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STUDY ON TOOL WEAR AND TOOL LIFE DURING MILLING JFRP USING UNCOATED CARBIDE CUTTING TOOL

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ABSTRACT

Jute fiber-reinforcement polymer (JFRP) composite is a cheap material that is broadly used in automotive, marine, aircrafts, domestic upholstery applications because of its various high quality properties. During machining, a few of problems arise due to the Jute fiber in JFRP. Abrasive nature of this composite creates tool wear on the cutting tools during JFRP machining, thereby the life of the cutting tool become shorter and damage the surface quality. In this study, the solid uncoated carbide cutting tool (8.0 mm) performance and the life of tool were measured on the JFRP composite panel during the CNC milling process were examined. A spindle speed ranging from 671.57 rev/min to 6328.43 rev/min and a feed rate ranging from 108.58 mm/min to 391.42 mm/min were used in the experiment. Results found that the longest tool life 41.6 min were achieved at lowest feed rate 108.58 mm/min and the highest spindle speed 6328.43 rev/min effects on tool life 14.4 min. The shining area of the cutting tool shows the abrasive nature of jute fiber and chips formation mechanism.

Keywords: jute fiber reinforcement polymer, solid uncoated carbide tool, tool wear, tool life, delamination, surface quality.

INTRODUCTION

The interest for jute fiber reinforced polymer (JFRP) composite has developed extensively as of late in different fields, for example, the aviation, automotive, and aerospace enterprises [1]. Fiber reinforced polymer (FRP) has high particular quality, high modulus or stiffness, and great dimensional accuracy. This mix of properties is strange and not effectively acquired in compounds [2]. FRP composites are usually fabricated through hands lay-up, winding, extrusion, vacuum bagging and molding. However, certain machining processes, such as milling drilling, turning and slotting are needed to get close designs, fitting and tolerances, similar to attain near-net shapes in classical manufacturing processes [3]. FRP composites contrast from metals from various perspectives in light of the fact that composites have two periods of materials with definitely recognized thermal and mechanical properties. FRP composites display complicate inter-connections between the reinforcement and the matrix amid machining [4]. The machining procedure altogether influences these materials, in this way prompting different methods of problems. The difficulties in these materials come in various structures, including fiber breakage, lattice splitting, and fiber pullout, among others. JFRP is to a great degree grating when machined, in this way influencing the execution of cutting devices and surface quality. Along these lines, the choice of cutting conditions and cutting tools is necessary in the machining procedure of composite materials. Though the demand of FRP is increasing but a very limited research is done on FRPs. Besides this, there are few researches focused on the machining of FRP composites in comparison to other traditional materials for maximum productivity and least production cost [5].

Tool wear is a very important aspect to do machining on FRP composite. Studies are going on to increase the tool performance especially on improved edge conditions with better applications [6]. The demand for good surface quality influences the mechanical structure of panel components. The basic concept of tool wear depends on various conditions. In terms of FRP machining, abrasion and surface damage effect on the panel significantly [7]. Tool wear is related with the mechanical and physical structure of reinforcement and matrix materials. Therefore, it is obvious to achieve high metal material removal rate and well defined surface finish within low tool wear [8].

According to Rawat [9], abrasive wear is clearly visible whenever machining is done on GFRP and CFRP panel because of excess abrasive nature. It is very difficult to find out the process which can reduce the tool wear.

Materials and Methodology

Analyses were led on a JFRP composite panel measuring 200 mm × 200 mm × 5 mm (Figure-2). The JFRP panel was made following the hands lay-up technique and arranged at unidirectional way. The JFRP panel comprises of five layers of jute fiber that had experienced on one after one placement procedure. Two flutes is being consisted by uncoated carbide cutting tool (S2FE-080), with helix angle of 30°, overall length is 60 mm, and diameter is 8 mm, were utilized as a part of the experiment (Figure-1). The cutting parameters utilized as a part of the test are appeared in Table-1. A computerized numerical control machine with a 6.5 kW shaft power and most extreme axle speed of 12000 rpm was utilized as a part of the analysis. Table-1 demonstrates the trial conditions for JFRP cutting. Tool wear was measured utilizing a Nikon Measuring Microscope MM-400 amid the processing operation. The processing operation was controlled and the cutting device was disposed of when flank wear (VB) or nose wear (VC) achieved 0.3 mm or 0.5 mm, separately (International Standard, 1989). Figure-3 shows that machining set up of JFRP composite. It is known as clamping method in where JFRP panel was

ARPN Journal of Engineering and Applied Sciences

clamped by screw on an Aluminum supporting tool. The 8.0 mm carbide cutting tool will run over the panel which is fixed on machine. Table-2 and Table-3 show the chemical and physical composition of carbide cutting tool. The general information of JFRP panel and the panel properties are described on Table-4 and Table-5. Tool wear values were collected after 600 mm distance travelled which is illustrated in Figure-3. Response surface methodology was used to conduct the experiment. To get better result of tool wear Central Composite Design (small type) was selected and Table-2.6 shows the input variable for machining.

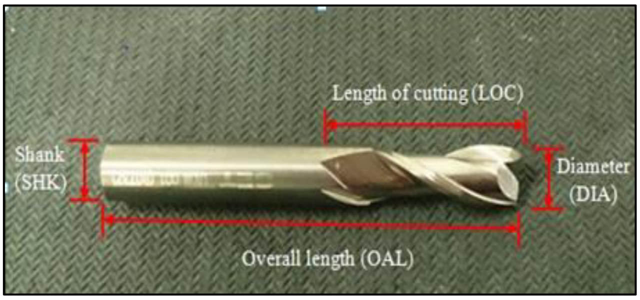

Figure-1. Carbide cutting tool.

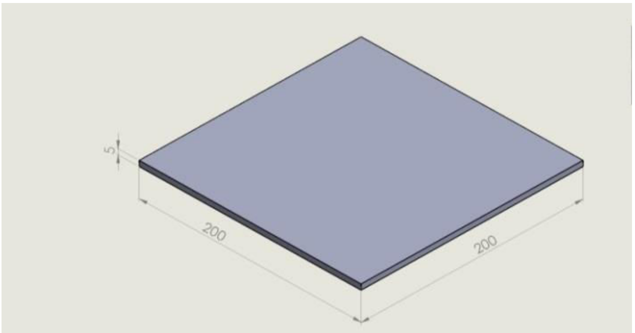

Figure-2. Illustration of JFRP panel.

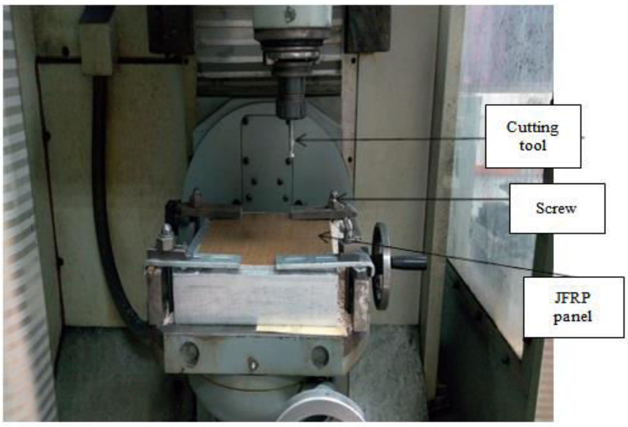

Figure-3. Machining set up.

Table-1. Cutting parameters of JFRP panel.

Tool material	**Solid uncoated carbide**
Work material	JFRP
Spindle speed (rev/min)	671.57, 3500, 6328.43
Feed rate (mm/min)	108.58, 250, 391.42
Depth of cut (mm)	0.79, 1.50, 2.21
Temperature of dry condition	24-28 °C

Table-2. Geometry of uncoated carbide cutting tool.

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

Table-3. 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-4. Physical properties of uncoated carbide cutting tool.

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

Table-5. General information of JFRP panel.

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

Table-6. Composite panel properties.

Tensile strength (MPa)	**82**
Flexural strength (MPa)	143
Impact strength(MPa)	11
Tensile modulus (GPa)	1.12
Flexural modulus (GPa)	4.3

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Table-7. 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

RESULT AND DISCUSSIONS

Tool wear analysis

From the Figure-4 shows that the more distance travel the cutting tool wear increase. It can be seen that, tool wear is more in higher spindle speed. The spindle speed 6328.43 rev/min reaches the ultimate flank wear 0.3 (ISO 1989) within 8400 mm distance travel but the lowest spindle speed 671.57 rev/min travelled 13800 mm to reach the targeted flank wear. It happened due to high spindle speed generate heat surrounding the cutting tool. The result is found from here that low spindle speed gives better tool life. The histogram Figure-5 shows that feed rate effect on tool wear. The higher feed rate 391.42 mm/min gives lower distance travel on composite panel that means tool wear is very high comparing to others feed rate. The tool wear is less in 108.58 mm/min feed rate because of its longer distance travelled on the JFRP panel. This was expected that lower feed rate is stable due to low traverse of the cutting tool. However, the tool wear was high at higher feed rate because of high heat was generated by the traversing of cutting tool. Figure-6 shows the depth of cut effect on tool wear. The higher depth cut 2.21 mm travel lower distance comparing to others depth cut because the tool wear become faster. It can be observed that depth of cut effect on tool wear in a very small portion

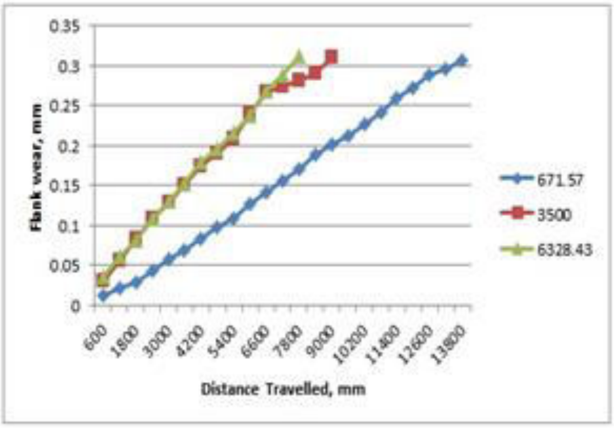

Figure-4. Comparisons of tool wear at different spindle speed.

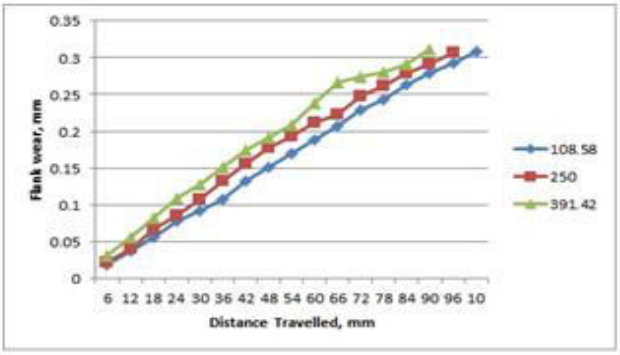

Figure-5. Comparisons of tool wear at different feed rate.

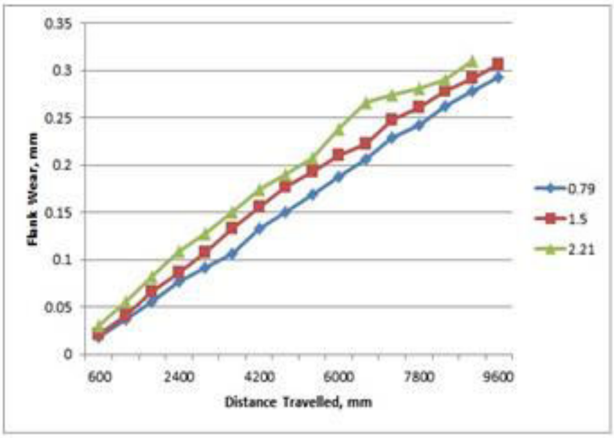

Figure-6. Comparisons of tool wear at different depth of cut.

Tool life analysis

Tool life is a basic aspect that should to be examined as it is main problem run into in assembling industry amid machining operations. The tool wear is one of the major issues for cutting JFRP. Figure-7 shows that tool life is decreasing with the increase of spindle speed. The spindle speed increases from 671.57 rev/min to 6328.43 rev/min with a constant feed rate 250 mm/min and depth of cut 1.50 mm. The better tool life 35.88 min was found at lower spindle speed 671.57 rev/min. The worst tool life 14.4 min were achieved at higher spindle speed 6328.43 rev/min. actually; the tool wear is increased with the increase of spindle speed. The percentage of difference between the shortest and longest tool life is 21.4%. Figure-8 shows that, higher feed rate gives shortest tool life and the longest tool life is obtained from lower feed rate. The feed rate starts from 108.58 mm/min to 391.42 mm/min. The higher feed rate generates heat between the work piece and cutting tool which gives poor result in tool life. During machining, the feed rate increases the chatter and leading to a higher flank wear [6]. Tool life 41.6 min was found in 108.58 mm/min feed rate, 21.6 min in 250 mm/min feed rate and 13.5 min in 391.42 mm/min. Based on the graph, longest tool life (41.6 min) was resulted when the feed rate was lowest (108.58 mm/min). While, The highest feed rate (391.42 mm/min) showed the opposite means shorter tool life (13.5 min). Figure-10 shows that the cutting tool reaches the ultimate limit of flank wear in where the shiny and polished area appears at the cutting edge due to the excessive wear.The histogram Figure-9 shows the tool life of cutting tool in three types of depth of cut 0.79, 1.50, 2.21 mm with a constant feed rate 250 mm/min and depth of cut 1.50 mm. It can be observed that longest tool life is achieved in the lowest depth of cut. This phenomenon is occurred due to the lowest depth of cut get the small contact area between the panel and the cutting tool that means less material removal and longer tool life. However, the effect of depth of cut is not so much like spindle speed (Vc).

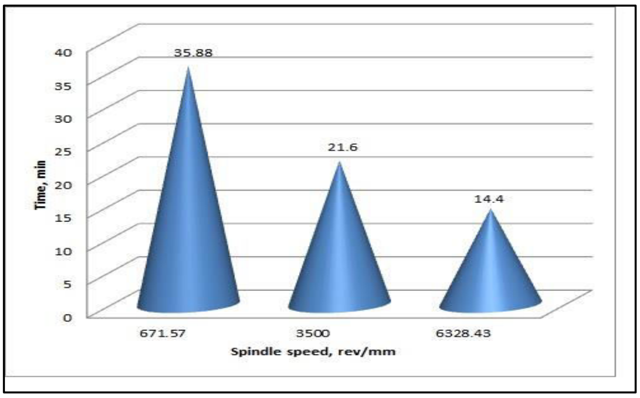

Figure-7. Comparison of tool life at different spindle speed.

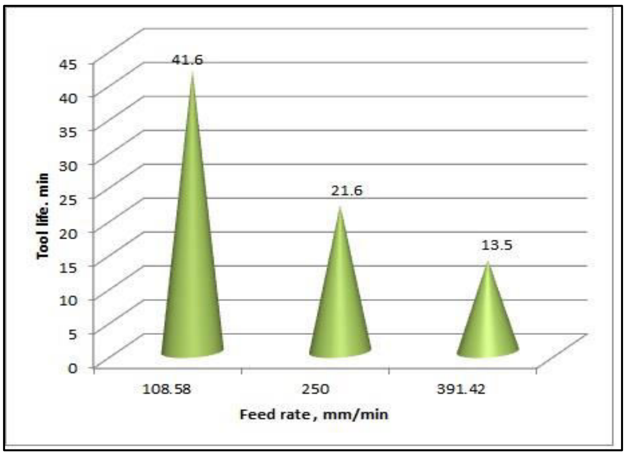

Figure-8. Comparison of tool life at different feed rate.

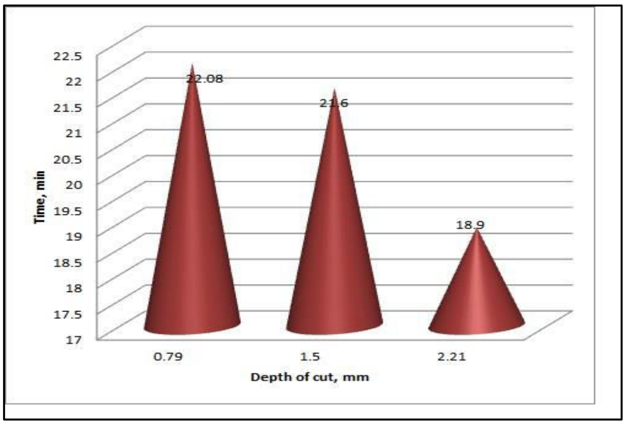

Figure-9. Comparison of tool life at different depth of cut.

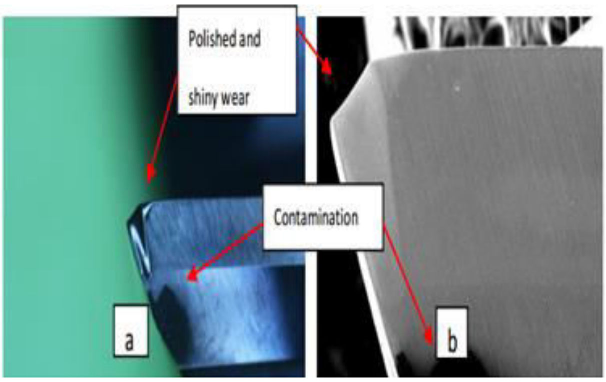

Figure-10. Tool wear under SEM.

CONCLUSIONS

Tool wear is an important aspects and crucial point to find out the highest tool life within the range of cutting parameters. From the experiment, it was observed that tool wear increased as the spindle speed, feed rate and depth of cut increased from 671.57 rev/min to 6328.43 rev/min, from 108.58 mm/min to 391.42 mm/min and 0.79 mm to 2.21 mm. The highest tool life achieved at lowest feed rate that means 108.58 mm/min feed rate gives 41.6 min tool life. The SEM figure showed the tool wear area due to the abrasive nature of JFRP.

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