Machinability Studies of K20 Carbide and PCD insert on turning GFRP composites

Joel Morris*, S.Karthik, Alluru Prasanna Reddy, and Mavillapalli Manideep

Abstract—In recent years, composite materials are finding increased applications in many engineering applications, and subsequently, the need for accurate machining of composite has increased enormously. Knowledge acquired in machining of ductile materials is not suitable for composites. In the present study, Glass Fiber Reinforced Plastics (GFRP) is machined in medium duty lathe of 2kW spindle power with K20 carbide and Poly crystalline Diamond (PCD) inserts. Various parameters are measured such as Surface finish and Power consumed by main spindle and compares the value with one another. Result provides some useful information. Machining with PCD gives good surface finish at higher cutting speeds while machining with K20 gives good surface finish at lower cutting speeds. Tool wear is approximately 80 % more in K 20 carbide than PCD insert.

Keywords— GFRP, Turning, k20 carbide, PCD, power consumed, surface finish, tool wear.

I. Introduction

COMPOSITE materials are continuously displacing traditional engineering materials because of their high specific stiffness, high specific strength, high damping and low coefficient of thermal expansion. The Glass Fiber Reinforced Plastic (GFRP) composites are extensively used in many applications such as power plants, waste water, etc.These GFRP application fields need the machining opportunity like drilling, milling, cutting off, etc which has increased for its development. However the industries faced difficulties to machine these composites, because knowledge and experiences acquired for conventional materials cannot be applied for composites. Machinability of these composites completely different from that of conventional materials [1] for the past 25 years, outcome of the machining of GFRP composites has been reviewed. The researchers [2] investigated the machining of fiber reinforced plastics using various machining process like drilling, routing and laser cutting was found that machining of GFRP is different from conventional materials in many aspects. They reported that, the material behavior is not only inhomogeneous, but also dependent on fiber and matrix properties, and type of weave. Some researchers [3] studied the theoretical work on chip formation, cutting force and surface quality in orthogonal cutting with varied fiber angles. Some others [4] studied the tool wear, surface finish and mechanism of metal removal. Only limited amount of literature exists on machining of GFRP composites. Most of the studies on GFRP machining shows that minimizing the tool wear and surface roughness was very difficult and is to be controlled. In this aspect a detailed study is carried on machining GFRP composites on medium duty lathe with Poly Crystalline Diamond (PCD) and K20 uncoated carbide insert.

II. Experimental Procedure

Machining tests were conducted with different cutting conditions on the composites. Samples were obtained from local market in the form of cylindrical rods of 65 mm diameter and 150 mm length. The material specification fiber, resin and mechanical properties of composites used in this work are given in Table 1 and 2. The tool holder used was PCLNR 25 25 M 12. The PCD insert was of geometry CNMA 120408, and K20 insert was of geometry CNMG 120408 which is the commonly used inserts geometry for general turning application. The tool material was PCD 1500 medium grade and K20 carbide was uncoated. Medium duty lathe of 2 kW spindle power was used for the turning tests. The machining of the composite was performed at three different cutting speeds of 40,80 & 120 m/min. Generally, GFRP machining with PCD inserts was observed to be more productive at higher cutting speeds. The cutting speeds were so chosen to reach the maximum cutting speed possible, for the given workpiece size. The feed rates were 0.108, 0.200 and 0.32 mm/rev. The depths of cuts used for machining were 0.5, 1.0 and 1.5mm. All the tests were carried out for one minute duration under dry machining conditions. The machining was interrupted at various time intervals and the surface roughness of the workpiece material was measured. One of the important characteristics indicating the machinability is the power consumed in machining. The power consumed by the main spindle is measured using digital wattmeter (make-Nippon Electrical Inst.Co, Model 96x96–dw 34 Sr.No:070521485 CTR 5A/415 V AC F.S 4 KW).The surface roughness of the machined component was measured using a Mitutoyo surf test (Make-Japan –Model SJ-301) measuring instrument with the cut off length 2.5 mm.The Ra value of the surface roughness corresponding to each machining condition was measured. The worn insert tip was observed under the Mitutoyo TM 500 Toolmaker's microscope and the flank wear land was measured. Worn tool images were captured by Scanning Electron Microscope (SEM) which is also presented. GFRP composites were machined with these combinations and best

Joel Morris*, S.Karthik, Alluru Prasanna Reddy, and Mavillapalli Manideep are Under Graduate students, Department of Mechanical Engineering, Sri Venkateswara college of Engineering, Pennalur, Sriperumbudur -602 105Tamilnadu, India.

*E-mail Id: karthiksridharan1792@yahoo.co.in

parameters were analyzed with the help of Power consumed and surface roughness. Now by setting these best parameters, tool wear study was conducted for duration of 30 minutes.

TABLE I
SPECIFICATION OF FIBER AND RESIN

Fiber: E Glass –RO99 2400 P556	Resin: Epoxy
R099 –Multi filament roving	Product :Araldite LY 556
2400 – Linear Density (Tex)	Bisphenol – A epoxy resin
P556 – Sizing reference for vertex	Hardener : HT 972 (Aromatic amine hardener)

TABLE II
MECHANICAL PROPERTIES OF COMPOSITE MATERIAL
(FIBER VOLUME RATIO = 0.55)

Tensile Strength	138 MPa
Tensile Modulus	49 Gpa
Shear modulus	5.7 Gpa
Poisson's ratio	0.32
'Mass Density	1886 kg/m^2

III. EXPERIMENTAL RESULTS AND DISCUSSION

A. *Effect of cutting speed on Power consumed*

Figs 1 and 2 show the effect of cutting speed on power consumed by main spindle at the feed rate of 0.108 and 0.32 mm/rev. It is clearly observed that power consumed by main spindle is increased as cutting speed increases.

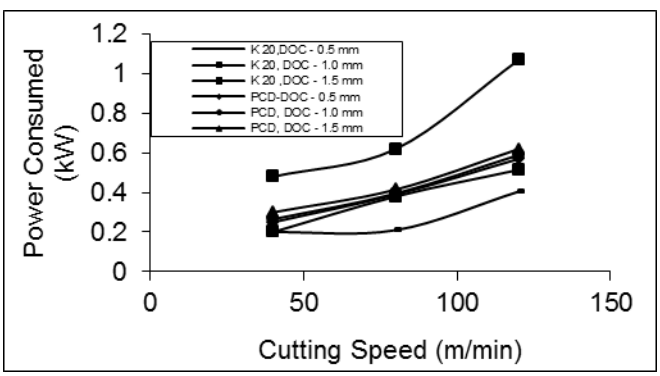


Fig. 1 Cutting Speed versus Power consumed (feed 0.108mm/rev)

This increase happens due to machining of the GFRP by both the cutting inserts irrespective of depth of cut and feed rate. Similar trend is observed in other conditions also. This increase in power is, believed to be high power is required, to chip the metal at higher cutting speeds. The power consumed is approximately 20 % higher for K 20 inserts compared to PCD with feed rate of 0.2 mm/rev.

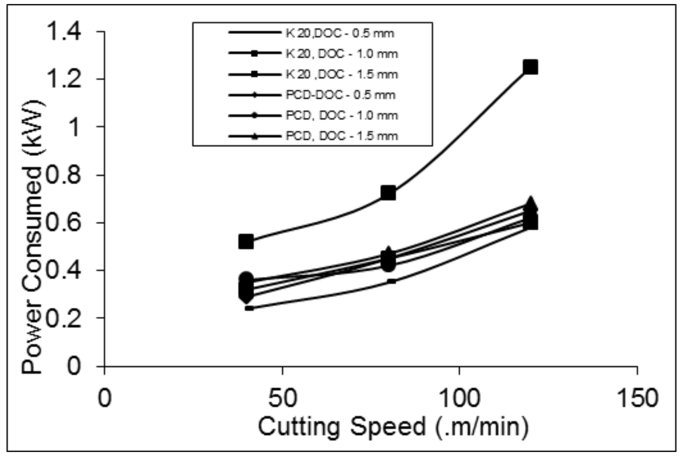


Fig. 2 Cutting Speed versus Power consumed (feed 0.32mm/rev)

IV. EFFECT OF DEPTH OF CUT ON POWER CONSUMED

Figs 3 and 4 show the effect of Depth of cut on power consumed at maximum and minimum cutting speed. In higher cutting speed, power consumed increases as depth of cut is increased for both the inserts. But in the case of power consumed in higher cutting speed power consumed is found minimum at 0.5 mm depth of cut for both the inserts.

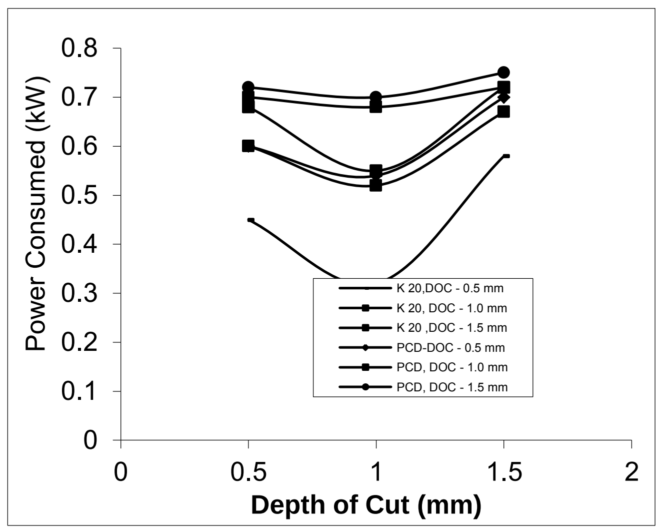


Fig. 3 Depth of Cut versus Power consumed (Cutting Speed 120 m/min)

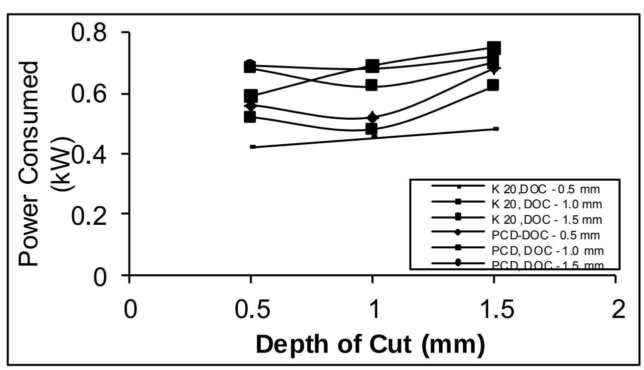


Fig. 4 Depth of Cut versus Power consumed (Cutting Speed 40 m/min)

http://dx.doi.org/10.15242/IIE.E1213517

V. EFFECT OF FEED RATE ON POWER CONSUMED

Figs -5 and 6 show the effect of feed on power consumed at lower depth of cut and higher depth of cut for both the K20 and PCD inserts. It is observed that in both the cases when feed increases power consumed also increases. It is the fact that power required to remove the material from the parent material is high. This increase is observed in both the inserts. On machining GFRP, in 1.5 mm depth of cut power consumed is 25% more than at machining the composite with 0.5 mm depth of cut.

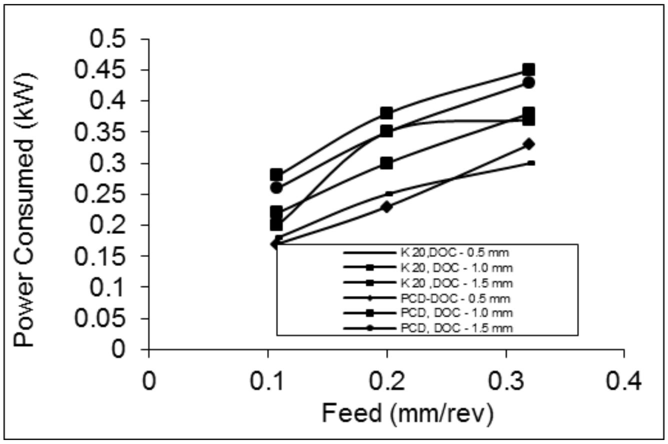


Fig. 5 Feed versus Power consumed (Depth of cut 0.5)

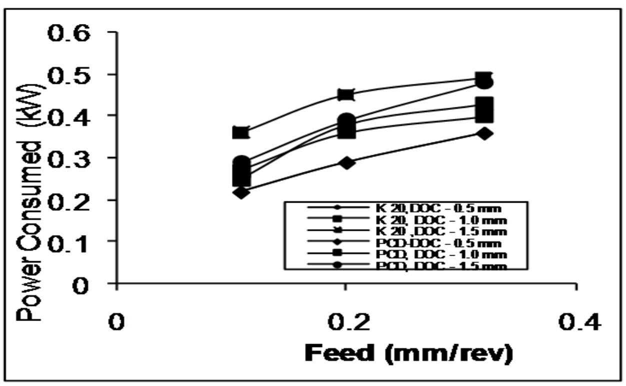


Fig. 6 Feed versus Power consumed (Depth of cut 1.5 mm)

VI. EFFECT OF CUTTING SPEED ON SURFACE ROUGHNESS

From Figs 7 and 8, it is observed that surface finish is good at lower cutting speed with less feed rate and medium depth of cut (1.0 mm) gives better surface finish. Fig 7 shows the effect of cutting speed on surface roughness at feed 0.108 and 0.32 mm/rev. similar trend exists in the other feed rate of 0.2 mm/rev. It is clearly understood that cutting speed increases surface roughness also increases. It is evident that feed rate is the factor which has great influence on surface roughness followed by cutting speed [5, 6]But in the case of machining GFRP with PCD insert we obtain good surface finish at higher cutting speeds. From this discussion we conclude that K20 insert is good at lower cutting speed (40 m/min) with less feed. rate (0.108 mm/rev) and medium depth of cut (1.0 mm), while machining with PCD insert it is observed that higher cutting speed (120m/min) with lower feed rate (0.108 mm/rev) and medium depth of cut (1.0 mm). Hence the optimum parameters are found as above.

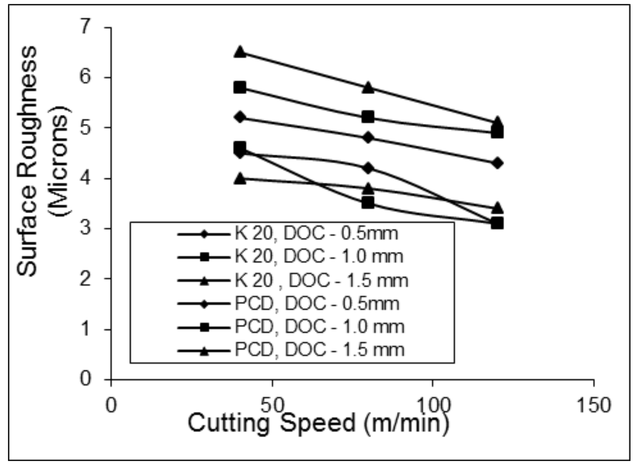


Fig. 7 Cutting Speed versus Surface Roughness (feed 0.108mm/rev)

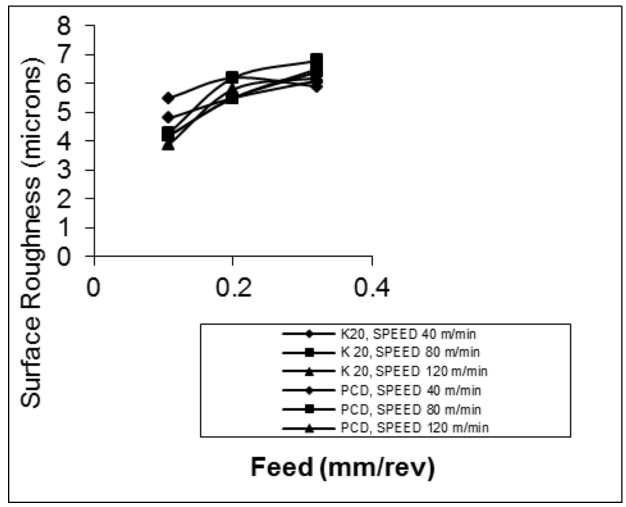


Fig. 8 Cutting Speed versus Surface roughness (feed 0.32 mm / rev)

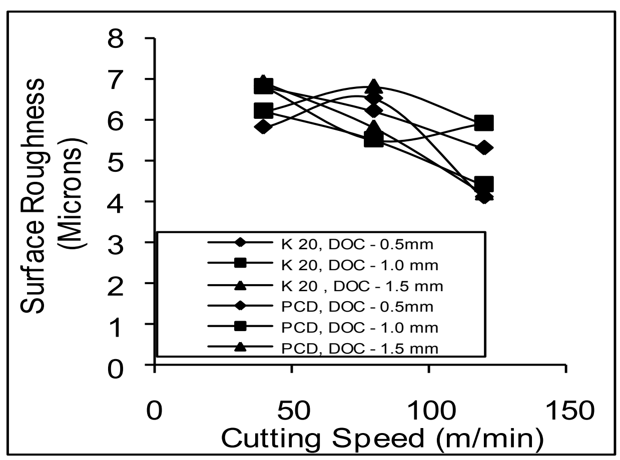


Fig. 9 Feed versus Surface roughness (Depth of cut 0.5 mm)

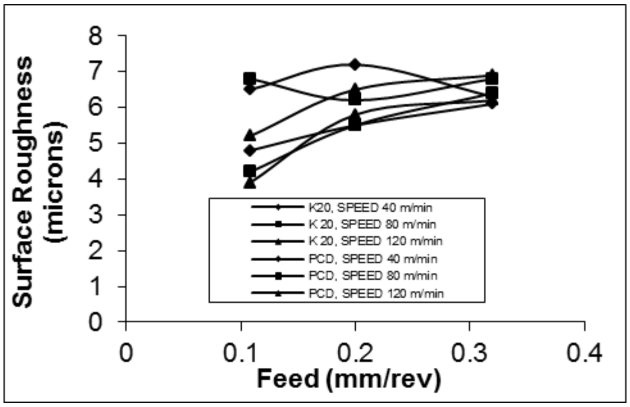
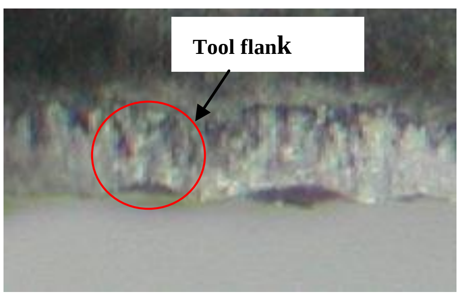


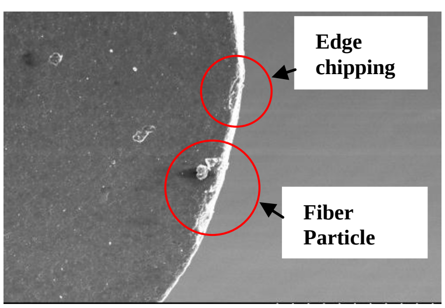
Fig. 10 Feed versus Surface roughness (Depth of cut 1.5 mm)

VII. Tool wear

Figs 11a and 11 b show the Scanning Electron Microscopic images of tool wear on K20 and PCD respectively. Fig 11 (a) shows the flank surface of the K20 insert. Flank wear was observed on the flank side. However, Built up edge was formed on the surface along with some micro chipping of the tool was noticed. Flank wear was caused by the abrasive nature of glass fiber in the work piece [9]. Crater wear was not observed. Built–up edge formed on the surface of the tool is probably a mixture of resin with small fibers [9]



K 20 insert (Fig- 11 a)



(Fig. 11 b) PCD insert

Fig. 11 SEM image of Tool wear of K 20, and PCD insert

Fig 11b shows the SEM images of PCD insert after machining the GFRP for 30 minutes duration. No substantial crater wear was observed. However, built-up edge formation was noticed. During machining of GFRP composites, tool continuously encounters alternate matrix and fiber materials, whose response to machining can vary greatly. Normally in machining of GFRP tool encounters a low temperature soft epoxy matrix and brittle glass fibers [10].Edge chipping was noticed along with some fiber particles stick over the top rake surface of the insert. It is clearly understood that machining of GFRP is associated with plastic deformation [4].

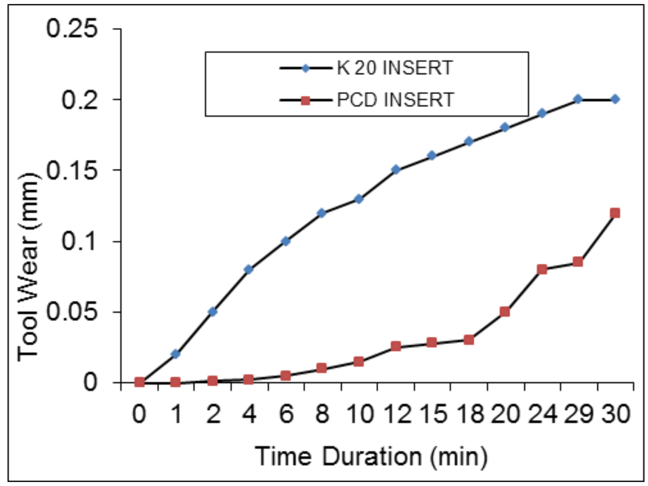


Fig. 12 Time duration versus tool flank wear (Cutting speed 120 m/min, DOC-0.5 mm, feed -0.108 mm/rev)

Fig 12 shows the flank wear of K20 and PCD insert after machining the GFRP composite continuously for 30 minute duration (Cutting speed 120 m/min, feed rate 0.108 mm/rev and depth of cut 0.5mm). It is clearly observed that flank wear is more in K20 compared to PCD. It is observed that flank wear of K 20 is nearly 100% more than that of PCD. This is because of the hard reinforcement of fibers and its constituents. More over k20 is not suitable for high speed machining. It is good for low cutting speed of GFRP. Figure 13 shows the machined component.

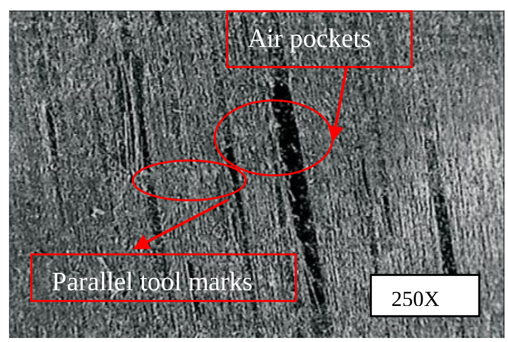


Fig. 13 Machined component

VIII. Conclusion

From the results discussed above, the following conclusions are arrived

1. Optimum machining parameters are found to be 120 m/min, feed rate of 0.108 mm/rev and depth of cut 0.5 mm for PCD insert where as cutting speed is 40 m/min for k20 insert. Other factors feed rate and depth of cut are same as that of PCD.
2. Machining of glass fiber composite is associated with plastic deformation.
3. Feed rate is the factor, which has great influence on surface roughness followed by cutting speed.
4. Power consumed is approximately 20 % more at higher cutting speeds.

5. Good surface finish is obtained at higher cutting speeds when machining with PCD, at the same time good surface is obtained at lower cutting speed for K20 insert.
6. Main tool wear is believed to be abrasion in the flank portion of both the insert. However tool wear of K 20 carbide is approximately 80 % higher than PCD
7. Most influential parameter in tool wear is cutting speed followed by depth of cut

REFERENCES

[1] Takeyam.H and Ikutoku (1998), Machinability of Glass fiber reinforced Plastics And Application of Ultra Machining, Annals of the CIRP 37/1, 93-96

[2] Konig W, Wulf.Ch, Grab P. and Willerscheid H, (1985) Machining of fiber Reinforced Plastics, Annals of CIRP, 34, 537-548.

[3] Evestine G.C And T.G.Rogers (1971), Theory of Machining of Fiber Reinforced Materials, J. Composite Mterials, 5, 94-106. http://dx.doi.org/10.1177/002199837100500109

[4] Santhanakrishnan G, Krishnamurthy R, and Malhotra.S.K (1988) Machinability Characteristics of Fiber Reinforced Plastics Composites, Journal of Mechanical WORKING Technology. 17, 195-204. http://dx.doi.org/10.1016/0378-3804(88)90021-6

[5] K.Palanikumar and L.Karunamoorthy (2004) Modeling the surface roughness and tool wear for turning of GFRP composites using design of experiments, Journal of Manufacturing Technology Today, issue 2, 3-8.

[6] K.Palanikumar, L.Karunamoorthy and R.Kartikeyan, Optimizing the machining parameters of minimum surface roughness in turning of GFRP composites using design of experiments. J.Mater.Sci.Technol, Vol 20 No.4, 2001.

[7] H.Takeyama and Ikutoku, Annals of the CIRP 1989, 37/1

[8] N.Bhatnagar, et al. Int .J.Mach.Tools manufact.1995. 35 (5), 701. http://dx.doi.org/10.1016/0890-6955(95)93039-9

[9] K.Palanikumar, L.Karunamoorthy and R.Kartikeyan, Optimal Machining Parameters for achieving Minimal Tool Wear in turning of GFRP Composites, The International Journal for Manufacturing science and production, Vol.6 No.3, 2004.

[10] Ranga Komanduri, 'Machining Fiber Reinforced Composites' Mechanical Engineering , April Issue (1993) pp 58-64.