Machinability Studies of Al/SiC/ (20p) MMC by Using PCD Insert (1300 grade)

R.Venkatesh [A], A.M.Hariharan[B], N.Muthukrishnan[C]

Abstract*— Aluminium *Silicon Carbide (A356-Sic) Metal Matrix Composite (MMC) materials have a set of mechanical and physical properties that are ideally suited for application in Aerospace and Automobile industries and not widely used because of its poor machinability. To over come this barrier, our investigation is to study on machinability analysis of A356 -SiC(20p) (MMC) with Poly Crystalline Diamond (PCD) insert of grade 1300.Base matrix material is Aluminium A356 reinforced with 20 % weight by volume of Silicon carbide particles of mean diameter 55 µm to 80 µm is used. The main focus of investigation is to determine minimum power consumed by main spindle, good surface finish and minimum tool wear. The worn out insert is also analyzed under Scanning Electron Microscope (SEM) and the results would be discussed.

***Key Words* - Metal Matrix composites, Machining, Tool wear, PCD power consumed, tool wear.**

I. INTRODUCTION

Increasing quantities of metal matrix composites (MMCs) are being used to replace conventional materials in many applications, especially in the automobile and recreational industries. The most popular types of MMCs are aluminum alloys reinforcing with ceramic particles. These low cost composites provide higher strength, stiffness and fatigue resistance [1, 2] with a minimal increase in density over the base alloy. Owing to the addition of reinforcing materials which are normally harder and stiffer than the matrix, machining becomes significantly more difficult than in the case for conventional materials, as reported in the earlier publications [1-5]. The SiC particles used in aluminum matrix composites are hardener than tungsten carbide. But Poly Crystalline Diamond (PCD) is approximately 3-4 times hardener than SiC particles [6] This is the reason why PCD is recommended by many researchers [7, 8]. Pramanik *etal* [9] developed the analytical model to the machining of ceramic particle reinforced MMCs. Davim [10] reported that machining of MMCs, the merchants prediction of shear angle was an over estimate than that of observed one. Muthukrishnan [11] observed that the specific power was minimum at cutting condition leading to maximum material removal rate.The above literature stated about the various works carried out by researchers in machining Al-SiC MMC.

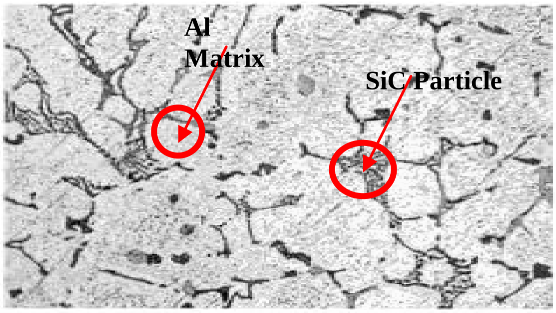
II. EXPERIMENTAL PROCEDURE

In the Al-SiC MMC, the composition of the matrix of the MMC was experimentally found to contain 11.6% Si, and 3.46 % Zn apart from traces of other elements. The chemical composition of this MMC is shown in Table - I. The reinforcement was particulate SiC grain size ranging from55 µm to 80 µm stirred in to the melt prepared in-house by stir casting method

TABLE I -Chemical composition of the Material

Al	Si	Fe	Mg	Zn	Pb	Ni	Zr	Mn	V
77.40	11.6(	1.34	2.44	3.46	0.184	0.97(	0.432	0.379	.05

Samples were fabricated in the form of cylindrical rods of ϕ 150 mm x 150 mm length.The microstructure of the specimen is shown in fig-1.Tool holder used was PCLNR 25 25 M 12. The PCD insert was of geometry CNMA 120408, which is one of the commonly used insert geometry for general turning applications. The tool material was PCD 1300 grade. Medium duty lathe was used for turning tests.



1ml HF + 200 ml H2o 500 X

Figure 1 – Microstructure of the specimen

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TABLEII-Characteristics of PCD 1300 grade

Characteristics	Grade 1300
Average particle Size (µm)	5
Volumetric % of Diamond (%)	92
Compressive Strength (GPa)	7.5
Elastic Modulus (GPa)	950
Transverse Rupture Strength (GPa)	1.4
Knoop Hardness - 3 kg Load (kg/mm^2)	4000

The machining of the fabricated composite was performed at five different cutting speeds (100 – 600 m/min) with two different feed rate (0.108 – 0.20 mm/rev) and three different depths of cut (0.25, 0.5 ,0.75 mm).Table -2 shows the characteristics of PCD 1300 grade.

Table – 3 shows the experimental details A356-SiC MMC machining with PCD inserts was observed to be more productive at higher cutting speeds. The machining was interrupted at various time intervals and the surface roughness of the work piece material and the flank wear land of the tool 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 by two wattmeter method using two 600 V/5A, UPF wattmeter for all the cutting conditions. Material Removal Rate (MRR), which is the volume of material removal per unit time, is calculated for each set of cutting conditions.

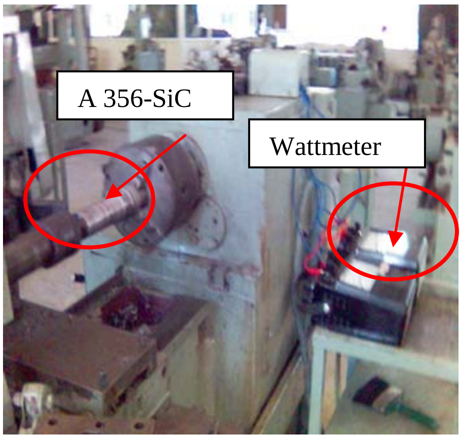

Fig- 2 Experimental set up

The surface roughness of the machined component was measured using a Mitutoyo Surf test 301 surface roughness tester. The Ra values of the surface roughness corresponding to each machining condition were measured. The worn insert tip was observed under Mitutoyo TM 500 Tool makers's microscope and the flank wear land was measured. Worn tool images are also presented.

Table-III Experimental details

Insert	PCD 1300
Substrate(for PCD)	Tungsten Carbide
Type	CNMA 120408
Nose Radius	0.8 mm
Shank size	25*25 mm
Tool holder specification	PCLNR 25 25 M 12
Product name	Diapax
Machining	Dry machining
Cutting Speed	100-600 m/min
Feed Rate	0.108 & 0.2 mm/rev
Depth of Cut	0.25, 0.5 & 0.75 mm

III. RESULTS AND DISCUSSIONS

A. Surface Roughness

We observed, the surface finish produced is strongly dependent on the cutting speed (V). The surface roughness for low speed is very high, much less surface roughness is obtained at higher cutting speeds. Also in controversy to cutting speed the surface roughness found to be good at lower feeds and getting worst as the feed increases. This can be attributed loss of point contact due to increase in contact area between tool and work piece as the feed increases.

B. Effect of cutting speed on MRR

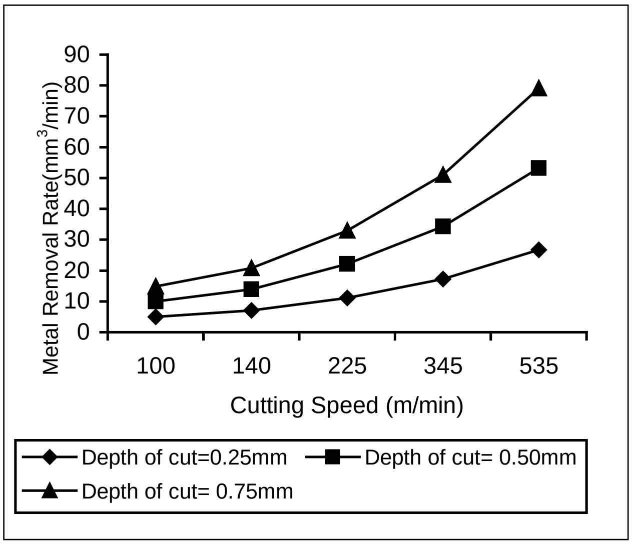

Fig-3 (a)Cutting Speed Versus MMR(Feed- 0.200 m/rev)

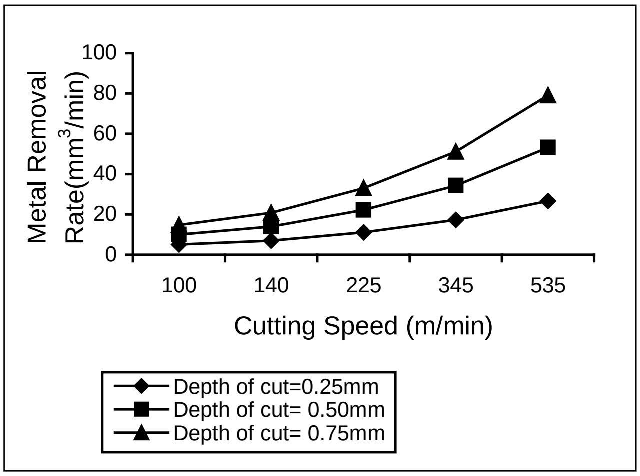

Fig-3(b)Cutting Speed Versus MMR(Feed-.108 m/rev)

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|From fig 3 –(a),(b)it is clearly under stood that the metal removal rate is increases as cutting speed increase.At higher depth of cut and feed the removal rate is more. This is due to high stability of tool at high speed and easy removal of metal. It is clearly understood that MRR depends on depth of cut, feed rate and cutting speed. If the parameters are higher, then MRR is also high.

C .Power consumption

It can be seen from Fig-4, power consumption is increases with the increase in cutting speed when the machining operation is carried out. At lower feed rate power consumption is low irrespective of the cutting speed and depth of cut. As the cutting speed and feed increase power required to chip the tool is also high.

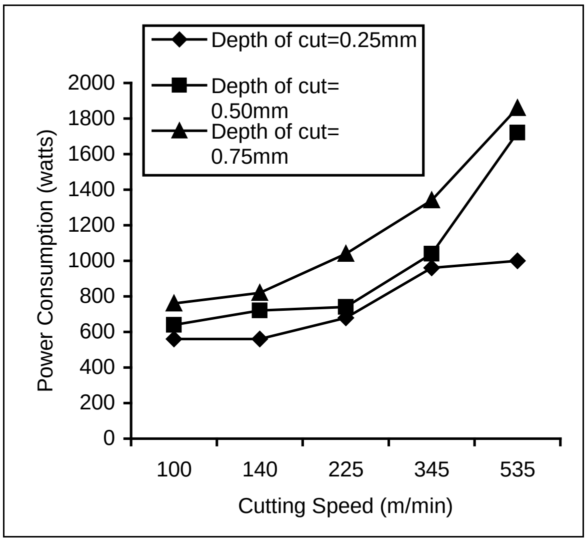

Fig-4 Power consumption Vs Cutting speed

D. Specific Power Consumption

Specific power consumption, (ie) power consumed per unit volume of material removed per minute, is one of the important indications of the machinability of the material. The material removal rate pertaining to a particular cutting condition was computed and the power consumed was experimentally measured. From these data specific power consumed was calculated. The results are plotted against the cutting speed for various depth combinations. Fig – 5 shows the plots for the 1300 grades of the PCD inserts. Fig-5, clearly shows the specific power increasing with the increasing cutting speed. This is expected because generally as rule specific power consumption increases as MRR increases.

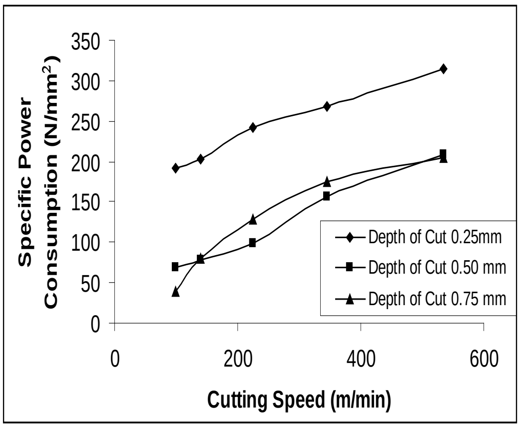

Fig- 5 Specific power consumption Vs Cutting Speed

E .Tool Wears

Figure 6 shows the tool wear of PCD 1300 grade under Scanning Electron Microscope. Typical observed scanning electron micrographs of worn out insert is shown in the wear land. Sticking of work material over the tool face is indicating the formation of BUE and

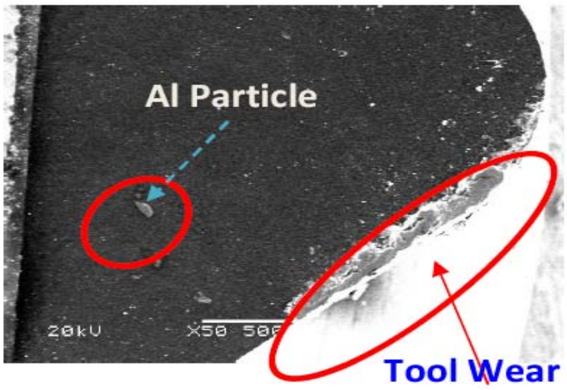

Fig –6 Scanning Electron Microscope view of Tool wears

subsequent removal. The ceramic particles present in the matrix are increasing the abrasive wear. In 1300 grade, the abrasive wear is more in nature. The over all performance of 1300 grade is not suitable for machining the above said composite under these stipulated machining conditions because the grain size is coarse which is not able to machine the hard materials.

IV.CONCLUSIONS

1. We found that the surface roughness is good as the cutting speed increases. This is because of the stability of the tool at higher cutting speed and easy removal of material at this stage. PCD 1300 grade performs well in metal removal rate, but wear is more.
2. The machining with the low feed of 0.108 mm/rev has resulted decrease in cutting force. Machining with high feed rate of 0.368 mm/rev with high

depth of cut has resulted good amount of metal removal.1300 grade insert is giving satisfactory result in many attributes.

3. Increase in cutting speed improves surface finish. We found that as the feed increases surface finish improves only up to certain level after that it starts deteriorates.
4. Over all this insert is not suitable for machining the above said Al-SiC(20p)(MMC).

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