mm tool diameter are preferred. From Fig. 5, it is asserted that maximum spindle speed, minimum feed rate and maximum tool diameter are preferred for drilling of abaca composite panel.



(a)



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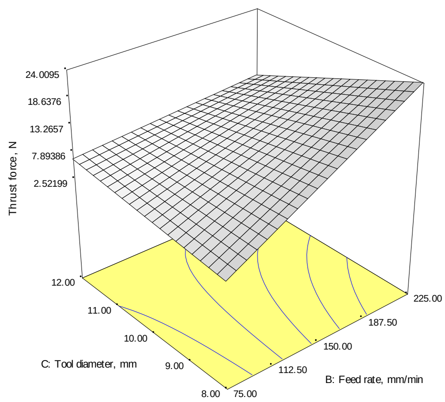

(c)

Fig 5.Three Dimensions (3D) surface graph: (a) Spindle speed versus feed rate. (b) Spindle speed versus tool diameter. (c) Feed rate versus tool diameter

Conclusion

The experiments are planned and conducted by using Box Behnken of Response Surface Methodology design to predict the influence of cutting parameters on thrust force at various cutting conditions in drilling of abaca composite panel by using HSS drill tool.
Based on the result of the experiment, the following conclusions can be obtained:

- The result indicates that all the drilling parameters influence the thrust force. Among the interactions considered, the interaction between the feed rate and tool diameter has significant influence on the drilling process.
- The decrease of spindle speed, increase of feed rate and decrease of tool diameter increases the thrust force.
- From surface plots it is confirmed that the thrust force developed is more at low spindle speed and high feed rate combinations and less at high spindle speed and low feed rate combinations.
- The combination of high spindle speed with low feed rate and big tool diameter minimizes thrust force developed in drilling of abaca composite panel with HSS drill tool.

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