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Machinability Studies on Turning Al 6061alloy with 10% Reinforcement of B_4C on MMC

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Abstract. Aluminum Boron Carbide Metal Matrix Composites (Al-MMC) have revolutionized aeronautical and automobile industries, in the recent times due to their exceptional mechanical and physical properties. However it is seen that the machinability of these composites is greatly reduced by the hardness of constituent reinforcement particles. Moreover these constituent reinforcement particles serve as disadvantage by increasing tool wear accompanying undesirable depression in life of tool. This paper presents the experimental investigations on turning of Al6061 matrix metal reinforced with 10 % by weight of boron carbide (B_4Cp) particles - which was fabricated using Stir casting method. Fabricated samples are turned on medium duty lathe of 2kW spindle power with Polycrystalline Diamond (PCD) inserts of 1500 grade at various cutting conditions by varying parameters. Hence, parameters such as power consumed by main spindle, machined surface roughness and tool wear are studied and recorded. Furthermore, study results are supported using concurring images obtained from Scanning Electron Microscopy (SEM). It is observed that surface finish and power consumed for 1500 grade insert are comparatively better at higher cutting speeds. Additionally it is observed that tool wear is strongly dependent on abrasive hard reinforcement particles.

1 Introduction

The improved and remarkable properties of metallic matrix composites such as increased strength, stiffness and superior resistance to wear (Weinert, 1993) [1] have made them excellent candidates for commodious applications in the fields of aerospace, automotive and electronic industries. (Tomac et al., 1992) [2]

However, harnessing of these composites into commercially viable engineering products invariably involves machining of some form, turning or milling.

The ease of performing this is greatly hindered by the presence of the reinforcement particles of hard and abrasive nature (Weinert, 1993) [1]. These reinforcement particles used in the MMCs are harder than most cutting tool materials. Several studies and researches have conclusively reported that diamond is the most preferred tool material for machining of MMCs. (Lane, 1992 [3]' Manna et al., 2000 [4] N.Muthu Krishnan et al., 2008 [5], 2009 Paulo davim et al [6]' 2000 Pramanik et al 2006 [7])' Trends also suggest that most of the research on

Machining MMCs is mainly concentrated on aspects of cutting tool wear and wear mechanism (Tomac et al., 1992 [2], Weiner, 1993 [1])' Investigations of the performance of both polycrystalline diamond and cemented carbide in machining MMCs containing aluminum oxide fiber reinforcement have been performed – determining conclusively the superiority of the former in consideration of aspects such as tool wear, sub surface damage and tool life. (Heat, 1991) [8]

Lane (1992) [3] studied the performance of PCD tools of varying grain size and reported that, PCD tools with a grain size of 25µm are better capacitated to withstand abrasion wear than tools of 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 (2005) [9] characterize the wear mechanisms of PCD and CVD diamond tools in the machining of MMCs. The conclusions can be constructively applied to design better diamond tools and to devise an optimized machining process. In view of the above problems, the main objective of the present work is to explore the influence of cutting parameters on surface finish and power consumption in machining process. The results are analyzed to determine the ideal machining parameter for optimal results. Tool flank wear and tool wear pattern were studied on using the ideal parameters for a time duration of 60 minutes.

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2 Experimental procedure

Fabricated cylindrical bars having 10 % of B_4C particles on matrix of Al 6061, using stir casting method. The fabricated workpiece of dimensions: 50 mm diameter and 150 mm length was turned on self-centered three jaw chuck, medium duty lathe of spindle power 2 KW. Fig -1(a) shows the microstructure of 10 % B_4C particles reinforced workpiece. Fig 1(b) shows the stir casting set up. Table -1 shows the chemical composition of the work piece for experimentation. Table -2 shows the physical and mechanical properties of Al-B_4C 10p-MMC.Parameters such as power consumed by main spindle were 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 (Ra) 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 variables. Table -3 shows the machining parameters and tool insert specifications.

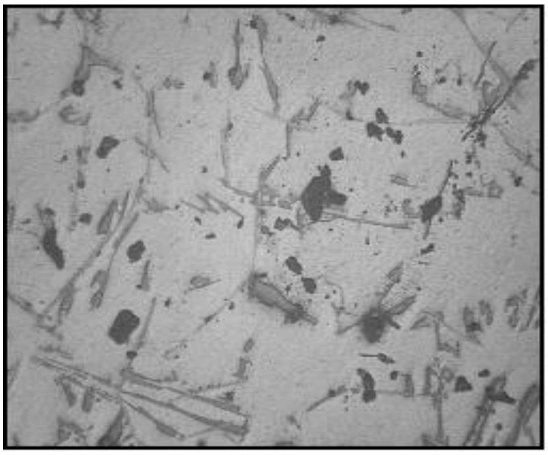

Figure 1. (a) Microstructure of Al 6061

Figure 1.(b) Stir casting set up reinforced with 10% B_4C

Table 1. Chemical composition of Al 6061-B_4C(10p)-MMC

Type of MMC	Particulate MMC
Reinforcement	B_4C-25µm
B_4C	10
%Si	0.8
%Mg	0.9
%Fe	0.8
%Cu	0.18
%Mn	0.15
%Zn	0.25
%Ti	0.1
%Al	Balance

Table 2. Physical and Mechanical properties of Al 6061-B_4C MMC

Material	Al6061-10B_4C_p
Density (gms/cm^3)	2.75
Tensile Strength (MPa)	287
Hardness (BHN)	96
Yield Strength (MPa)	82
%Elongation	20-25

Table 3. Machining parameter

Cutting Speed	30,60 & 90 m/min
Feed Rate	0.1, 0.2, 0.3 mm/rev
Depth of Cut	0.5, 1, 1.5 mm
Tool Holder	PCLNR 25*25 M12
Tool Insert	CNMA 120408 (1500grade)

3 Results and discussions

3.1 Power consumed

Figs 2 and 3 show the plot between cutting speed and power consumed for a given set of feed rates at constant depth of cuts 0.5mm and 1.5 mm. It was observed that power consumed increases as cutting speed increases for all combinations of machining conditions. It has been described that more power was required for pulling the particles rather than cutting them (Lane, 1992) [3]. Power consumed was more generally if the percentage of reinforcing particles were more. At higher cutting speeds removal of hard boron particles from aluminum matrix becomes easier (Muthu Krishnan. et al, 2008) [5].

Analyzing the results of the investigations for the first set of conditions – understanding variations of power consumed at different cutting speeds while machining with PCD 1500 grade insert– for a set of feed rates at the constant depth of cut of 0.5 mm – it is seen that power consumed is higher at lower cutting speed for feed rate of 0.2mm/rev than 0.3 mm/rev ; however conversely – at higher cutting speeds , power consumed for feed rate of 0.3 mm/rev is greater than that of feed rate 0.2 mm/rev . Therefore an irregularly varying trend where power consumed is greater for lower feed rates at lower cutting speeds and conversely lesser for higher feed rates at higher cutting speeds is observed.

However – in the next set of conditions where the variations of power consumed are studied for varying cutting speeds at a given set of feed rates with the constant parameter of depth of cut 1.5 mm – fairly regular trends of increasing power consumption with increasing cutting speeds and increasing feed rates is observed.

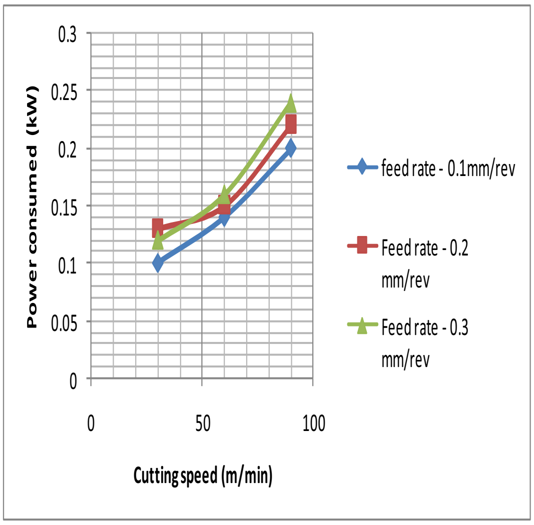

Figure 2. Cutting Speed Versus Power Consumed (Depth of cut 0.50 mm)

It is also noteworthy that the power consumed at feed rate of 0.3 mm/rev is almost double that of 0.1mm/rev for varying cutting speeds. It was concluded that, to decrease the power consumed and to improve the tool life, it is necessary to machine the work piece at lower depth of cut with low feed rate.

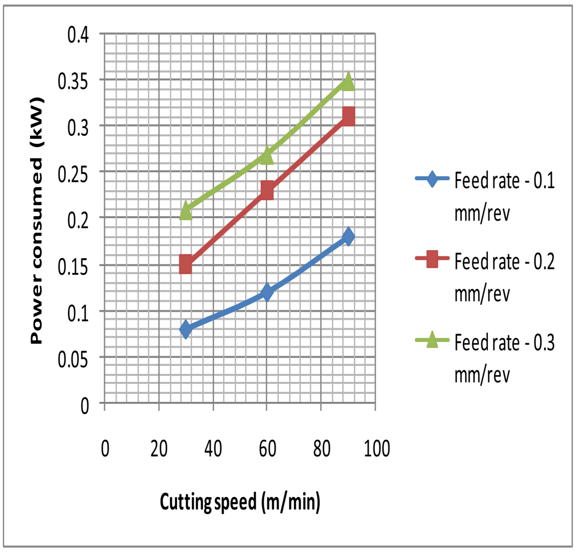

Figure 3. Cutting Speed Versus Power Consumed (Depth of cut 1.5 mm)

3.2 Surface roughness

The turning operation was performed at a given set of feed rates (0.1, 0.2 and 0.3 mm/rev) for constant depth of cuts of 0.5, 1.0 and 1.5 mm each. The variation in surface finish for different cutting speeds – at the given set of feed rates for constant depth of cut is represented in fig 4 and 5. The figures show the relationship pertaining to depth of cut 0.5 mm and 1.5 mm respectively for machining the samples. General trend of the graphs show that average surface roughness value (Ra) decreases 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 boron particles from the matrix become easier (Manna et. Al, 2003) [4]

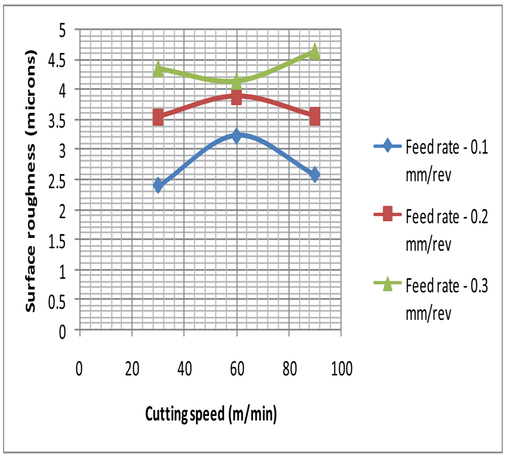

Figure 4. Cutting Speed Versus Surface Roughness (Depth of Cut=0.5mm)

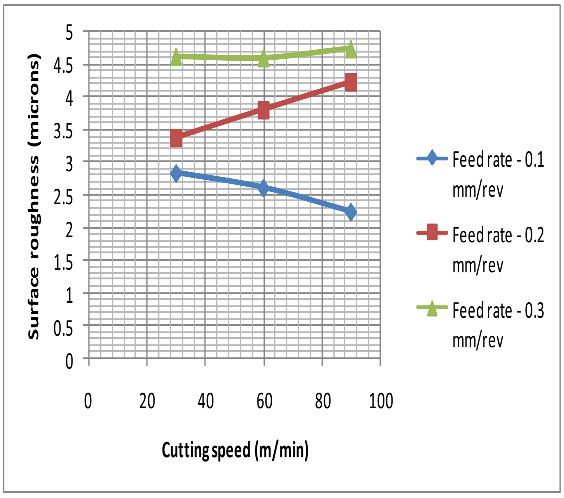

Figure 5. Cutting Speed Versus Surface Roughness (Depth of Cut= 1.5mm)

3.3 Tool wear

From the above observations for machining PCD with 1500 grade insert - in consideration of power consumed as well as surface finish ideal machining parameters were determined as

- Cutting speed 90 m/min
- Feed rate 0.1mm/rev
- Depth of cut 0.5 mm.

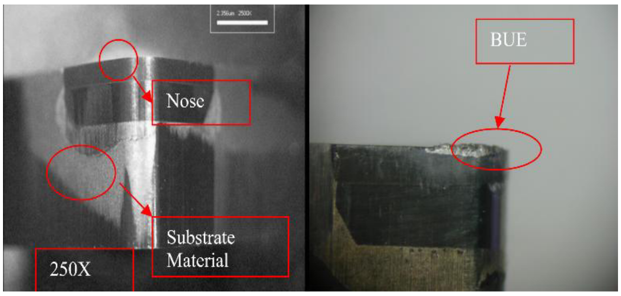

Figure 5.(a) Fresh PCD 1500 insert

Figure 5.(b) Tool wear of PCD 1500

Now setting these cutting condition as constant, machined the samples for a time duration of 60minutes and the tool flank wear was studied. It is known that tool flank wear is caused by abrasive nature of the hard reinforcement particles present 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) [9]. It was evident that on the flank face of the tool, vertical grooves were visible. It has been proven that the constituent boron particles are harder than diamond particles of PCD and are thus able to competitively chafe the cutting tool.

4 Conclusions

From the conducted studies, the notable features are as follows.

The power consumed is lesser at lower cutting speeds because of negligible friction between tool and workpiece interface. The primary wear mechanism is believed to be abrasion between reinforcing particles and cutting tool material. Tool wear is mostly observed in flank portion of the PCD. Built up edge also seen in the nose region. The surface finish improves at higher cutting speeds. Tool wear is strongly influenced by two factors - cutting speed followed by depth of cut. Surface roughness shows a direct correlation with feed rate. As the feed rate increases, surface roughness increases. It is concluded that PCD 1500 grade is preferred for fine finishing.

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