Machining Of Metal Matrix Composite by DLC Coated Tool

Kunal Patil[1] , Dr. Anil R. Sahu[2]
[1]PG Student, G H Raisoni college of engineering and management Wagholi, Pune
2Professor, G H Raisoni college of engineering and management Wagholi, Pune

Abstract - Machining is essentially required to obtain desired dimensional accuracy, form accuracy, surface finish to satisfy functional requirements. Machinability will be considered desirably high when cutting forces, temperature, surface roughness and tool wear are less, tool life is long and chips are ideally uniform and short enabling short chip-tool contact length and less friction. Diamond tools are considered the most effective and preferred choice for the machining of abrasive metal matrix composites due to its high hardness, high abrasion and fracture resistance, high thermal conductivity, low coefficient of friction and low adhesion properties. However the relatively high cost factors tagged with such tools has left a space to look for relatively low cost cutting tool materials to perform in an acceptable range. Diamond like carbon (DLC) coating is the proposed alternative in this regard due to its low cost compared to diamond tool and at the same time, it will improves the economics of machining process. Machining of metal matrix composite is difficult due to hard abrasive particles. Aluminum based metal matrix composites (AMMC) have found its applications in the automobile, aerospace, medical, and metal industries due to their superior mechanical properties. Fabricated Aluminum based metal matrix composites require machining to improve the surface finish and dimensional tolerance. This paper focuses the machining of Aluminum based metal matrix composites to investigate the effect of DLC coated tool. Surface roughness and cutting forces has been evaluated. The medium cutting speed has been recommended for better surface roughness.

Keywords: - metal matrix composite, hardness, tensile, surface roughness, machining

I. INTRODUCTION

Machinability is the property of material which indicates how much machinable a material. Many authors have been tried to define machinability as the ability of workpiece material to be machined or it refers to workpiece response to machining or it is normally applied to the machining properties of work material or it indicates how easily and fast a material can be machined. Machinability will be considered desirably high when cutting forces, temperature, surface roughness and tool wear are less, tool life is long and chips are ideally uniform and short enabling short chip-tool contact length and less friction. Traditional tool materials like high speed steel is not suitable for machining MMCs due to rapid growth of tool wear [1]. Machinability depends on work piece material, tool material, cutting conditions (cutting speed, depth of cut, feed rate) and Tool Geometry

The major issue inhibiting the wider use of metal matrix composite (MMCs) is the poor machinability which occurs due to the ceramic reinforcements (whiskers, particles and fibers) in the soft metal matrix. Due to rapid wear of the conventional cutting tool was not performed so longer to maintaining the desired accuracy therefore, the near net shape of as cast MMCs required a hard material inserts such as carbide insert or diamond tipped inserts for less wear and better performance [2].

Composites consist of two or more physically and/or chemically different materials. There are three components of a composite that are matrix, reinforcement, and the interface between matrix and reinforcement. A matrix is a continuous phase of composites and serves to hold reinforcements in predetermined orientation. Reinforcement is a hard material distributed within the matrix. Matrix and reinforcements are chemically bonded or mechanically locked together. MMCs are newly developed materials in recent years having favorable mechanical properties like high strength, hardness, wear resistance and strength to weight ratio. In the MMC particulate type reinforcements are predominantly used. Silicon carbide (SiC), aluminum oxide (Al_2O_3), Zirconia (ZrO_2), Boron carbide (B_4C) and graphite (Gr) were the widely used particulate reinforcements [3].

Ajay R. Bhardwaj [4] has discussed several machinability aspects of MMCs. Machining of composite materials depends on the properties and relative content of the reinforcements and the matrix materials as well as on its response to the machining process. Machining of composite materials differs significantly in many aspects from machining conventional metals and their alloys. In the machining of composites, the material behavior is not only non-homogeneous and anisotropic, but also depends on diverse reinforcement and matrix properties, and the volume fraction of matrix and reinforcement. The tool encounters alternatively matrix and reinforcement, whose response to machining can be entirely different. Thus machining of composite materials imposes special demands on the geometry and wear resistance of the cutting tools. Accordingly tool wear mechanisms and development must be attentively considered to establish correct cutting tool selection. In this review paper the author reports that MMC machinability is critically affected by the reinforcement and the matrix hardness. Higher hardness shortens the tool life. Cubic Boron Nitride (CBN) and Polycrystalline Diamond (PCD) tools are one and two orders of magnitude better than carbide tools in terms of wear resistance. While Carbide tools could be used economically for roughing operations, PCD tools should be used for finishing operations because of their longer tool life [5]. From this review paper it is observed that the availability of information regarding the effects of the cutting parameters on cutting force/resultant force and tool wear is scarce especially for an Al-Graphite-SiC hybrid composite

Seyed Ali Niknam et al., in their work have presented experimental investigations involving measurement of chip curvature, chip thickness and cutting forces during orthogonal machining of composite materials. Volume of reinforcements, process parameters and tool rake angles were taken as dependent parameters. It has been concluded here that the cutting forces do not increase monotonically with the increase in the volume of reinforcement in the composite which is somewhat contradictory to the expectations. They also report that the magnitude of forces required for machining of composite material are not substantially different from those required for the unreinforced alloy [6].

II. METHODOLOGY

Metal matrix composite selected for the turning operation is combination of silicon card bide and graphite. Silicon Carbide (SiC) is the only chemical compound of carbon and silicon. It was originally produced by a high temperature electro-chemical reaction of sand and carbon. Graphite (Gr) has a high melting point, similar to that of diamond. In order to melt graphite, it isn't enough to loosen one sheet from another. You have to break the covalent bonding throughout the whole structure. Gr is a soft, slippery feel, and is used in pencils and as a dry lubricant for things like locks. Fabricated Al/SiC composite increases the toughness, ductile strength. SiC in the range of 15–30 μm was considered for squeeze casting. Al/Gr composite increases wear resistance. Reinforced matrix improved the mechanical behavior upto 10 wt. % and decreased the mechanical properties with the increasing reinforcement wt. % due to agglomeration of the hard ceramic particles that leads to porosity. The composites were produced by taking fixed reinforcements (5wt. %). Each wt. % of reinforcement consisted of equal proportion (1:1 ratio) of SiC and Gr particles. Vickers hardness is used for hardness testing. Universal testing machine is used to measure the tensile strength. The samples are cut from the casting rod and at three different locations the hardness were tested. The hardness was found in the range of 136.8 to 139.4 Hv. The hardness tested samples are shown in fig no.1

Fig no. 1 hardness samples of MMC

Fig no. 2 Tensile strength samples

The reinforcement in matrix phase taken the load and support the soft matrix phase from fracture. The tensile strength value was found in the range of 394.5 to 401.2 MPa. The tensile strength samples are shown in fig no 2.

Turning operation was carried out under dry cutting environment. Dry turning has been considered as the machining of future due to concern regarding the safety of environment. Dry cutting environment was used for the experimentation process. Dry cutting process is one that uses no coolant during machining. By the use of dry cutting, costs of cutting fluid were alleviated. The turning operation was performed according to table no. 1

Table no 1 Process parameters for turning MMC

Sr.No	Levels	Speed in RPM	Feed in mm/rev	Depth of cut in mm
1	Low	200	0.1	0.2
2	Medium	400	0.13	0.4
3	High	600	0.15	0.6

The cutting speed taken is low level (200 rpm) and higher (600 rpm). The machining processes are conducted in the lathe machine to measuring the surface roughness of sample MMC material of Al6061/SiC/Gr. The effect of the turning parameters for surface roughness according to the level of the turning parameters, wide range of each level of parameter means the more effect of surface finish for the changes of depth of cut, spindle speed and feed applied in this effect of the surface finish compared to the other parameter. The cutting forces are measure by using dynamometer. The turning tool is fixed on dynamometer and the dynamometer is fixed on the cross-slide of the lathe.

III. RESULTS AND DISCUSSION

Surface roughness

The surface roughness is usually measured in a direct way by the use of devices called Profilometer. The Profilometer is a stylus probe instrument in which the stylus mounted in the pick-up unit traverses across the machined surface by means of a motor drive. The pick-up receives ad rectifies the output which is further amplified and the average height of the roughness is reported digitally. One of the common types of profile-meter available is the Taylor-Hobson Talysurf. It works on the principle of carrier modulation [7]. The average surface roughness (Ra), which is mostly used in industries, is taken for this project. The surface roughness was measured at three positions spaced at 120 degree intervals around the rod circumference with the cut off length 0.8mm using SURFTEST SJ-211. Three different location reading then compile to form one reading and this reading is used for the analysis

The average surface roughness values are 0.251, 0.209 and 0.303 μm. The minimum surface roughness obtained at the medium cutting process parameters. The medium process parameters are cutting speed 500 rpm, feed rate 0.13 mm/rev and depth of cut of 0.4mm.

Effect of process parameters on surface roughness

The relation between cutting speed and surface roughness in MMC turning using DLC coated tool is shown in Fig 2 at different feed and depth of cut. The surface roughness first decreases sharply with the increase in cutting velocity. After a point, it gradually increases with further increase in cutting velocity. Cutting speed affect the surface roughness slightly. As the cutting speed increases along with feed and depth of cut the surface finish will be affect.

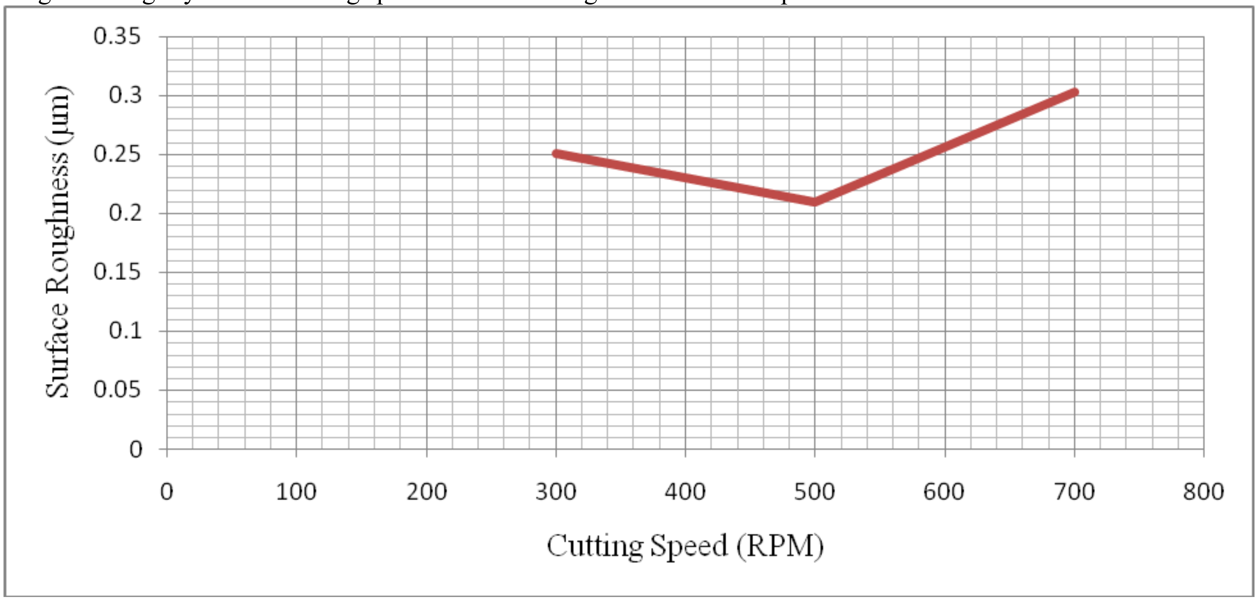


Fig no. 2 Cutting speed vs surface roughness

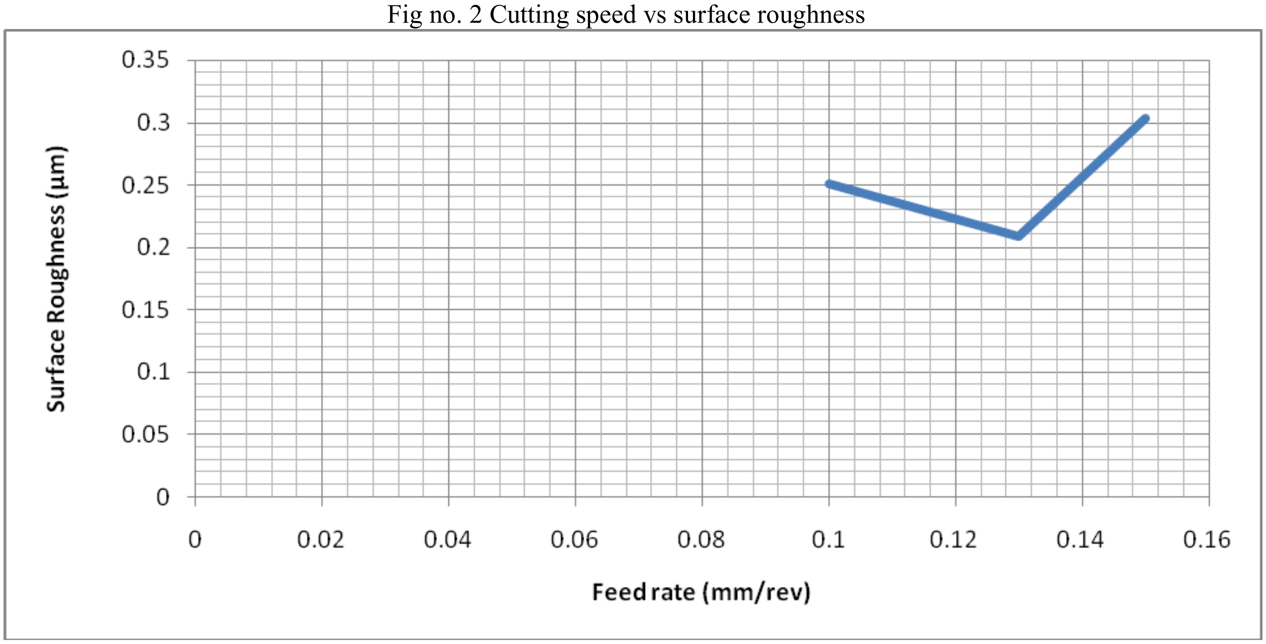


Fig no3. Effect of feed rate on surface roughness

The effect of feed rate on surface roughness is shown in fig 3. Feed rate mostly plays the vital role for the surface roughness. The lower feed rate the surface roughness was at medium level. As the feed rate increases to higher level the surface roughness is affected. Increase in feed rate increase the temperature at tool tip and MMC interface. This increase in temperature produces more friction which leads to higher roughness. The feed rate in machining MMC using DLC coated tool influenced the surface roughness. Feed rate plays the major in determining the final component surface roughness. Increasing the feed rate also produce more vibration which leads to poor surface roughness. The feed rate of 0.1 mm/rev along with 300 rpm cutting speed, 0.2 depth of cut gives surface roughness of 0.251µm. Better surface roughness of 0.209µm was observed at cutting speed 500 rpm, feed rate 0.13mm/rev and depth of cut 0.4mm. Cutting forces are also found lower at cutting speed 500 rpm, feed rate 0.13mm/rev and depth of cut 0.4mm.

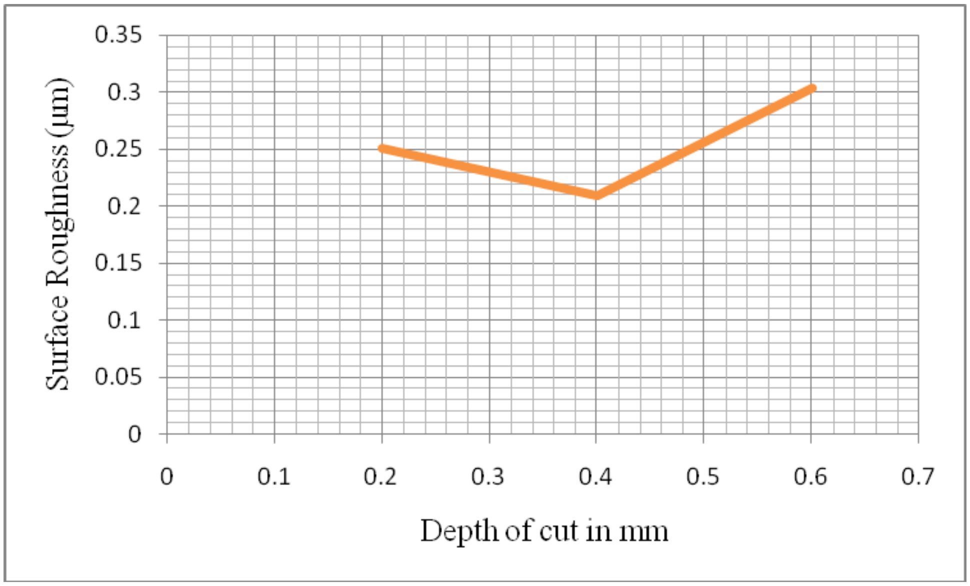
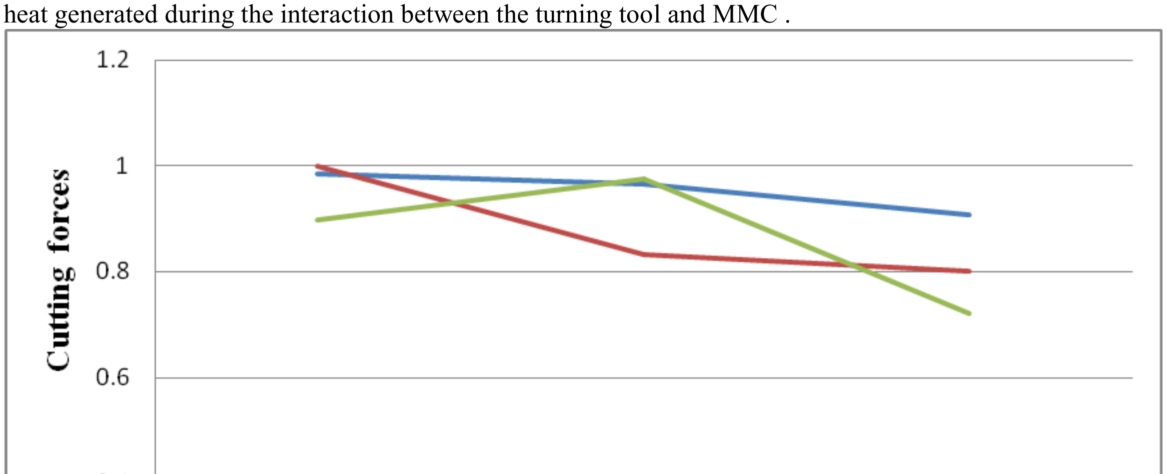


Fig 4. Effect of depth of cut on surface roughness

It is clearly seen from fig 4 the increases in depth of cut increases the surface roughness. Higher depth of cut produces more temperature and friction between MMC component and tool. Rubbing action has been found when the depth of cut values reaches comparable to radius of cutting edge. Due to this rubbing action the cutting process energy increases and the MMC particles near the tip of tool interfacing are plastically deformed which leads to higher surface roughness. Increasing depth of cut increased the cutting forces. This increased in cutting forces produce more vibration which result in scratches between MMC component and turning tool tip.

Cutting Forces

At low speed (300rpm), feed (0.1 mm/rev) and depth (0.2mm) of cut more cutting force is required to cut the MMC. This is due to the friction between MMC and cutting tool. The energy require to cut the MMC is more at low process parameters. At medium cutting process parameters (speed-500rpm, feed 0.13 mm/rev, depth of cut 0.4mm) the energy require to cut the MMC is slightly low compare to low level process parameters. At higher level process parameters the energy require to cut the MMC is low compare to other level, this is due to the more friction and heat generated during the interaction between the turning tool and MMC .



	1	2	3
Fx	0.984	0.966	0.907
Fy	1	0.833	0.801
Fz	0.898	0.974	0.721

Fig. 5 Cutting forces obtain during turning of MMC

IV. CONCLUSION

Al6061/SiC/Gr was successfully fabricated using squeeze casting route. Mechanical properties show improvement by addition of reinforcement. DLC coating was successfully done on turning tool by using Plasma Enhanced chemical vapour deposition method. Turning operation was perfume on metal matrix composite using DLC coated tool. Cutting forces was measure by dynamometer. Surface roughness of machining surface was taken for analysis. The feed rate and depth of cut are major process parameters which affect surface roughness. The feed rate 0.13mm/rev and depth of cut 4mm gives better surface roughness of 0.209µm compared to other process parameters. The higher surface roughness of 0.303 µm was obtained at 700 rpm cutting speed, 0.15mm/rev feed rate and 0.6mm depth of cut.

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