Machinability behavior of PCD 1600 Grade Inserts on Turning AL/SiC/B4C Hybrid Metal Matrix Composites

T.S.Mahesh babu [1] N.Muthu Krishnan [2*]

1- Associate Professor, Department of Aeronautical Engineering, Sathyabama University,Jeppiar Nagar, Rajiv Gandhi Road, Chennai – 600 119,Tamil Nadu, India

2- Professor and Head, Department of Automobile Engineering, Sri Venkateswara College of Engineering, Pennalur, Sriperumbudur – 602 105.Tamilnadu, Chennai, INDIA.

ABSTRACT

Aluminium metal matrix composites reinforced with SiC and B_4C particles are a unique class of advanced engineered materials that have been developed to use in high strength , high wear resistant and tribological applications. The conventional techniques of producing these composites have some drawbacks. In this study, the aluminium hybrid composite is fabricated using stir casting method. 10 % by weight of SiC particles with an average size of 55 µm along with 7 % by weight of B_4C particulates were reinforced in to the molten aluminium alloy of designation Al356. The hardness, chemical composition and the micro-structure of the hybrid composite were investigated. Homogeneous distribution of SiC and B_4C within Al hybrid composites is clear from the SEM images. Finally an attempt is made to study the machinability characteristics of the hybrid MMC in turning by Poly crystalline Diamond inserts (PCD) of Grade 1600. The experiment was conducted in a medium duty lathe of spindle power 2kW at various cutting speeds, feeds and depths of cut and parameters such as Power consumed, surface roughness were measured. The surface finish observed was found to be very close to the theoretical surface finish. The deviation in the value is concluded as the other parameters which is influencing the machining. The optimum cutting conditions were obtained from the analysis of the results. By using this optimum cutting condition tool wear study was carried out. It is concluded that, tool wear mechanism is purely abrasive in nature. Surface finish is strongly dependent on cutting speed.

KEY WORDS: Hybrid MMC, turning, surface roughness, power consumed

INTRODUCTION

Metal Matrix Composites (MMC) have become a leading composite material and particle reinforced aluminium MMC have received considerable attention due to their excellent engineering properties. Out of this hybrid metal matrix composites (having more than two different reinforcing components of varying properties) are a relatively new class of materials characterized by lighter weight, greater strength, high wear resistance, good fatigue properties and dimensional stability at elevated temperatures than those of conventional materials. These materials are known as difficult- to – machine materials because of the hardness and abrasive nature of reinforcement particles [1, 2]. MMCs are gaining increasing attention for application in aerospace, defense and automobile industries. Hybrid MMCs are fabricated by reinforcing the matrix alloy with more than one type of reinforcements having different properties [3]. In view of the growing engineering applications of these composites, need for detailed and systematic study of their turning characteristics was investigated. The efficient and economic production methods are required for the near net shape of MMC. Parts manufactured by the stir casting route requires good surface finish to decrease the sliding friction [4] Hybrid MMC's have good potential for application in automotive and aerospace industries. The major issue preventing wider use of these materials is their poor machinablity. Since the hybrid MMC contain a soft matrix holding together very hard particulates or fibrous reinforcements, machining of these composites particularly in turning is very difficult. The machining of these high hardness hybrid composites with conventional high speed tool steels is very difficult. It has been found through this investigation that machining of these hybrid composites can be done easily with Poly crystalline Diamond tools (PCD) inserts under dry machining conditions. Prasad and Astana reported that reinforcement of aluminium alloys with graphite solid lubricants and hard ceramic parts were used in automotive parts [5].Jha et al. concluded that, in aluminium alloys cast composites wear rates were found to be 20-30% lower than the matrix alloy [6].

Optimum machining condition in turning Al356 /SiC/20p metal matrix composites for minimizing the surface roughness was determined using desirability function approach [7]. Uday et al. have reported an elaborative experimentation with the help of Taguchi methods on Al/SiC MMC to analyze the effects of size and volume fraction of reinforcements in the composites on cutting forces and surface roughness [8]. Kremer et al conducted the experiment to study the effect of SiC percentage in the Al/SiC particulate metal matrix composites on the machinability studies [9]. Artificial Neural Network (ANN) based model for the prediction of surface roughness during turning of composite material by Back Propagation algorithm [10]. The effect of machining parameters on the surface roughness was evaluated and optimum machining conditions for maximizing the metal removal rate and minimizing the surface roughness were determined using response surface methodology in turning particulate MMC [11].

In this direction an attempt has been made to explore the feasibility of turning Al base alloy of designation 356 of 10% by weight of Silicon carbide particles and 7% by weight of boron carbide particles reinforced in the base matrix metal fabricated in-house by stir casting process.

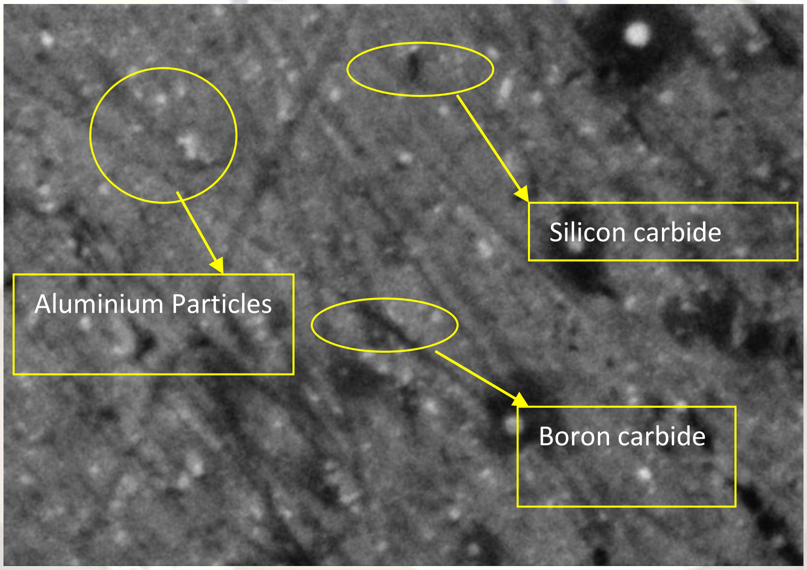


Figure 1 Microstructure of the work piece

Table-1.Chemical composition of Al-SiC (10p) B_4C (7_P) – HybridMMC

Type of Hybrid MMC	Reinforcement	%Si	%Mg	%Fe	%Cu	%Mn	%Zn	%Ti	%Al
Particulate MMC	SiC and B_4C -55 µm	7.85	0.68	0.25	0.14	0.07	0.07	0.16	Balance

EXPERIMENTAL PROCEDURE

Commercially Fabricated cylindrical bars having 10% of SiC particles and 7% of B_4C on matrix of Al 356, using stir casting method of diameter 50 mm and 200 mm long are turned on medium duty lathe of spindle power 2 kW. Fig – 1 shows the microstructure of the specimen and Table 1 shows the chemical composition of the specimen. Parameters such as power consumed by main spindle and surface roughness of machined component were measured by using digital wattmeter (make-Nippon Electrical Inst.Co, Model 96x96–dw 34 Sr.No:070521485 CTR 5A/415 V AC F.S 4 KW) Mitutoyo surf test (Make-Japan –Model SJ-301). The cutting tool selected for machining Al-SiC/B_4C metal matrix composites was Poly Crystalline Diamond (PCD) insert of fine grade (1600 grade). The PCD inserts used were of ISO coding CNMA 120408 and tool holder of ISO coding PCLNR 2525M12. The specifications for PCD insert are as follows: substrate for PCD is tungsten carbide, nose radius 0.8 mm, shank height- 25 mm, shank width – 25 mm, average particle size - 25µm, volume fraction of diamond- 94%, compressive strength- 7.5 GPa, elastic modulus – 1100 GPa.

RESULTS AND DISCUSSIONS

EFFECT OF CUTTING SPEED ON POWER CONSUMED

Fig- 2, 3 shows the plot between cutting speed and power consumed for depth of cut 0.25 mm and 1.00 mm respectively. From this plot it is clearly understood that, cutting speed increases power consumed for turning also increases. This is a general criteria, however power consumed for turning the work piece is very low at 0.1 mm feed rate compared to other two chosen feed rates. In the other two feed rates power consumed is more or less same in 150 and 200 m/min. It is evident that feed has less influence on power consumed [7]. In depth of cut 1.00 mm power consumed is linearly increases in all feed rates except feed rate of 0.2 mm/rev.

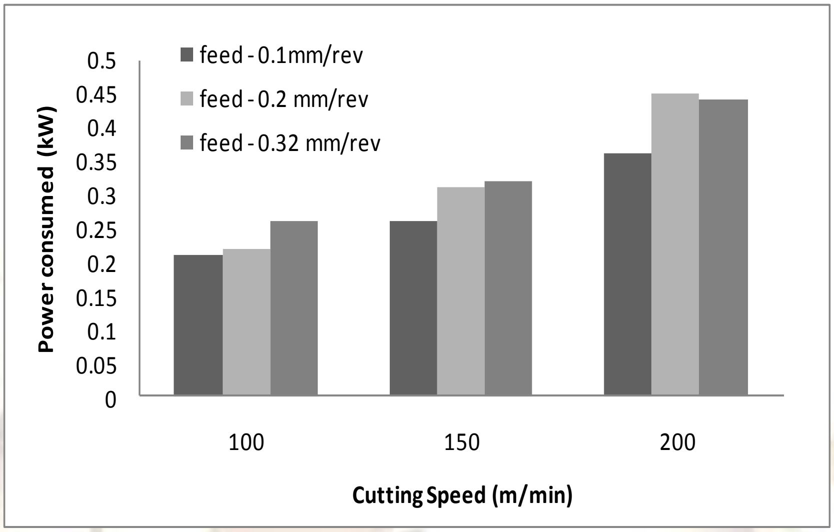


Fig – 2 Cutting Speed versus Power Consumed (Depth of cut -0.25 mm)

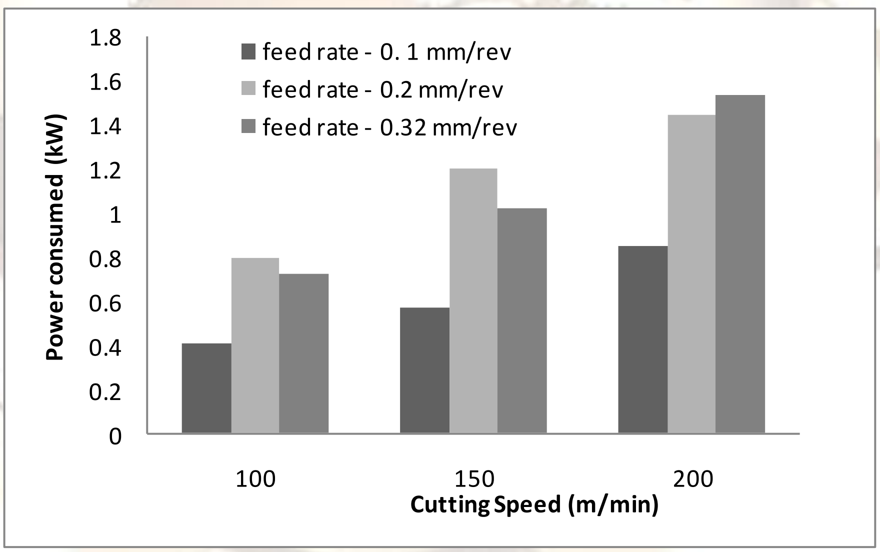


Fig – 3 Cutting Speed versus Power Consumed (Depth of cut – 1.00 mm)

Similar trend is existing in 0.5 mm depth of cut. Power consumed point of view it is advisable to turn the work piece at 0.1 feed rates with 0.25 mm depth of cut. In all three depths of cut for all cutting speeds power consumed is lower than other two feed rates. It is proved that power is directly proportional to cutting speed. However there were fluctuations in the power consumed at feed rate of 0.2 mm/ rev, with depth of cut 1.00 mm, at cutting sped between 140 m/min and 220 m/min. It is evident that, the reinforcing particles in the work piece in less than the matrix. Due to this inhomogeneous nature of the reinforcing particles at this zone is comparatively less than matrix [7,]. When machining at depth of cut 0.25 mm with feed rate of 0.1 mm/rev, it is observed that power consumed is around 0.2 kW at 90 m/min cutting speed and 0.4 kW at 220 m/min cutting speed. It is approximately doubled the value when machining at 1.0 mm depth of cut with same feed rate. It is clearly evident that depth of cut has high influence in power consumed. In higher feed rates power consumed is more than 300% difference in machining the work piece with 0.25 mm and 1.00 mm depth of cut.

EFFECT OF CUTTING SPEED ON SURFACE ROUGHNESS

Fig- 4, 5 shows the plot between cutting speed and average surface roughness of the machined component at depth of cut 0.25 mm and 1.00 mm with different feed rates respectively. In manufacturing industries normally average surface roughness value only measured for judging the surface finish [11], hence it is adopted in this investigation.

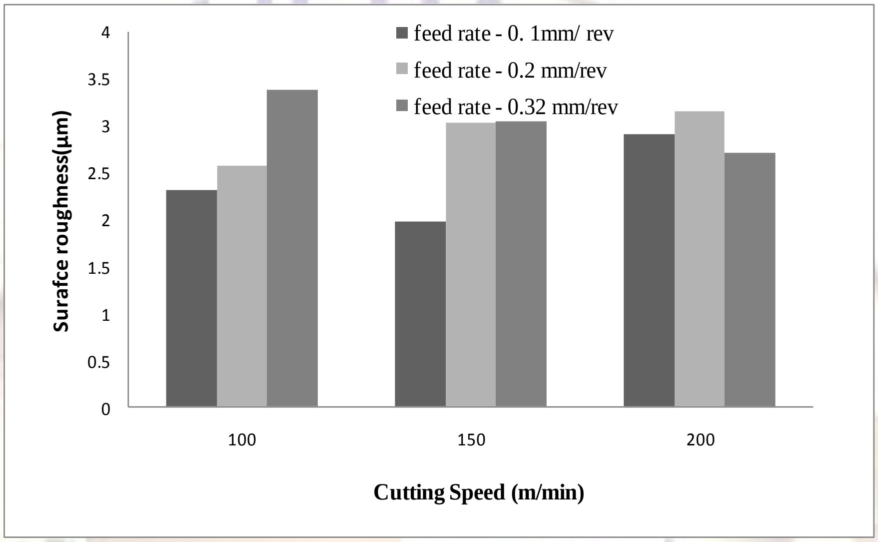


Fig – 4 Cutting Speed versus Surface Roughness (Depth of cut – 0.25 mm)

From fig -4 it is observed that, feed rate of 0.32 mm/rev is only showing the correct plot. Normally when the cuttingg speed increases surface roughness decreases. But when machining the work piece at 0.1 mm/rev and 0.2 mm /rev feed rates the trend is not showing the correct

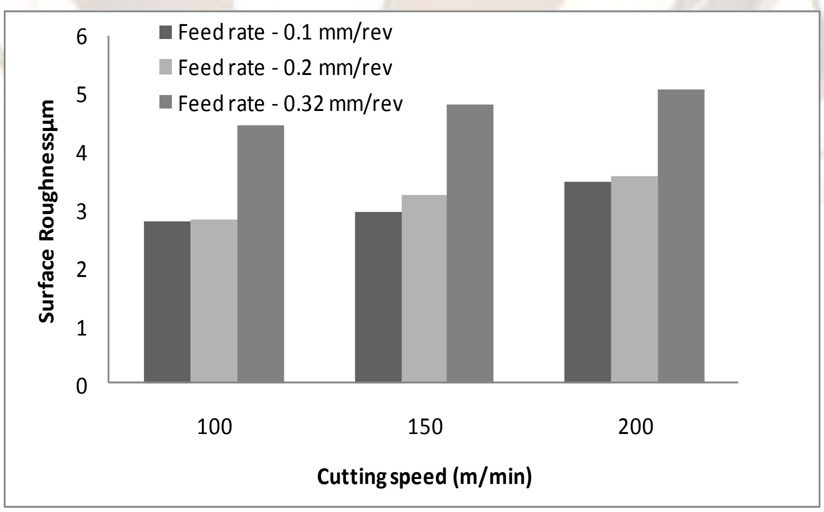
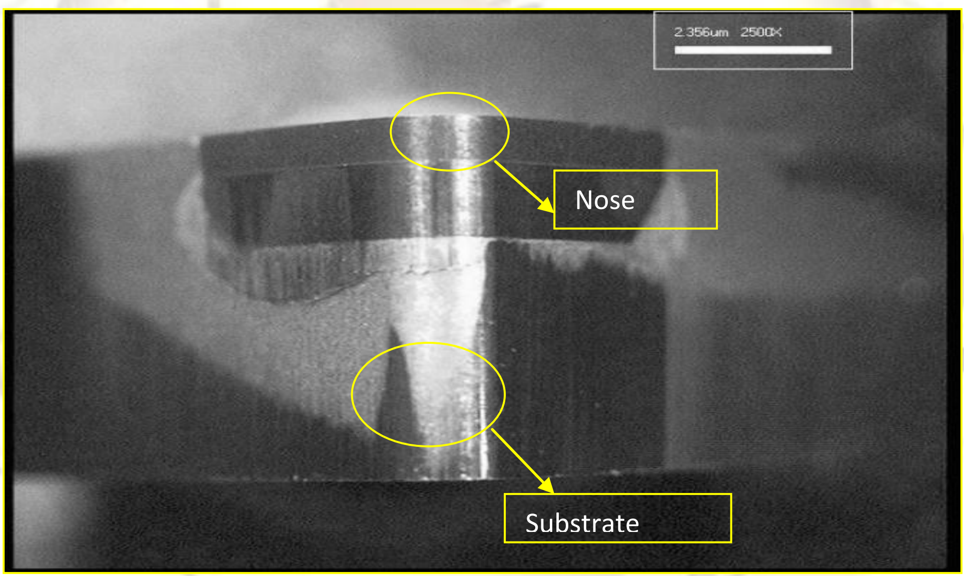


Fig – 5 Cutting Speed versus Surface Roughness (Depth of cut – 1.00 mm) performance, this is the fact that, reinforcing particles in the section disturbed the stylus when measuring the surface roughness value [11-13]. Only feed arte of 0.32 mm/rev is showing the exact trend line in both the figures. However feed rate of 0.2 mm/rev is also showing the correct trend line up to 140 m/min cutting speed after that it increases at depth of cut 1.0 mm. It is clearly under stood that, feed rate of 0.1 mm/rev is showing good surface roughness in both the depth of cut. Remaining feed rates show unacceptable surface roughness in both the depth of cut. It is recommended to machine the work piece with lower feed rate, lower depth of cut and higher cutting speed to achieve good surface finish [12, 13].

TOOLWEAR

From the above observations best machining parameter was determined as cutting speed 100 m/min, feed rate 0. 1mm/rev and depth of cut 1.00 mm (experimental reading number – 3). Now setting this cutting condition as a constant parameter and machined the samples for a time duration of 20minutes 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 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 [1, 14, 15, 17,18]. Fig- 6 shows the Scanning Electron Microscope (SEM) image of fresh insert. Fig- 7 shows SEM image of PCD 1600 grade insert after machining the work piece for 20 minute duration. It is proved that hard silicon and boron carbide particles which have higher hardness than diamond abrading the cutting tool 14, 15. It is observed that the tool life of PCD 1600 grade is performing well in the chosen cutting condition



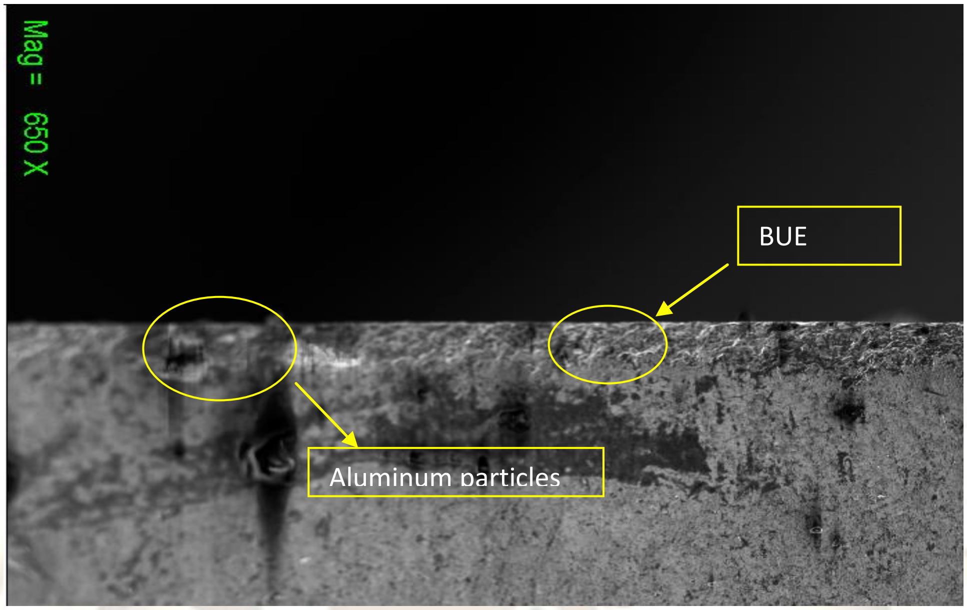


Fig – 7 SEM image of worn out insert after 15 minute duration

CONCLUSION

Machinability studies on fabricated Al-SiC-B_4C were carried out with Poly Crystalline Diamond insert of 1600 grade. From the experimental investigation the following conclusions were arrived.

1. Micro structure supports the homogeneous distribution of hard reinforcing particles in the matrix alloy
2. Power consumed is directly proportional to cutting speed. Power consumed is irrespective of removing hard reinforcing particle from the matrix. Depth of cut has high influence than the feed rate.
3. Surface roughness is strongly dependent on feed rate. Power consumed and surface finish is directly proportional to the cutting speed.
4. Tool wear is believed to be abrasion nature of hard reinforcing particles. Tool life is inversely proportional to cutting speed.

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