Machinability Effect During Milling on Different Composition of JFRP using Uncoated Carbide Cutting Tool

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***Abstract*— Nowadays, jute fiber reinforcement polymer (JFRP) is used as a cost-effective, eco-friendly and obtainable material. It can be widely used in aircraft, marine, automotive, domestic upholstery approaches due to its various properties. During machining of JFRP, some problem arises in the time of assembly stage. Abrasive nature of jute fiber also effects on tool wear on the carbide cutting tools throughout the JFRP machining. For this reason, the life of the cutting tool becomes shorter and damages the surface quality. In this research, different compositions of the JFRP panel were fabricated and tool wear and delamination were measured after the CNC milling process. A preliminary experiment was conducted following the range of spindle speed from 1500 rev/min to 3500 rev/min and feed rate ranging from 150 mm/min to 350mm/min. Results revealed that tool wear is higher at 70/30 comparing to 60/40 JFRP panel and delamination is lower in 60/40 panel comparing to 70/30 panel. The selected 60/40 jute composite was machined in different feed rate, spindle speed, and depth of cut according to the design of experiment (DOE) table. It was found that tool wear is higher in higher spindle speed (6328.43 rev/min), feed rate (391.42 mm/min) and depth of cut (2.21 mm). Highest tool life was achieved at the lowest depth of cut (0.79 mm).**

Keywords*— *JFRP; tool wear; tool life; delamination; solid carbide cutting tool omponent; formatting; style; styling;

I. INTRODUCTION

The importance of JFRP composite has quickly expanded in the fields of various application such as aviation, automotive, marine, and domestic appliances [1]. Fiber-reinforced polymer (FRP) has a particular specific quality, high modulus of strength, great production rate, good dimensional perfection. The mix of two different properties makes a stronger bond and rarely found in other compounds [2]. FRP composites are usually fabricated through hands lay-up technique, winding, extrusion, vacuums bagging, and molding [3]. However, a certain machining process is needed to get a close design, fittings, and tolerances. Machining processes are known as milling, drilling, slotting, turning, etc. FRP composites are the formation of two different properties in a one compound to increase the thermal and mechanical properties [4]. Jute fiber and epoxy resin are two different components in where reinforcement is jute fiber and epoxy resin is the polymer that plays an important role to form bonding with the fiber. JFRP composites are recently used as complex inter-connections between the matrix and reinforcement. The machining of JFRP influences the materials and creating different types of problems. During machining fiber breakage, lattice splitting, fiber pull out generate and make difficulties in machining [5]. JFRP is a great degree of grating while machining and influence the execution of cutting devices with surface quality. Accordingly, the cutting tool and cutting conditions are necessary for the machining of composite materials. However, the demand for JFRP is increasing but the limited research is done to solve the machining problem at an optimum level. Some researchers focused on the machining f FRP composites in comparison to increase productivity comparing to traditional machining. Palanikumar et al. [6] focused on the machining of glass fiber composite machining. Until now, no research has been conducted to find out the machining performance on the JFRP panel. Actually, machining of JFRP in a different composition is quite hard due to discontinuity, anisotropic nature and different percentages of reinforcement and matrix material.

The research on different compositions of JFRP panel machining has become one of the major aspects to find out the suitable composite panel for machining which will give less effect on tool wear and delamination. In this study, machining on the JFRP panel has been focused to find out machining outcomes.

II. MATERIAL AND METHODS

The experimental process was conducted on different compositions of the JFRP panel by using the CNC machine. The fabrication was done using a hands lay-up technique. The first composite panel was made in 60% reinforcement and 40% matrix material which consists of 5 alternatives layers of jute fabric. The panel dimension was 200 mm x 200 mm x 5 mm. Another panel 70/30 was fabricated by 70% reinforcement and 30% matrix material with the same dimension. Fig. 1 shows the illustration of the JFRP panel. An uncoated carbide-cutting tool with a diameter of 8.0 mm, an overall length of 60 mm, helix angle 300 with two flutes were used. Fig. 2 and Table 1 show the cutting tool and geometrical properties of the solid carbide tool respectively. Chemical and physical properties are demonstrated in Table 2 and Table 3. A CNC machine of 7.5 kW spindle power and a maximum spindle speed of 12000 rpm was used. The tool wear of the cutting tool and Delamination were measured by using Nikon Measuring Microscope MM-400. After 200 mm

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distance traveling, the tool wear and delamination were recorded. Fig. 3 shows the machining set up of the JFRP panel. The machining set up is known as the clamping method. The panel was screwed on an aluminum supported tool. Fig. 4 shows the illustration of delamination measurement. Table 4 represents the general information of the JFRP panel. The selected composite was machined following DOE Table 5.

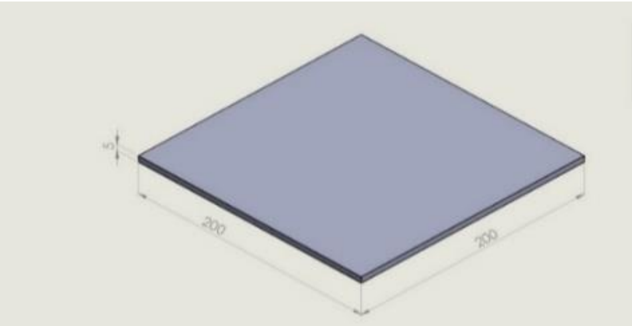

Fig 1. Illustration of JFRP panel

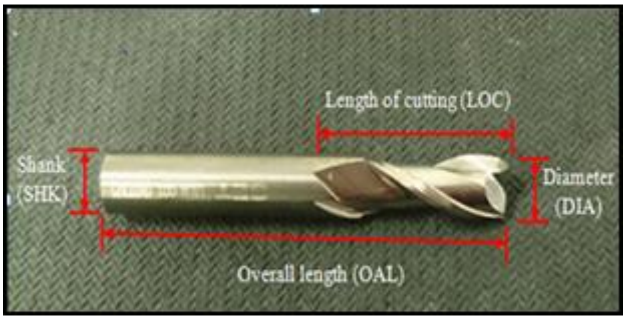

Fig 2. Carbide cutting tool

Fig 3. Machining set up

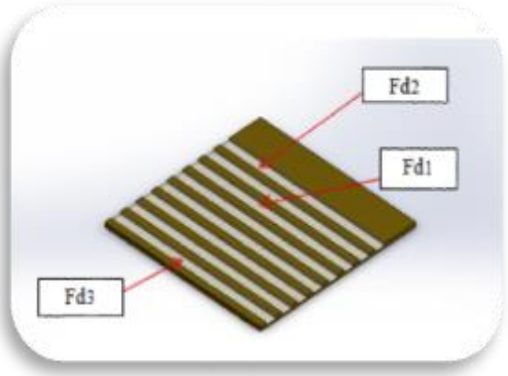

Fig 4. Delamination measurement

Table 1. Geometry of uncoated carbide cutting tool

DIA (mm)	SHK (mm)	OAL (mm)	LOC (mm)
8.0	8.0	60.0	20.0

Table 2. Chemical composition of uncoated carbide cutting tool

Element	Weight %
Tungsten Carbide, WC	88.4–90.0
Cobalt, Co	9.5–10.5
VC+Cr3C2	0.5–1.1

Table 3. Physical properties of uncoated carbide cutting tool

Density, g/cm3	Hardness, HRA
14.35 ± 0. 1	9.18 ± 0.5

Table 4. General information of JFRP panel

Panel	Property
Resin type	Modified epoxy. Hexply @ 914
Tg resin	190º
Yarn type	Tossa grade 1
Fabric type	Woven

Table 5. Experimental Design

Run	Spindle speed (rev/min)	Feed Rate (mm/min)	Depth of cut (mm)
1	3500.00	250.00	1.50
2	6328.43	250.00	1.50
3	3500.00	250.00	1.50
4	3500.00	250.00	1.50
5	3500.00	391.42	1.50
6	3500.00	250.00	0.79
7	5500.00	150.00	2.00
8	3500.00	250.00	1.50
9	3500.00	250.00	2.21
10	3500.00	108.58	1.50
11	1500.00	350.00	2.00
12	1500.00	150.00	1.00
13	3500.00	250.00	1.50
14	5500.00	350.00	1.00
15	671.57	250.00	1.50

III. RESULTS AND DISCUSSION

A. Tool Wear Analysis

Tool wear is very important aspect that should to examined during machining. It can be seen that figure 5 (a) and (b) shows the effect of spindle speed and feed rate on the cutting tool. Figure 5 (a) shows that the different spindle speed 1500 rev/min and 3500 rev with a constant feed rate 150 mm/min, depth of cut 1mm. Here, the JFRP panel 60/40 can be observed that at 3500 rev /min spindle speed tool wear 0.041mm and 1500 rev/min gives 0.036mm. On the other hand, 70/30 JFRP panel shows that whenever spindle speed 3500 rev/min then the tool wear is 0.046 mm and the spindle speed is 1500 rev/min then the tool wear 0.033mm. It was found that due to the increase of spindle speed the tool wear increase also. The comparison study between these two composites. It was observed that 60/40 composite panel tool life is better than 70/30 composite panel. Figure 5 (b) shows the feed rate effect on tool life in between two composite panel. It can be seen that the feed rate is increasing tool wear

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is increasing also. Many studies reported that feed rate effects on tool life significantly, due to the friction between the cutting tool and workpiece. The matrix removal is higher in the case of a higher feed rate. The feed rate was 150 mm/min and 350 mm/min with a constant spindle speed 3500 rev/min and depth of cut 1.0 mm. The 60/40 composite panel gives the tool wear 0.036 mm and 0.048mm whenever the feed rate was 150 mm/min and 350 mm/min. Another panel 70/30 shows that the tool wear 0.046 mm and 0.056 mm within the same feed rate like 150 mm/min and 350 mm/min. To do compare, it can be seen that 60/40 panel shows the better tool life compared to 70/30 panel. It would be happened due to the less matrix percentage in 70/30 panel.

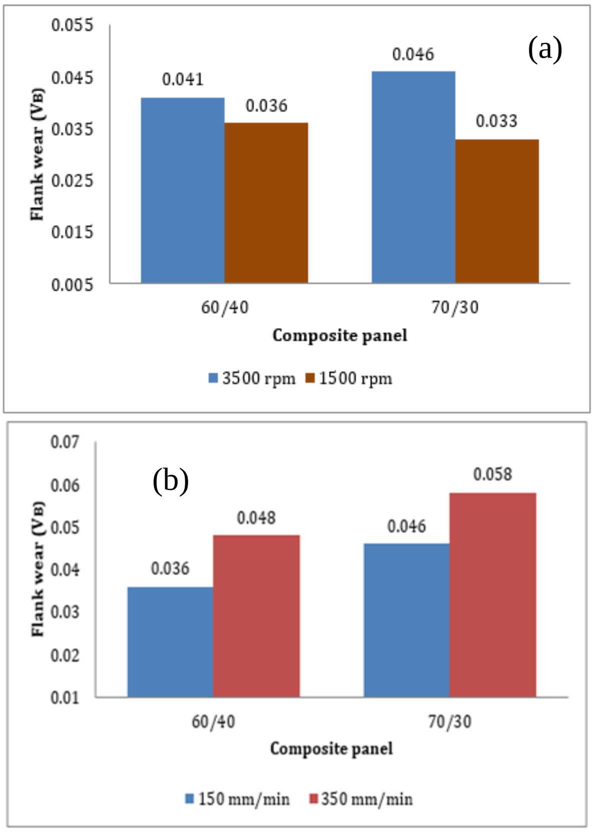


Figure 5 (a) Different spindle speed (3500 rpm & 1500 rpm) effect on Tool wear; (b) different feed rate (350 mm/min and 150 mm/min) effect on tool wear

B. Delamination Analysis

Delamination is one of the most important factors for the rejection of the industrially made components which draw serious attention to the engineers for machining JFRP. The delamination factor was measured for these two composite panels in different spindle speeds like 1500 rev/min and 3500 rev/min within constant feed rate 150 mm/min and depth of cut 1 mm. Figure 7 shows that, For 70/30 panel, it was found that 1500 rev/min and 3500 rev/min spindle speed gives delamination 1.34 mm and 1.02 mm. Similarly, for 60/40 panel the same spindle speed gives 1.23 mm and 0.86 mm delamination. Delamination in 60/40 is less than 70/30 panel. Now the delamination measured on different feed rates like 150 mm/min and 350 mm/min with a constant spindle speed 3500 rev/min and depth of cut 1 mm. Figure 8 shows that feed rate 350 mm/min effect for 70/30 and 60/40 panel delamination was 1.31mm and 1.22mm. For, 150 mm/min feed rate shows the delamination was 1.11 mm and 1.02 mm for 70/30 and 60/40 panel. It was found that 60/40 panel gives the lowest delamination comparing to 70/30 composite panel.

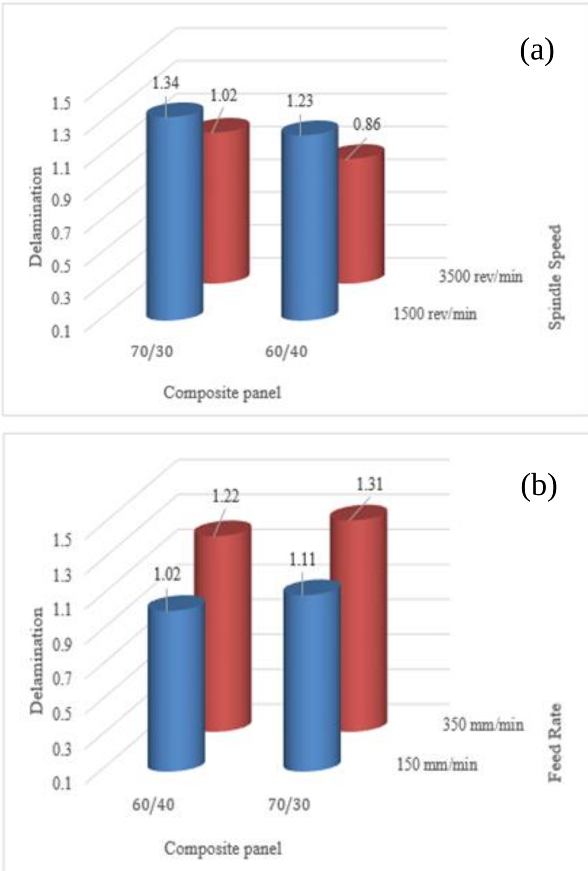
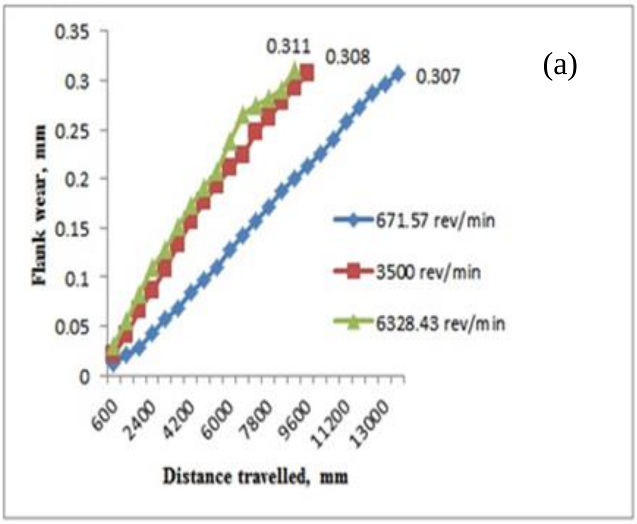


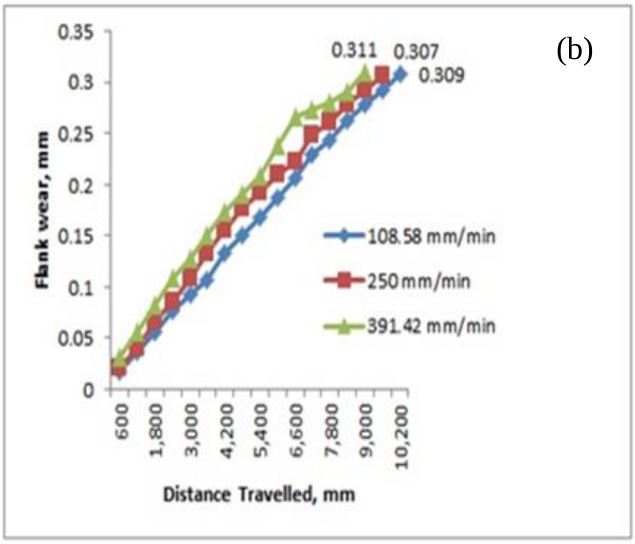
Figure 6 (a) Different spindle speed (3500 rpm & 1500 rpm) effect on delamination; (b) different feed rate (350 mm/min and 150 mm/min) effect on delamination

C. Tool Wear Analysis for 60/40 panel

Tool wear is measured in the view of flank wear according to ISO (1989) standard until 0.3 mm. In this machining also followed the machining until the carbide cutting tool reaches the ultimate flank wear. It can be seen from the figure 7 that different spindle speed (671.57 rev/min to 6328.43 rev/min), feed rate (108.58 mm/min to 391.42 mm/min) and depth of cut (0.79 mm to 2.21 mm) is used to find the flank wear of the cutting tool. Figure 7 (a) exhibits that whenever the spindle is higher (6328.43 rev/min) then the flank wear is very faster and after traveling 9600 mm distance reaches 0.311 mm flank wear. Gradually the spindle speed was decreasing from 6328.43 rev/min to 671.57 rev/min then the cutting tool traveled a long distance to reach the ultimate flank wear. It can be seen from the figure also that 671.57 rev/min spindle speed takes a long time to reach 0.307 mm flank wear. It can travel 13600 mm distance at lower spindle speed. It could happen because the cutting tool creates lower temperatures surrounding the cutting tool due to lower spindle speed [7]. It also can be seen in figure 7 (b) that different feed rate (108.58 mm/min to 391.42 mm/min) has an effect on tool wear as well. The lower feed rate 109.58

mm/min takes a longer time to reach at 0.309 mm flank wear and the distance traveled 10200 mm. On the other hand, the highest feed rate 391.42 mm/min traveled shorter distance (9200 mm) to reach at 0311 mm flank wear. It can be done because the traversing rate increased with the increase in feed rate and the tool wear become faster [8]. Finally, it can be seen in figure 7 (c) that whenever the depth of cut increased from 0.79 mm to 2.21 mm then the flank wears also affected. The depth of cut is higher then the cutting tool has to remove more materials from the surface and tool wear increases. At a lower depth of cut 0.79 mm shows that the carbide cutting tool can travel more distance comparing to 2.21 mm and 1.50 mm.





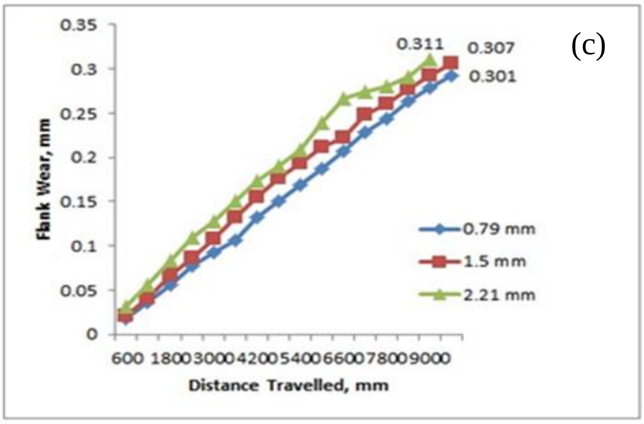
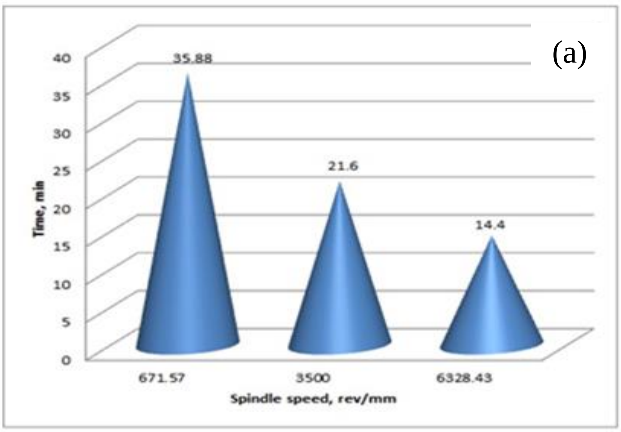


Figure 7 (a) Different spindle speed (6328.43, 3500 & 671.57 rev/min) effect on tool wear; (b) Different feed rate (391.42, 250 & 108.58 mm/min) effect on tool wear; (c) Various Depth of cut (2.21, 1.5 & 0.79) effect on tool wear

D. Tool life Analysis

Tool life is one of the major issues to cut the JFRP panel for the better output performance of machining. Figure (8) illustrates that tool life is affected by the changes in spindle speed, feed rate and depth of cut. From the figure 8 (a), it can be seen that whenever spindle speed increases from 671.57 rev/min to 6328.43 rev/min and the feed rate (250 mm/min) and depth of cut (1.50 mm) was constant then the tool life was decreasing from 35.88 min to 14.4 min. It could happen because the higher spindle speed has an interaction force between the workpiece and tool material [9]. It generates high temperatures between the workpiece material and tool to create faster wear in the carbide cutting tool. Figure 8 (b) reveals that with the increase of feed rate from 108.58 mm/min to 391.42 mm/min then the tool life also decreased because the friction arises between the workpiece and tool material. It also generates high temperatures and decreases the tool life from 41.6 min to 13.5 min. Figure 8 (c) shows that, higher the depth of cut and lower the tool life. The depth of cut was increased from 0.79 mm to 2.21mm then tool life also decreased because of the lowest depth of cut have to remove less material comparing to higher depth cut. However, it can be seen that the lowest depth of cut (0.79 mm) shows the tool life is longer comparing to the highest depth of cut (2.21 mm).



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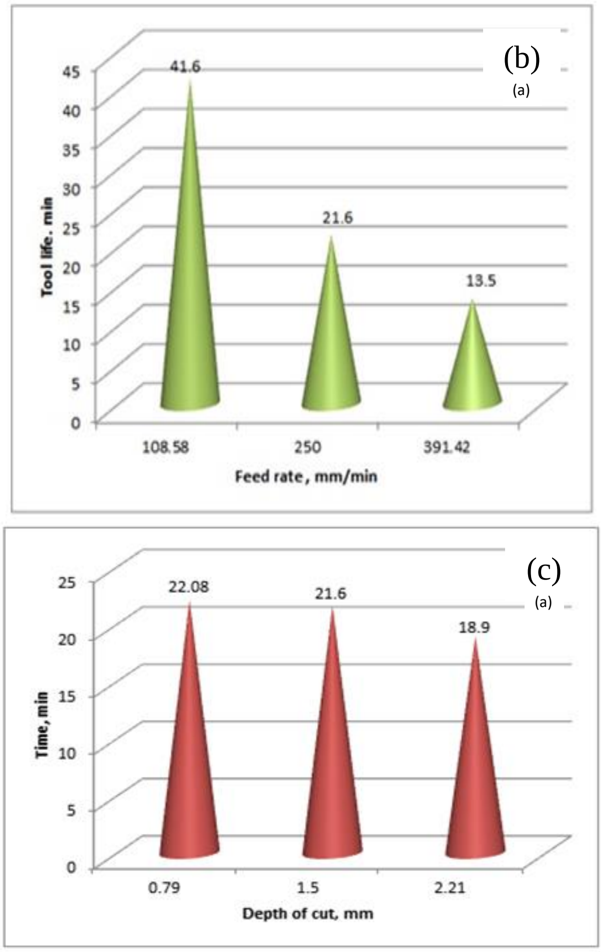

Figure 8 (a) Different spindle speed (6328.43, 3500 & 671.57 rev/min) effect on tool life; (b) Different feed rate (391.42, 250 & 108.58 mm/min) effect on tool life; (c) Various Depth of cut (2.21, 1.5 & 0.79) effect on tool life

IV. CONCLUSION

In the investigation of the above study, it was found that a preliminary experiment on different composite panels shows that 60/40 JFRP panel is better than 70/30 panel. The spindle speed and feed rate both have an effect on this composite panel to. Tool wear is higher at 70/30 panel and delamination also comparing to 60/40 panels. The selected 60/40 composite panel was machined according to DOE table. After machining the selected composite panel, it was found that higher spindle speed (6328.43 rev/min), feed rate (391.42 mm/min) depth of cut (2.21) gives the highest flank wear and tool life is decreased. The tool life increased at a lower depth of cut (0.79 mm). These experimental table gives us the range of machining parameter and also the tool wear and tool life analysis.

V. ACKNOWLEDGEMENTS

This research was conducted in Tool and die lab, workshop and metrology lab in International Islamic University Malaysia. Composite lab was used to fabricate the JFRP panel. Author is grateful towards the modern lab facility and help of lab assistant as well.

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