

Study and analysis of PCD 1500 and 1600 Grade inserts on turning Al 6061 alloy with 15% reinforcement of SiC particles on MMC

Nikhlesh.A.Malli ⁺, V.Aaditya and R.Raghavan

Department of Mechanical Engineering, Sri Venkateswara college of Engineering, Pennalur,
Sriperumbudur – 602 105, Tamil Nadu, India

Abstract: Aluminum silicon carbide Metal Matrix Composites (Al-MMC) are widely used in aeronautical and automobile industries due to their excellent mechanical and physical properties. However machining this composites find difficult because of the harder reinforcement particles. Tools wear more quickly and reduce the life of the tool. This paper presents the experimental investigation on turning Al 6061 matrix metal reinforced with 15 % by weight of Silicon carbide (SiC_p) particles, fabricated in house by stir casting method. Fabricated samples are turned on medium duty lathe of 2kW spindle power with Poly crystalline Diamond (PCD) inserts of 1500 and 1600 grade at various cutting conditions. Parameters such as power consumed by main spindle, machined surface roughness and tool wear are studied. Scanning Electron Microscope (SEM) images support the result. It is evident that, surface finish, and power consumed are good for 1600 grade compared with 1500 grade at higher cutting speed and tool wear is strongly dependent on abrasive hard reinforcement particles.

Key words: Al 6061 Alloy, PCD, Power consumed, Surface roughness, Tool wear

1. Introduction

Metallic matrix composites have found considerable applications in aerospace, automotive and electronic industries (Tomac et al.,1992) because of their improved strength, stiffness and increased wear resistance over unreinforced alloys (Weinert, 1993). However, the final conversion of these composites in to engineering products is always associated with machining, either by turning or by milling. A continuing problem with MMCs is that they are difficult to machine, due to the hardness and abrasive nature of the reinforcing particles (Weinert, 1993). The particles used in the MMCs are harder than most of the cutting tool materials. Most of the researchers reported that diamond is the most preferred tool material for machining MMCs (Lane, 1992, Manna et al., 2000 N.Muthu Krishnan et al.,2008,2009 Paulo davim et al.,2000 Pramanik et al 2006) Most of the research on machining MMCs is concentrated mainly on the study of cutting tool wear and wear mechanism (Tomac et al., 1992, Weinert, 1993). (Heat, 1991) investigated the performance of polycrystalline diamond in machining MMCs which containing aluminum oxide fiber reinforcement. They compared the tool life of cemented carbide with PCD and concluded that sub-surface damage is greater with cemented carbide than that of PCD tools.

Lane (1992) studied the performance of different PCD tools grain size. He reported that, PCD tools with a grain size of 25µm are better withstand of abrasion wear than tools with grain size 10 µm. He also reported that further increases in the grain size do not have any influence on the tool life but it cause significant deterioration in the surface roughness.

The works carried out by (Andrews et al., 2005) characterize the wear mechanisms of PCD and CVD diamond tools in the machining MMCs. The conclusions can be applied to the design of better diamond tools and optimization of machining process. In the view of above machining problems, the main objective of the present work is to investigate the influence of cutting parameters on surface finish and power

⁺ Corresponding author.
E-mail address: aaditya.gem@gmail.com

consumption. The results are analyzed to determine the best machining parameter. Tool flank wear was studied by using the best parameter for time duration of 60 minutes and also to study the tool wear pattern.

2. Experimental Procedure

Fabricated cylindrical bars having 15 % of SiC particles on matrix of Al 6061, using stir casting method of diameter 65 mm and 200 mm long are turned on self centered three jaw chuck, medium duty lathe of spindle power 2 KW. Fig -1 shows the microstructure of 15 % SiC particles reinforced workpiece. Table -1 shows the chemical composition of the work piece for experimentation. Table -2 shows the physical and mechanical properties of Al-SiC 15p-MMC. Parameters such as power consumed by main spindle was 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 machined surface was measured at three different positions and the average surface roughness (R_a) value was taken using a Mitutoyo surf test (Make-Japan –Model SJ-301) measuring instrument with the cutoff length 2.5 mm.

According to Taguchi method, three machining parameters are considered as controlling factors (cutting speed, feed rate and depth of cut) and each parameter has three levels. Table -3 shows the machining parameters and tool insert specification.

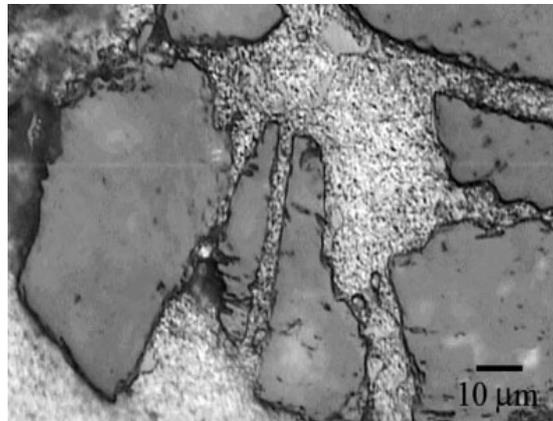


Fig-1 Microstructure of Al 6061 reinforced with 15% SiC

Table1. Chemical composition of Al 6061-SiC(15p)-MMC

Type of MMC	Reinforcement	%Si C	%Si	%Mg	%Fe	%Cu	%Mn	%Zn	%Ti	%Al
Particulate MMC	Sic -45 μm	15.00	0.77	0.9	0.8	0.18	0.15	0.25	0.10	Balance

Table2: Physical and Mechanical properties of Al 6061-SiC –MMC

Material	Density (gms/cm ³)	Tensile Strength (Mpa)	Hardness (BHN)	Yield strength Mpa	%of Elongation
Al 6061 15 SiC _p	2.65	300	100	75	26-30

Table3. Machining parameter

Cutting Speed	50,100, and 150 m/min
Feed Rate	0.1,0.2, and 0.3 mm/rev
Depth of Cut	0.5, 1.0 and 1.25 mm
Tool holder	PCLNR 25*25 M 12
Tool Insert	CNMA 120408 (1500 & 1600 Grade)

3. Results and Discussions

3.1. Power Consumed

Figs 2 and 3 show the plot between cutting speed and power consumed for depth of cut 0.5 mm and 1.0 mm respectively. It was observed that power consumed increases as cutting speed increased for all combinations of machining conditions. Power consumed was more at higher cutting speed and it decreases at the lower cutting speed. It was observed that more power was required to pull the particles rather than cutting it (Lane, 1992). Power consumed was more generally with the reinforcing particles were more. At higher cutting speeds removal of hard silicon particles from aluminum matrix becomes easier (Muthu Krishnan. et al, 2008). It was also observed that, in fig- 2, when feed rate of 0.3 mm/rev, machining with PCD 1500 grade insert is more than machining the material with same feed rate which showed more power at lower cutting speed than the feed rate of 0.3 at 0.5 mm depth of cut. This trend was changed when machining the workpiece at 1.0 mm depth of cut; power consumed was more at lower cutting speed for feed rate 0.3 mm/rev compared to 0.2 mm/rev. This is true at higher depth of cut power required is high irrespective of feed rate. At 0.5 mm depth of cut, power consumed was lesser at higher cutting speed at 0.3 mm feed rate compared to other feed rates. When machining the workpiece at 1.0 mm depth of cut, Power consumed was approximately double the times greater than machining the workpiece at 0.5 mm depth of cut.

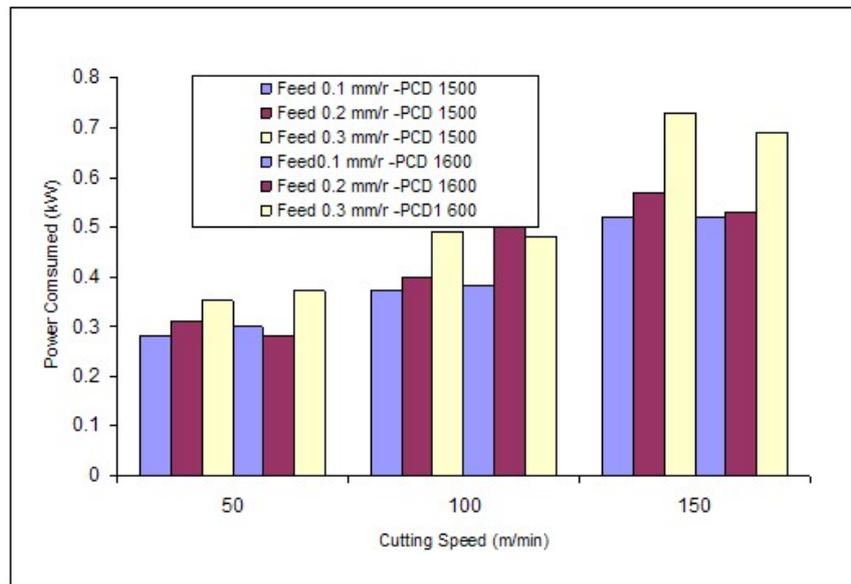


Fig 2 Cutting speed Versus Power consumed (Depth of cut 0.50 mm)

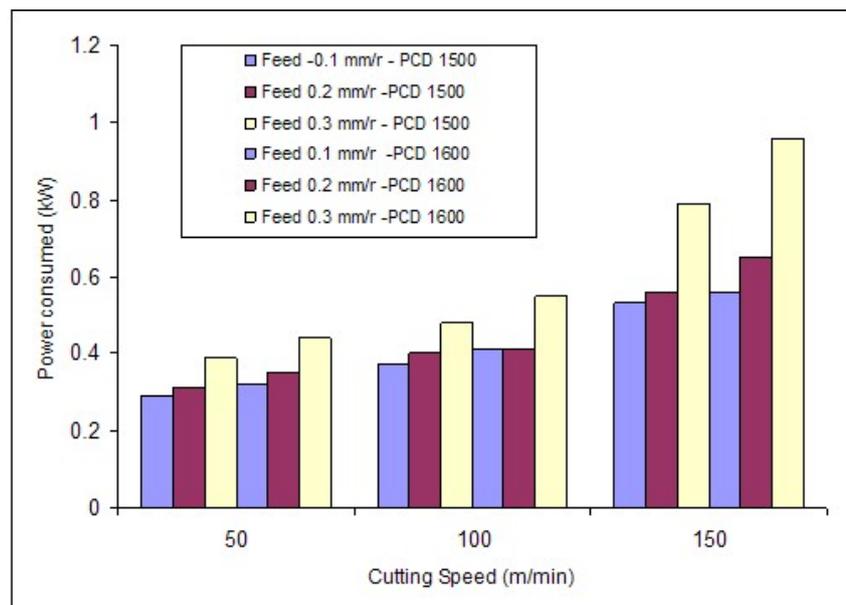


Fig 3 Cutting speed Versus Power consumed (Depth of cut 1.0 mm)

3.2. Surface Roughness

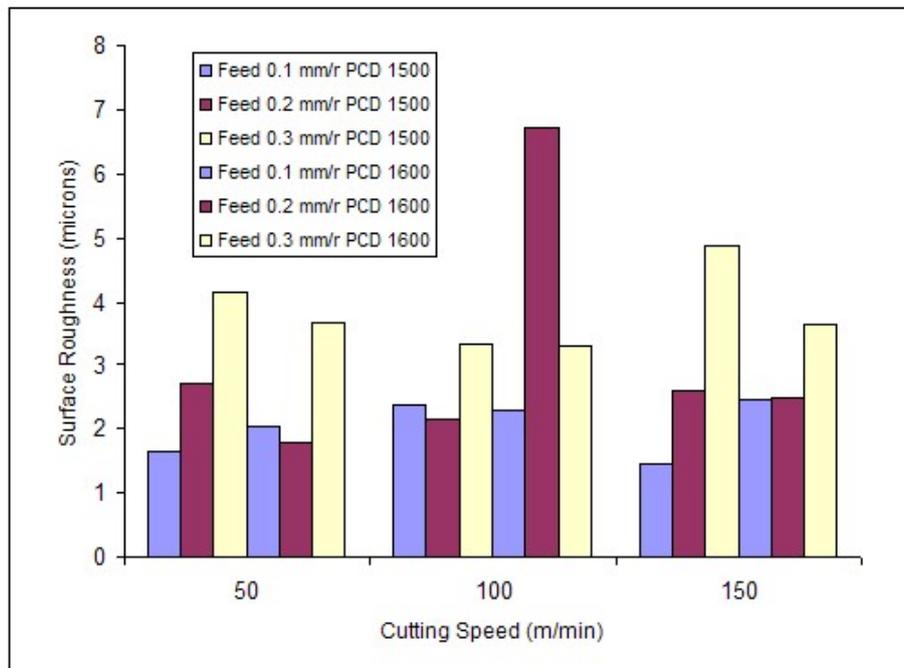


Fig4.Cutting speed Versus Surface Roughness (DOC=0.5mm)

The turning operation was performed at feed rates 0.1, 0.2 and 0.3 mm/rev with depth of cut 0.5, 1.0 and 1.25 mm respectively. The influence of surface finish on cutting speed is represented in fig 4 and 5. The figures show the relation ship pertaining to depth of cut 0.5 mm and 1.0 mm respectively for machining the samples. General trend of the graphs show that average surface roughness value Ra decreasing as the cutting speed increases. Similar trend exist for other depth of cut also. In both the figures machining with low feed rates show good surface finish irrespective of depth of cut. It is believed that, depth of cut has less influence on surface roughness. Machining with depth of cut 0.5 mm, and feed 0.1 mm/rev show better surface roughness at higher cutting speed. This is due to the fact at higher cutting speed removal of hard silicon particles from the matrix become easier (Manna et. Al, 2003)

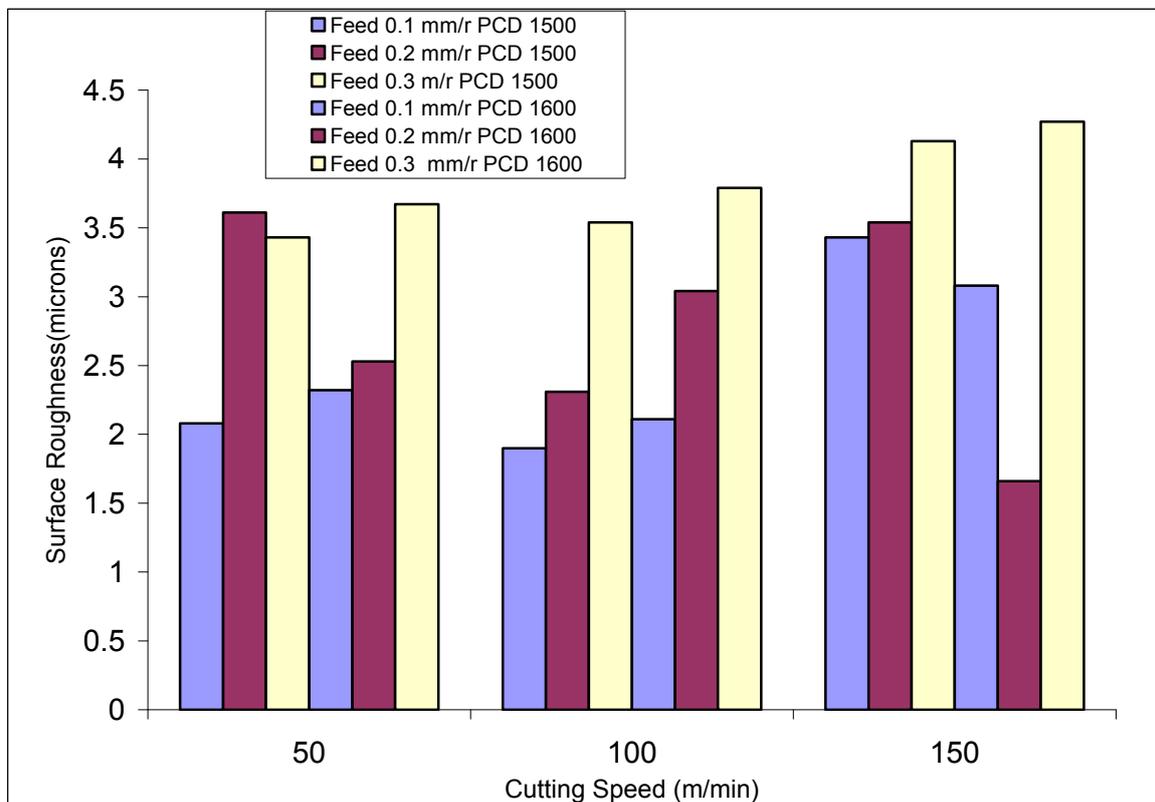
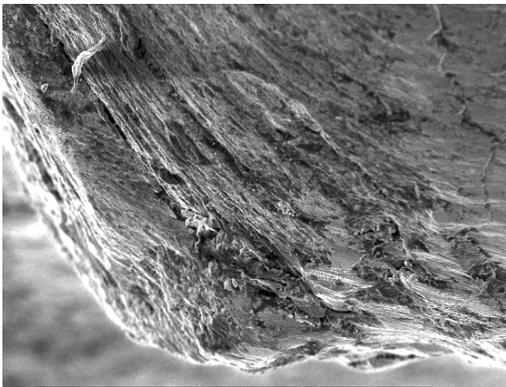
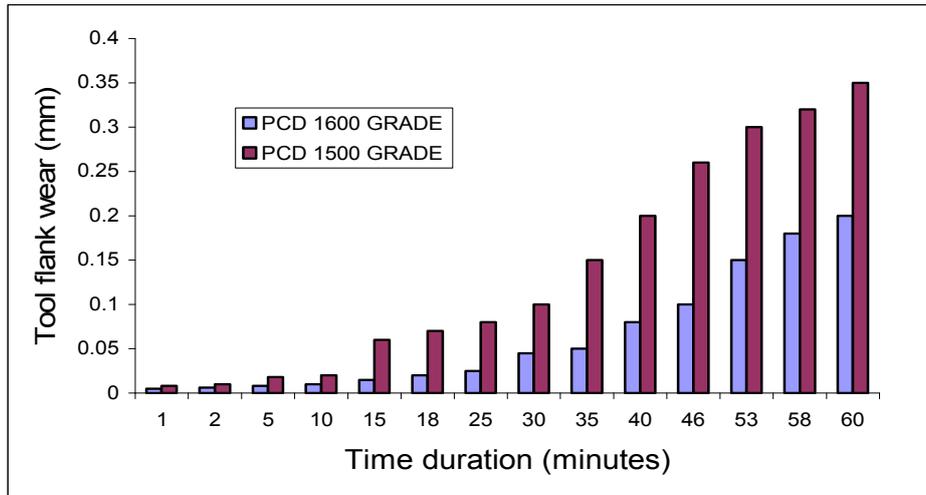


Fig 5.Cutting speed Versus Surface Roughness (DOC= 1.0mm)

3.3. Tool Wear

From the above observations best machining parameter was determined as cutting speed 150 m/min, feed rate 0.1 mm/rev and depth of cut 0.5 mm.



Tool wear of PCD 1500



Tool wear of PCD 1600

Now setting this cutting condition as a constant parameter and machined the samples for a time duration of 60 minutes and the tool flank wear study was carried out. Tool was monitored for normal types of wear namely flank wear, crater wear and nose wear using a tool maker's microscope. Tool flank wear was caused by abrasive nature of the hard particles presented in the work piece. At low cutting speed worn flank encourages the adhesion of work piece material on the tool insert and formed Built-Up-Edge (Andrews et al, 2005). It is evident that on the flank face of the tool, vertical grooves are visible. It is proved that hard silicon particles which have higher hardness than diamond abrading the cutting tool. It is observed that the tool life of PCD 1600 grade is near about 80- 90% of life more than that of 1500 grade. Both the grades can be used for finish machining.

4. Conclusions

1. Power consumed is less at lower cutting speeds because of less friction between tool and workpiece interface. Power consumed is less for 1500 grade compared to 1600 grade. Power consumed is 25 % more in PCD 1600 grade compared with PCD 1500 for the same machining condition.
2. Primary wear mechanism is believed to be abrasion for both the grades of PCD between reinforcing particles and cutting tool material
3. Tool wear is more in flank portion of the PCD. Wear is more at 1500 grade. In other words the life of PCD 1600 grade is 80-90% lesser than 1500 grade.

4. Surface finish improves at higher cutting speeds. Surface finish is good for 1600 grade compared to 1500 grade
5. Tool wear strongly depends on cutting speed followed by depth of cut.
6. Surface roughness strongly depends on feed rate. If feed rate is more surface roughness is also more. It is applicable to both the grades
7. It is concluded that PCD 1500 and PCD 1600 grades are preferred for fine finishing.

5. References

- [1] Andrewes C, Feng H, and Lau W (2005), "Machining of an aluminum/SiC composite using diamond inserts", *J.Mater. Process. Techno*, Vol. 102, pp. 25-29.
- [2] Caroline J.E, Andrews, His-yung Feng, and Lau W.M (2000), "Machining of an aluminum - SiC composite using diamond inserts", *Journal of Materials Processing Technology*, Vol. 102, pp. 25-29.
- [3] Lane G, (1992), "The effect of different reinforcement on PCD tool life for aluminium composites", *Proceedings of the Machining of Composites Materials Symposium, ASM Materials Week, Chicago, IL*, pp. 3-15.
- [4] Manna A and Bhattacharyya B (2003), "Study on Different Tooling Systems during Turning for Effective Machining of Al-SiC MMC", *Journal of Production Engineering Institution of Engineers*, Vol. 83, pp. 46-50.
- [5] Muthukrishnan N and Paulo Davim J (2009), "Optimization of machining parameters of Al-SiC –MMC with ANOVA and ANN analysis", *J. Mater. Process Techno*, Vol. 209. pp. 225-232.
- [6] Muthukrishnan N, Murugan.M, and Prahlada Rao K (2008), "Machinability issues in turning of Al-SiC (10p) metal matrix composites", *Int J Adv Manuf. Technol*, Vol. 38. pp. 21- 218.
- [7] Paulo Davim. J, and Montiro Baptista A (2000), "Relationship between cutting force and PCD cutting tool wear in machining silicon carbide reinforced aluminum", *J. Mater. Process Technol*, Vol. 103, pp. 417-423.
- [8] Pramanik A , Zhang LC and Arsecularatne JA (2006), "Prediction of cutting forces in machining of metal matrix composites", *International Journal of Machine Tools & Manufacture*, Vol. 46 pp. 1795 – 1803.
- [9] Tomac N and Tonnessen K (1992), "Machinability of particulate Aluminum Metal Matrix Composites", *. Annals of the CIRP*, Vol. 41, pp. 55-58.
- [10] Weinert. K (1993), "A consideration of tool wear mechanism when machining metal matrix composites (MMC)", *CIRP Ann*, Vol. 42, pp. 95-98.
- [11] Heat P (1991), "Cutting composites with PCD", *Comp. Manuf.* Vol. 7, pp 1-3.
- [12] G.A. Chadwick G.A and Heat P (1990), "Machining metal matrix composites", *Met. Mater.* Vol. 6, pp 73-76.
- [13] T. Clyne T and Withers P (1995), "An introduction to metal matrix composites", *Camb. Solid State Sci.SER.* pp 1-10.