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Study On Machinability Of Cfrp Composite Using Tin Coated Pcbn And Uncoated Pcbn Cutting Tool

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ABSTRACT : *This experimental study concentrates on the understanding of machining process in turning of carbon fiber reinforced polymer (CFRP) composite using uncoated polycrystalline cubic boron nitrite (PCBN) and TiN coated polycrystalline cubic boron nitrite cutting tools. CFRP composite materials are replacing various traditional engineering materials a long back due to the excellent properties the possess for various application in engineering and technology. Though they are produced to near net shape, often they are in need of machining. But it contains matrix and reinforcement. Which are soft and hard in nature respectively, resulting in anisotropic and non-homogeneous properties. This paper aims to investigate the machinability in turning processes of CFRP composite manufactured by hand lay-up. This experiment is investigated the tool wear on uncoated PCBN and TiN coated PCBN cutting tool by scanning Electron microscope and also measured the surface roughness of the workpiece(CFRP) by 2D roughness tester. A critical range of cutting temperature also has been carried out.*

Keywords - *CFRP, PCBN cutting tool, Turning, Tool wear, surface roughness, Temperature*

I. INTRODUCTION

Surface characteristics and dimensional accuracy very important when components come in contact with other counter parts, in the case of polymeric materials reinforced with fibers. This is because of the fiber reinforced polymer (FRP) composites materials are replacing traditional engineering materials for various applications such as aircraft, automobile, sports, marine bodies etc [1-3]. This is due to the advantages includes high strength to weight ratio, high fracture toughness, high damping capacity excellent corrosion and thermal resistance [4-5]. Though even FRP parts may be produced to near net shape, they require further machining to facilitate dimensional control for easily assembly and control of surface quality for functional aspects.

The machining of FRP is different and more complicated to that of metals because of their anisotropic and inhomogeneous nature, along with the chip formation mode for its brittle behavior. When using FRP it is often necessary to cut the material, but the cutting of FRP is often made difficult by the delaminating of the composite and the short tool life [6-8]. Thus the selection of cutting tool and cutting parameters is very important in the machining processes. By proper selection of cutting tool material and geometry, excellent machining of the work piece is achived.

Various researchers have studied machining characteristics of Carbon Fiber Reinforced Polymer (CFRP) composites using various cutting tools such as ceramics tool, and PCD. Further this work is related to the same workpiece material using different cutting tool material such as uncoated PCBN and TiN coated PCBN and various methodology also have been considered here as a literature study [9-11].From literature survey super hard materials are best suitable for machining of CFRP composite materials [12]. Like here PCBN cutters were found to produce to better machined surface quality.In this study turning operation is carried out on CFRP composite material using uncoated PCBN and TiN coated PCBN cutting tool in using various important machining parameters namely cutting speed, feed, and depth of cut.Surface roughness of the workpiece was measured using 2D surface roughness tester. Surface roughness obtained from experimentation was analyzed to understand the surface quality of machined CFRP material using uncoated PCBN and TiN coated PCBN cutting tool.Tool wear on uncoated PCBN and TiN coated PCBN cutting tool was analyzed by using Scanning Electron Microscope (SEM). Tool wear experimentation was analyzed to understand the tool wear characteristics of both coated and uncoated cutting tool. Here critical range of cutting temperature also has been carried out.

II. EXPERIMENTAL DETAILS

2.1 Workpiece materials

The material used for the experimental study is carbon fiber reinforced polymer (CFRP) composite rod of diameter 20mm in found in fig 1(a). This CFRP composite was manufactured by hand lay-up method. CFRP is widely used in many engineering application, such as aircraft, automobile, sports, marine bodies etc. The advantage includes high strength to weight ratio, high fracture toughness, excellent corrosion and thermal resistance [3-5].

Fig. 1 CFRP composite rod

2.2 Cutting tools

Two types of cutting tools were used for the present work, such as uncoated PCBN cutting insert and the other insert was TiN coated using physical vapor deposition (PVD) method.

ISO specification of PCBN inserts- CNMM 120404

C = 80 Deg Rhombus

N = Insert clearance angle (0°)

M= Tolerance class (N)

M = Type of insert, Hole

12 = Edge length (12mm)

04 = Insert thickness (4.76mm)

04 = Radius (0.4mm)

TiN coating on the PCBN cutting inserts done by PVD coating at oerlikon Balzers Coating Services, Chennai.

Coating parameters

Chemical composition -90 % Ti +10 % N

Coating temperature - 350 ◦ C

Coating thickness -4 µm

2.3 CNC machine

The machine used for the turning tests was a Jobber XL Industrial type of CNC lathe machine. The lathe equipped with variable spindle speed from 50 rpm to 10000 rpm, and a 15 kW motor drive was used for the tests.

Fig. 2 CNC turning center

2.4 Experimental procedure

The material is fixed between the chuck and tailstock of a cnc lathe to ensure stability during machining. PCBN tools is used widely for cutting various materials in manufacturing industry for machined various hardened materials due to the favorable material properties such as high melting point, excellent hardness and good wear resistance and also highly improved cutting performance [13-15]. PCBN tool material is chosen for machining of carbon fiber reinforced polymer (CFRP) composite rod due to its best performance compared with other tools such as high hot hardness and wear resistance [4].The surface roughness was measured the commonly used and important known parameter, the average surface, Ra, which is the average of three values measured from three different location. 2D roughness tester, Stylus Tip radius of 2 µm was used for this study. The roughness tester was set to a cut-off length of range 0.8mm.In general, two types of wear apply to tool life, i.e., Flank wear and crater wear. Flank wear remains the more common measure of tool wear compared with crater wear because of ease of measurement. This experiment is investigated the tool wear on uncoated PCBN and TiN coated PCBN cutting tool by scanning Electron microscope.

III. RESULTS AND DISCUSSION

3.1 Surface roughness characterization

Turning operation was carried out on carbon fiber reinforced polymer composite material using uncoated PCBN and TiN coated PCBN to understand the influence of machining parameters, the trend of machining parameter in deciding machining quality of machined surface and the combination of machining parameter that could offer better surface roughness of machined surface. Further to identify the machining parameter that plays an important role in deciding the surface quality of workpiece The measured response surface roughness and their cutting temperature corresponding to the varying machining parameter have been summarized in table 1 and table 2.

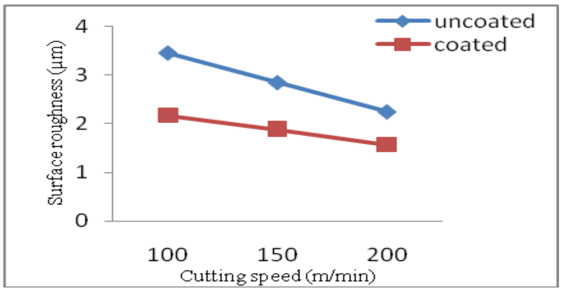
TABLE 1 Input parameter and response parameter for uncoated PCBN cutting tool

Cutting speed v_c(m/min)	Feed f (mm/rev)	Depth of cut d (mm)	Surface roughness Ra (µm)	Cutting temperature T (◦c)
100	0.05	0.25	3.450	41.5
150	0.10	0.25	2.845	49.5
200	0.15	0.25	2.250	55.5
100	0.05	1.25	3.854	50.4
150	0.10	1.25	3.554	55.4
200	0.15	1.25	2.855	61.5

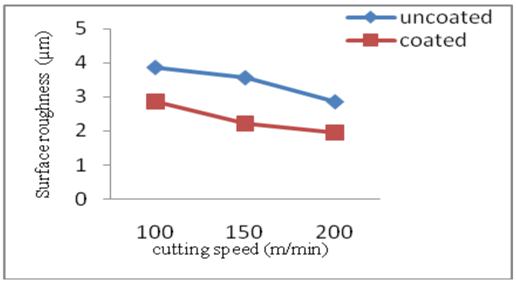
TABLE 2 Input parameter and response parameter for TiN coated PCBN cutting tool

Cutting speed v_c(m/min)	Feed f (mm/rev)	Depth of cut d (mm)	Surface roughness Ra (μm)	Cutting temperature T (◦c)
100	0.05	0.25	2.171	33
150	0.10	0.25	1.891	40.4
200	0.15	0.25	1.570	44.4
100	0.05	1.25	2.855	40.5
150	0.10	1.25	2.220	44.7
200	0.15	1.25	1.950	49.6

It shows the general trend of various process parameters such as cutting speed, feed and depth of cut on the response variable surface roughness.



(a)

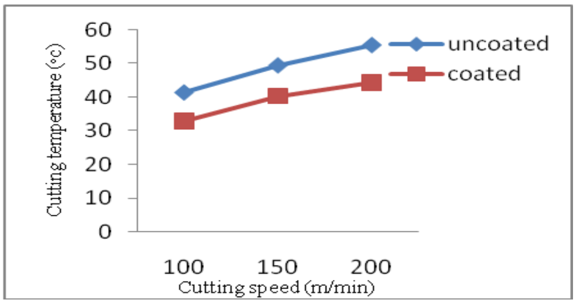


(b)

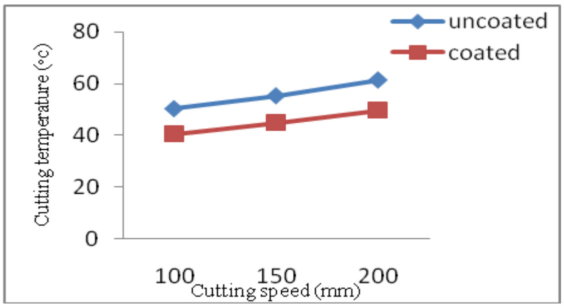
Fig 5 Cutting Speed Vs Surface Roughness (A) D=0.25 (B) D=1.25

From fig 5 (a) and (b) shows the relationship between the surface roughness and cutting speed parameters for TiN coated and uncoated PCBN cutting inserts at different depth of cut conditions. While cutting speed increases corresponding surface roughness of workpiece has been decreases. When compared to the overall performance, the TiN coated PCBN cutting inserts provides higher surface quality while compared to uncoated PCBN cutting inserts. For ex: At cutting speed of 200 m/min, at depth of cut in the range of 0.25, the

TiN coated PCBN cutting insert gives surface roughness of workpiece is 1.570 μm and uncoated PCBN cutting insert gives surface roughness of 2.250 μm.



(a)



(b)

Fig 6 Cutting Speed Vs Cutting Temperature (A) D=0.25 (B) D=1.25

From fig 6 (a) and (b) shows the interrelationship between the cuttings speeds Vs Cutting Temperature at different depth of cut conditions. While cutting speed increases, the corresponding cutting temperature also increases. When comparatively the induced cutting temperature of TiN coated PCBN cutting insert reaches lower level than the uncoated PCBN cutting insert. For ex: At cutting speed of 200m/min, at depth of cut in the range of 1.25mm the cutting temperature of TiN PCBN insert reaches 49.5˚c and uncoated PCBN insert reaches 61.5˚c, because of TiN coated PCBN cutting tool is having better hot hardness than uncoated PCBN cutting tool material.

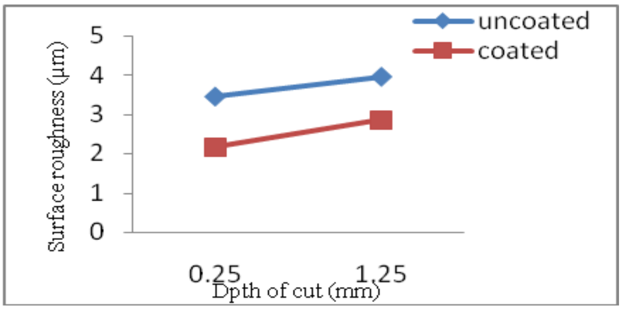
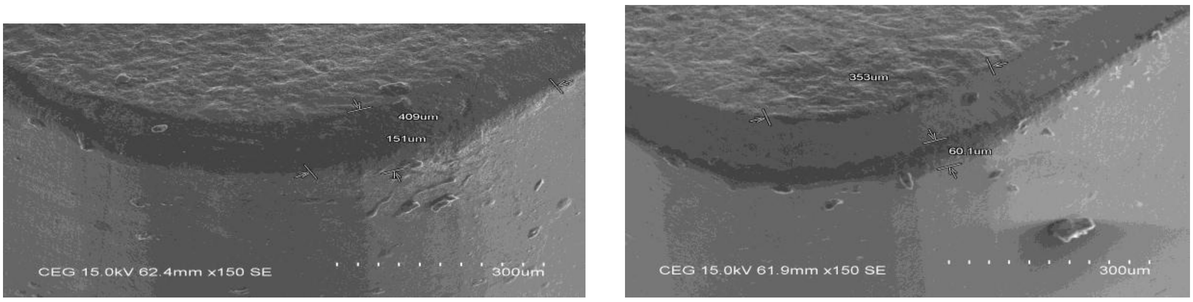


Fig. 7 Depth of cut vs surface roughness (v$_c$=100m/min)

From Fig 7 indicates that relation between depth of cut and surface roughness. While depth of cut increases, the surface roughness of workpiece value also increases. When comparatively the TiN coated PCBN cutting insert gives lowest surface roughness of workpiece than uncoated PCBN cutting insert. For ex: At depth of cut 1.25mm, the TiN coated PCBN cutting insert gives 2.98µm and uncoated PCBN cutting insert gives 3.98µm, because of TiN coated PCBN cutting insert provide better surface quality than uncoated PCBN cutting insert.The combination of machining parameters that offer the desired surface roughness is lower value of feed, depth of cut and increasing cutting speed and also reducing cutting speed is induced lower cutting temperature. Higher cutting speed reduces the length of contact between the tool and the chip, which in turn, reduces the friction in the machining interface. This leads to the reduction in fiber fracture and fiber pulling outside the surface resulting in reduced surface roughness.

3.2 Wear characterization

The tool wear is the one of the very important issues in machining processes; it directly affects the tool life, surface quality and also production cost. Tool wear in the machining of CFRP composite materials occurs due to the rubbing of the cutting tool edge with the hard fiber impregnated in the matrix materials. When machining of CFRP composite material, flank wear is the mainly form of wear. Figure 8 is SEM image collection of tool edge sharpness for both TiN coated and uncoated PCBN cutting tool after cutting 600mm of CFRP composite material.



(a) (b)

Fig. 8 SEM images of uncoated and TiN coated PCBN cutting tool edge. (a) Cutting edge of uncoated PCBN cutting tool after cutting 600mm of CFRP; (b) Cutting edge of TiN coated PCBN cutting tool after cutting 600mm of CFRP.

IV. CONCLUSION

This experimental work illustrates the understanding on machining carbon fiber reinforced polymer composites, the behaviour of its surface roughness and tool wear characterization.

Also this investigation achieves an understanding of the parameters of machinability and leads to the following conclusions;

[1] TiN coated PCBN cutting tool presents smaller values of surface roughness than uncoated PCBN cutting tool.
[2] TiN coated PCBN cutting tool presents smaller level of cutting temperature than PCBN cutting tool.
[3] Wear rate for TiN coated PCBN tool is less than uncoated PCBN tool.

Therefore TiN coated PCBN cutting tool gave the best overall performance than uncoated PCBN cutting tool.

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